'894 File History

8454681

THE UNITED STATES OF AMERICA

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office

February 1, 2024

THIS IS TO CERTIFY THAT ANNEXED IS A TRUE COPY FROM THE RECORDS OF THIS OFFICE OF THE FILE WRAPPER AND CONTENTS OF:

APPLICATION NUMBER: *16/548,453*
FILING DATE: *August 22, 2019*
PATENT NUMBER: *10,574,894*
ISSUE DATE: *February 25, 2020*

By Authority of the
Under Secretary of Commerce for Intellectual Property
and Director of the United States Patent and Trademark Office

Curtis Goffe

Curtis Goffe
Certifying Officer

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
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TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	
Filing Date	Herewith
First Named Inventor	Thomas Derbanne
Title	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
Art Unit	
Examiner Name	
Attorney Docket Number	46DG-026061

SIGNATURE of Applicant or Patent Practitioner

Signature	/D. Benjamin Esplin/	Date (Optional)	
Name	D. Benjamin Esplin	Registration Number	58297
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☐ *Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82B (07-13)
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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 137002

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☐ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with **Customer Number:**

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature		Date (Optional)	
Name	Sharon Zezima		
Title	General Counsel of GoPro, Inc.		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☐ Total of forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Doc Code: ECOMM.AUTH/ECOMM.WTDW
Doc Description: Internet Communications Authorized/Internet Communications Authorization Withdrawn

PTO/SB/439 (11-15)

AUTHORIZATION FOR INTERNET COMMUNICATIONS IN A PATENT APPLICATION OR REQUEST TO WITHDRAW AUTHORIZATION FOR INTERNET COMMUNICATIONS		
	Application No.	
	Filing Date	
	First Named Inventor	Thomas Derbanne
	Art Unit	
	Examiner Name	
	Practitioner Docket No.	46DG-026061

To: Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

I. To authorize permission for Internet Communications.

☑ Recognizing that Internet communications are not secure, I hereby authorize the USPTO to communicate with the undersigned and practitioners in accordance with 37 CFR 1.33 and 37 CFR 1.34 concerning any subject matter of this application via video conferencing, instant messaging, or electronic mail. I understand that a copy of these communications will be made of record in the application file. (MPEP 502.03)

II. To withdraw authorization for Internet Communications.

☐ The authorization given on _____, to the USPTO to communicate with the undersigned and any practitioner in accordance with 37 CFR 1.33 and 37 CFR 1.34 concerning any subject matter of this application via Internet communications such as video conferencing, instant messaging, or electronic mail is hereby withdrawn. I understand that the withdrawal is effective when approved rather than when received.

I am the

☐ applicant.

☑ attorney or agent of record. Registration number 58297.

☐ attorney or agent acting under 37 CFR 1.34. Registration number _____.

/D. Benjamin Esplin/ — Signature

August 22, 2019 — Date

D. Benjamin Esplin — Typed or printed name

760-814-5268 — Telephone Number

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Juristic entities must be represented by a patent practitioner (see 37 CFR 1.31, which is applicable to any paper filed on or after September 16, 2012, that is presented on behalf of a juristic entity, regardless of application filing date). Submit multiple forms if more than one signature is required, see below*.

☐ * Total of _____ forms are submitted.

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal					
Application Number:					
Filing Date:					
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS				
First Named Inventor/Applicant Name:	Thomas Derbanne				
Filer:	D. Benjamin Esplin/Chelsea Pearsall				
Attorney Docket Number:	46DG-026061				
Filed as Large Entity					
Filing Fees for Utility under 35 USC 111(a)					
Description		**Fee Code**	**Quantity**	**Amount**	**Sub-Total in USD($)**
Basic Filing:					
UTILITY APPLICATION FILING		1011	1	300	300
UTILITY SEARCH FEE		1111	1	660	660
UTILITY EXAMINATION FEE		1311	1	760	760
Pages:					
Claims:					
Miscellaneous-Filing:					
Petition:					
Patent-Appeals-and-Interference:					

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1720**

Electronic Acknowledgement Receipt	
EFS ID:	36948936
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	D. Benjamin Esplin/Chelsea Pearsall
Filer Authorized By:	D. Benjamin Esplin
Attorney Docket Number:	46DG-026061
Receipt Date:	22-AUG-2019
Filing Date:	
Time Stamp:	17:01:37
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1720
RAM confirmation Number	E20198LH02111362
Deposit Account	602731
Authorized User	Chelsea Pearsall
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Application Data Sheet	WebADS.pdf	144731 507e66218f09cb9ca4deaa581587edce5ff7eb1f	no	8
Warnings:					
Information:					
2		46DG-026061_Specification.pdf	257318 6b6e2fc240768efdbffbeda233f784b543feb5cd	yes	47

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Specification	1	38
	Claims	39	46
	Abstract	47	47

Warnings:					
Information:					
3	Drawings-only black and white line drawings	46DG-026061_Drawings.pdf	115038 4580c6272eadeff5a43b8413eb060be68955524b	no	8
Warnings:					
Information:					
4	Oath or Declaration filed	46DG-026061_Declaration-Assignment.pdf	177408 e1dbff91c1af191efe4fc3c6fd1bb8122bdae90c	no	3
Warnings:					
Information:					
5	Power of Attorney	46DG-026061_POA.pdf	313228 bd02143d2bb8a1e5f6119a332317bbe67ba5c70e	no	2

Warnings:					
Information:					
6	Internet Communications Authorized	46DG-026061_Email_Authorization.pdf	78500 6f58bf1e0984908ee074d0672233a5e58ed35603	no	2
Warnings:					
Information:					
7	Fee Worksheet (SB06)	fee-info.pdf	35024 500484d116b316eb5f2f808d40047fe39356d202	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	1121247		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026061
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2:

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Thomas		Derbanne	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

City	Paris	Country of Residence i	FR

Mailing Address of Inventor:

Address 1	3000 Clearview Way		
Address 2			
City	San Mateo	**State/Province**	CA
Postal Code	94402	**Country** i	US

Inventor 2

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	César		Douady	

Residence Information (Select One) ○ US Residency ◉ Non US Residency ○ Active US Military Service

City	Les Molieres	Country of Residence i	FR

Mailing Address of Inventor:

Address 1	3000 Clearview Way		
Address 2			
City	San Mateo	**State/Province**	CA
Postal Code	94402	**Country** i	US

Inventor 3

Legal Name

PTO/AIA/14 (08-15)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026061
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Prefix	**Given Name**	**Middle Name**	**Family Name**	**Suffix**
	Maxim		Karpushin	

Residence Information (Select One) ◯ US Residency ◉ Non US Residency ◯ Active US Military Service

City	Paris	Country of Residence i	FR

Mailing Address of Inventor:

Address 1	3000 Clearview Way		
Address 2			
City	San Mateo	**State/Province**	CA
Postal Code	94402	**Country** i	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ **An Address is being provided for the correspondence Information of this application.**

Customer Number	137002		
Email Address	docketing@esplin.legal	Add Email	Remove Email

Application Information:

Title of the Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS		
Attorney Docket Number	46DG-026061	**Small Entity Status Claimed**	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	8	**Suggested Figure for Publication (if any)**	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country i

PTO/AIA/14 (08-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026061
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	**Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	137002		

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix	Remove

Registration Number	

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix	Remove

Registration Number	

Additional Representative Information blocks may be generated within this form by selecting the **Add** button.

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
	Continuation of	16418203	2019-05-21

PTO/AIA/14 (08-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026061
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Prior Application Status	Patented			Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
16418203	Continuation of	16150066	2018-10-02	10341564	2019-07-02

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
16150066	Continuation of	15987786	2018-05-23

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
15987786	Claims benefit of provisional	62673388	2018-05-18

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country	Filing Date (YYYY-MM-DD)	Access Code (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

PTO/AIA/14 (08-15)
Approved for use through 04/30/2017. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026061
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026061
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor:

If the Applicant is an Organization check here. ☒

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Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026061
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Signature:

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See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/D. Benjamin Esplin/			Date (YYYY-MM-DD)	
First Name	D. Benjamin	Last Name	Esplin	Registration Number	58297

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SYSTEMS AND METHODS FOR STABILIZING VIDEOS

FIELD

(01) This disclosure relates to stabilizing videos using positions of an image capture device during a capture duration.

BACKGROUND

(02) A video may have been captured by an image capture device in motion. The motion of the image capture device during the capture of the video may cause the video to appear jerky/shaky.

SUMMARY

(03) This disclosure relates to stabilizing videos. Images with an optical field of view may be captured by an image capture device during a capture duration. Image information defining the images, position information characterizing positions of the image capture device at different moments within the capture duration, and/or other information may be obtained during the capture duration. An observed trajectory of the image capture device during the capture duration may be determined based on the position information and/or other information. The observed trajectory may reflect the positions of the image capture device at different moments within the capture duration. The observed trajectory may include a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment

subsequent to the first moment within the capture duration. A capture trajectory of the image capture device may be determined based on a subsequent portion of the observed trajectory and/or other information such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory may be determined based on the second portion of the observed trajectory. The capture trajectory may have smoother changes in the positions of the image capture device than the observed trajectory. Orientations of the capture field of view for the images with respect to the optical field of view of the images may be determined based on the capture trajectory of the image capture device and/or other information. Video content may be generated based on visual content of the images within the capture field of view and/or other information.

(04) A system that stabilizes videos may include one or more electronic storages, one or more processors, and/or other components. An electronic storage may store image information, position information, information relating to an observed trajectory of an image capture device, information relating to a capture trajectory, information relating to an optical field of view, information relating to a capture field of view, information relating to video content, and/or other information. In some implementations, the system may include one or more image sensors, one or more position sensors, and/or other components.

(05) One or more components of the system may be carried by a housing, such as a housing of an image capture device. For example, the image sensor(s) and the position

sensor(s) of the system may be carried by the housing. The housing may carry other components, such as the processor(s) and/or one or more optical elements. An optical element may be configured to guide light within an optical field of view to an image sensor. The optical field of view may be greater than a capture field of view for generating video content. An image sensor may be configured to generate an image output signal based on light that becomes incident thereon during a capture duration. The image output signal may convey image information that defines images with the optical field of view.

(06) A position sensor may be configured to generate a position output signal based on positions of the housing during the capture duration. The position output signal may convey position information that characterizes positions of the housing at different moments within the capture duration. In some implementations, the position sensor may include one or more of a gyroscope, an accelerometer, and/or an inertial measurement unit. The position information may be determined independent of the image information.

(07) The processor(s) may be configured by machine-readable instructions. Executing the machine-readable instructions may cause the processor(s) to facilitate stabilizing videos. The machine-readable instructions may include one or more computer program components. The computer program components may include one or more of an observed trajectory component, a capture trajectory component, an

orientation component, a generation component, and/or other computer program components.

(08) The observed trajectory component may be configured to determine an observed trajectory of the housing during the capture duration based on the position information and/or other information. The observed trajectory may reflect positions of the housing at different moments within the capture duration. The positions of the housing may include rotational positions and/or translational positions of the housing. The observed trajectory may include a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration.

(09) The capture trajectory component may be configured to determine a capture trajectory of the housing based on a subsequent portion of the observed trajectory and/or other information. The capture trajectory may be determined such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory is determined based on the second portion of the observed trajectory. The capture trajectory may have smoother changes in the positions of the housing than the observed trajectory.

(10) In some implementations, the capture trajectory having smoother changes in the positions of the housing than the observed trajectory may be characterized by the capture trajectory having less jitters in the positions of the housing than the observed trajectory.

(11) In some implementations, the capture trajectory of the housing may be determined based on minimization of a rotational velocity of the housing and a rotational acceleration of the housing while respecting a set of constraints. The set of constraints may include a margin constraint, a trajectory constraint, a target constraint, and/or other constraints. The margin constraint may be determined based on a difference between the optical field of view and the capture field of view, and/or other information. The trajectory constraint may be determined based on a subsequent portion of the observed trajectory and/or other information. The target constraint may be determined based on positions of a target in the images and/or other information.

(12) The orientation component may be configured to determine orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing and/or other information.

(13) The generation component may be configured to generate video content based on visual content of the images within the capture field of view and/or other information.

(14) These and other objects, features, and characteristics of the system and/or method disclosed herein, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however,

that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the invention. As used in the specification and in the claims, the singular form of "a," "an," and "the" include plural referents unless the context clearly dictates otherwise.

BRIEF DESCRIPTION OF THE DRAWINGS

(15) FIG. 1 illustrates a system that stabilizes videos.

(16) FIG. 2 illustrates a method for stabilizing videos.

(17) FIG. 3 illustrates an example image capture device.

(18) FIG. 4 illustrates an example observed trajectory.

(19) FIG. 5A illustrates example predicted trajectories.

(20) FIG. 5B illustrates an example smoothed trajectory.

(21) FIG. 5C illustrates an example capture trajectory.

(22) FIG. 6A illustrates example optical field of view and capture field of view.

(23) FIG. 6B illustrates example orientations of a capture field of view with respect to an optical field of view.

DETAILED DESCRIPTION

(24) FIG. 1 illustrates a system 10 for stabilizing videos. The system 10 may include one or more of a processor 11, an interface 12 (e.g., bus, wireless interface), an electronic storage 13, and/or other components. In some implementations, the system

10 may include one or more image sensors, one or more position sensors, and/or other components. Images with an optical field of view may be captured by an image capture device during a capture duration. Image information defining the images, position information characterizing positions of the image capture device at different moments within the capture duration, and/or other information may be obtained during the capture duration. Image information, position information, and/or other information may be obtained by the processor 11. An observed trajectory of the image capture device during the capture duration may be determined based on the position information and/or other information. The observed trajectory may reflect the positions of the image capture device at different moments within the capture duration. The observed trajectory may include a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration. A capture trajectory of the image capture device may be determined based on a subsequent portion of the observed trajectory and/or other information such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory may be determined based on the second portion of the observed trajectory. The capture trajectory may have smoother changes in the positions of the image capture device than the observed trajectory. Orientations of the capture field of view for the images with respect to the optical field of view of the images may be determined based on the capture trajectory of the image capture device

and/or other information. Video content may be generated based on visual content of the images within the capture field of view and/or other information.

(25) The electronic storage 13 may be configured to include electronic storage medium that electronically stores information. The electronic storage 13 may store software algorithms, information determined by the processor 11, information received remotely, and/or other information that enables the system 10 to function properly. For example, the electronic storage 13 may store information relating to images, image information, information relating to image capture device, information relating to optical element, information relating to image sensor, information relating to position sensor, position information, information relating to observed trajectory of the image capture device, information relating to capture trajectory of the image capture device, information relating to optical field of view, information relating to capture field of view, information relating to video content, and/or other information.

(26) The processor 11 may be configured to provide information processing capabilities in the system 10. As such, the processor 11 may comprise one or more of a digital processor, an analog processor, a digital circuit designed to process information, a central processing unit, a graphics processing unit, a microcontroller, an analog circuit designed to process information, a state machine, and/or other mechanisms for electronically processing information. The processor 11 may be configured to execute one or more machine-readable instructions 100 to facilitate stabilizing videos. The machine-readable instructions 100 may include one or more

computer program components. The machine-readable instructions 100 may include one or more of an observed trajectory component 102, a capture trajectory component 104, an orientation component 106, a generation component 108, and/or other computer program components.

(27) Images with an optical field of view may be captured by an image capture device during a capture duration. An optical field of view of image may define a field of view of a scene captured within the image. A capture duration may be measured/defined in terms of time durations and/or frame numbers. For example, images may be captured during a capture duration of 60 seconds, and/or from one point in time to another point in time. Images may be captured during a capture duration including capture of 1800 images. If the images are captured at 30 images/second, then the capture duration may correspond to 60 seconds. Other capture durations are contemplated.

(28) The system 10 may be remote from the image capture device or local to the image capture device. One or more portions of the image capture device may be remote from or a part of the system 10. One or more portions of the system 10 may be remote from or a part of the image capture device.

(29) For example, one or more components of the system 10 may be carried by a housing, such as a housing of an image capture device. For instance, image sensor(s) and position sensor(s) of the system 10 may be carried by the housing of the image capture device. The housing may carry other components, such as the processor 11 and/or one or more optical elements.

(30) An image capture device may refer to a device for recording visual information in the form of images, videos, and/or other media. An image capture device may be a standalone device (e.g., camera) or may be part of another device (e.g., part of a smartphone). FIG. 3 illustrates an example image capture device 302. The image capture device 302 may include a housing 312, and the housing 312 may carry (be attached to, support, hold, and/or otherwise carry) an optical element 304, an image sensor 306, a position sensor 308, a processor 310, and/or other components. Other configurations of image capture devices are contemplated.

(31) The optical element 304 may include instrument(s), tool(s), and/or medium that acts upon light passing through the instrument(s)/tool(s)/medium. For example, the optical element 304 may include one or more of lens, mirror, prism, and/or other optical elements. The optical element 304 may affect direction, deviation, and/or path of the light passing through the optical element 304. The optical element 304 may be configured to guide light within an optical field of view 305 to the image sensor 306. The optical field of view 305 may include the field of view of a scene that is within the field of view of the optical element 304 and/or the field of view of the scene that is delivered to the image sensor 306. For example, the optical element 304 may guide light within its field of view to the image sensor 306 or may guide light within a portion of its field of view to the image sensor 306. The optical field of view 305 may be greater than a capture field of view for generating video content.

(32) The image sensor 306 may include sensor(s) that converts received light into output signals. The output signals may include electrical signals. For example, the image sensor 306 may include one or more of a charge-coupled device sensor, an active pixel sensor, a complementary metal-oxide semiconductor sensor, an N-type metal-oxide-semiconductor sensor, and/or other image sensors. The image sensor 306 may generate output signals conveying information that defines one or more images (e.g., video frames of a video). For example, the image sensor 306 may be configured to generate an image output signal based on light that becomes incident thereon during a capture duration. The image output signal may convey image information that defines images with the optical field of view.

(33) The position sensor 308 may include sensor(s) that converts experienced positions/motions into output signals. The output signals may include electrical signals. For example, the position sensor 308 may refer to a set of position sensors, which may include one or more inertial measurement units, one or more accelerometers, one or more gyroscopes, and/or other position sensors. The position sensor 308 may generate output signals conveying information that characterizes positions of the position sensor 308 and/or device(s) carrying the position sensor 308. For example, the position sensor 308 may be configured to generate a position output signal based on positions of the housing/image capture device during the capture duration. The position output signal may convey position information that characterizes positions of the housing 312 at different moments (points in time, time durations) within the capture

duration. The position information may characterize positions of the housing 312 based on specific translational and/or rotational positions of the housing 312 and/or based on changes in translational and/or rotational positions of the housing 312 as a function of progress through the capture duration. That is, the position information may characterize translational and/or rotational positions of the housing 312 and/or changes in translational and/or rotational positions (motion) of the housing 312 (e.g., direction, amount, velocity, acceleration) during the capture duration.

(34) The position information may be determined based on signals generated by the position sensor 308 and independent of the information/signals generated by the image sensor 306. That is, position information may be determined without using images/videos generated by the image sensor 306. Use of images/videos to determine positions/motions of the housing 312/image capture device 302 may be computationally expensive in terms of processing power, processing time, and/or battery consumption. Using the information/signals from the position sensor 308 to determine positions/motions of the housing 312/image capture device 302 may be computationally cheaper. That is, less processing power, processing time, and/or battery consumption may be required when positions/motions of the housing 312/image capture device 302 are determined from the information/signals from the position sensor 308 than the information/signals from the image sensor 306. The position information determined independent of the image information may be used to determine the trajectory of the housing 312/image capture device 302 during the capture duration.

(35) The processor 310 may include one or more processors (logic circuitry) that provide information processing capabilities in the image capture device 302. The processor 310 may provide one or more computing functions for the image capture device 302. The processor 310 may operate/send command signals to one or more components of the image capture device 302 to operate the image capture device 302. For example, the processor 310 may facilitate operation of the image capture device 302 in capturing image(s) and/or video(s), facilitate operation of the optical element 304 (e.g., change how light is guided by the optical element 304), and/or facilitate operation of the image sensor 306 (e.g., change how the received light is converted into information that defines images/videos and/or how the images/videos are post-processed after capture). The processor 310 may obtain information from the image sensor 306 and/or the position sensor 308, and/or facilitate transfer of information from the image sensor 306 and/or the position sensor 308 to another device/component. The processor 310 may be remote from the processor 11 or local to the processor 11. One or more portions of the processor 310 may be part of the processor 11 and/or one or more portions of the processor 10 may be part of the processor 310.

(36) Referring back to FIG. 1, the processor 11 (or one or more components of the processor 11) may be configured to obtain information to facilitate stabilizing videos. Obtaining information may include one or more of accessing, acquiring, analyzing, determining, examining, identifying, loading, locating, opening, receiving, retrieving, reviewing, storing, and/or otherwise obtaining the information. The processor 11 may

obtain information from one or more locations. For example, the processor 11 may obtain information from a storage location, such as the electronic storage 13, electronic storage of information and/or signals generated by one or more sensors, electronic storage of a device accessible via a network, and/or other locations. The processor 11 may obtain information from one or more hardware components (e.g., an image sensor, a position sensor) and/or one or more software components (e.g., software running on a computing device).

(37) For example, the processor 11 (or one or more components of the processor 11) may obtain image information defining images with an optical field of view, position information characterizing positions of an image capture device at different moments within a capture duration, and/or other information. One or more information may be obtained during acquisition of the images and/or after acquisition of the images by an image capture device. For example, image information, position information, and/or other information may be obtained while the images are being captured by an image capture device and/or after the images have been captured and stored in memory (e.g., the electronic storage 13).

(38) The observed trajectory component 102 may be configured to determine an observed trajectory of the image capture device/housing of the image capture device during the capture duration based on the position information and/or other information. The determination of the observed trajectory may be referred to as trajectory generation/observed trajectory generation. The observed trajectory may refer to one or

more paths and/or progression followed by the image capture device/housing during the capture duration. The observed trajectory may reflect positions of the image capture device/housing of the image capture device at different moments within the capture duration. The positions of the image capture device/housing of the image capture device may include rotational positions (e.g., rotations about one or more axis of the image capture device) and/or translational positions of the image capture device/housing of the image capture device. For example, the observed trajectory component 102 may determine an observed trajectory of the image capture device/housing of the image capture device during the capture duration based on the position information characterizing specific translational and/or rotational positions of the image capture device/housing and/or changes in translational and/or rotational positions of the image capture device/housing as a function of progress through the capture duration.

(39) The observed trajectory may include different portions corresponding to different moments within the capture duration. For example, the observed trajectory may include a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment within the capture duration. The second moment may be subsequent to the first moment within the capture duration.

(40) FIG. 4 illustrates an example observed trajectory of an image capture device. The observed trajectory may include an observed yaw trajectory 400 of the image capture device. The observed yaw trajectory 400 may reflect yaw angle positions (e.g.,

rotational positions defined with respect to a yaw axis, rotation to the left or right) of the image capture device/housing of the image capture device at different moments within the capture duration. The observed yaw trajectory 400 may show that the image capture device was rotated in a negative yaw direction, rotated in a positive yaw direction, rotated back in the forward configuration, then rotated in the negative yaw direction. For example, the image capture device, during capture of images, may have been rotated to the right, then to the left, to the front, then to the right. Other types of observed trajectory (e.g., pitch trajectory, roll trajectory, translational trajectory) are contemplated.

(41) Generating a video based on the images captured along the observed yaw trajectory 400 may be undesirable. For example, generating a video based on the images captured along the observed yaw trajectory 400 may result in a video with footage that is shaky and/or that appears to include unintended camera motion. For instance, sharp/quick changes in the yaw angle positions of the image capture device may result in abrupt changes in the direction of visuals within the video (e.g., quick left or right camera motion). Multiple changes in the yaw angle positions of the image capture device may result in a footage that is changing the direction of view (e.g., to the right, to the left, to the front, to the right).

(42) Videos generated from such images may be stabilized to provide a smoother view of the captured content. Stabilization of such videos may include using smaller visual content portions of the images to provide a punch-out view of the images that

creates a more stable view than when generating videos by using the entire visual content of the images. For example, such stabilization may be provided by creating a stabilized trajectory over the capture duration and determining the punch-outs from the images based on the stabilized trajectory. A punch-out of an image may refer to one or more portions of the image that is used for presentation, such as a cut-out of the image or a cropped portion of the image. A punch-out of an image may include one or more visual portions of the image presented on a display and/or one or more visual portion portions of the image used to generate video frames of video content. However, some stabilization techniques may not preserve the intent of the user that captured the images.

(43) For example, videos may be stabilized by predicting positions/motions of the camera based on past positions/motions. For example, when attempting to determine the location and/or shape of the punch-out for an image captured at a given moment within the capture duration, the positions/motions of the image capture device preceding that moment may be used to determine how to position/shape the punch-out to create a stabilized view. Such use of “past” position/motion information may conflict with the motion intended by the user of the image capture device.

(44) For example, in the observed yaw trajectory 400, the rotation of the image capture device to the right, then to the left, and then to the front may be the result of the image capture device being unintentionally rotated to the right, the user overcorrecting the rotation to the left, and then rotating the image capture device to the right to a front-

facing direction. Determining punch-out of the images using "past" position/motion information may result in a predicted trajectory as shown in FIG. 5A.

(45) For example, based on the rotation of the image capture device to the right during duration A 502, a predicted yaw trajectory A 512, which continues the rotation to the right, may be predicted for duration B 504. Based on smaller rotation of the image capture device to the right during duration D 506, a predicted yaw trajectory B 514, which continues the smaller rotation to the right, may be predicted for duration D 508. The predicted yaw trajectory A 512 may be in opposite direction of the actual motion of the image capture device during duration B 504, and the predicted yaw trajectory B 514 may be off from the observed yaw trajectory by a large margin. Such discrepancy between the observed yaw trajectory and the predicted yaw trajectory may result in the images not including enough visual information (e.g., pixels) to account for the attempted stabilized and/or the punch-out location/shape.

(46) As another example, videos may be stabilized by smoothing the observed changes in positions/motions of the image capture device. For instance, a low-pass filter may be applied to the observed trajectory to smooth out the abrupt rotational and/or translational changes in the positions/motions of the image capture device.

(47) For example, as shown in FIG. 5B, by applying a low-pass filter to the observed yaw trajectory 400, a smoothed yaw trajectory 516 may be determined. The smoothed yaw trajectory 516 may have smoother changes in the positions/motions of the image capture device than the observed yaw trajectory. However, such smooth may not take

into account how the positions/motions changes during the capture duration and may not preserve the intent of the user that captured the images. For example, even though a video generated from the smoothed yaw trajectory 516 may not include abrupt changes in the direction of visuals within the video, the video may still include footage that is changing the direction of view to the right, then to left, to the front, and then to the right in a non-continuous motion (e.g., rotating to the right to a certain angle, holding that position for a time, then rotating to the right, then back a little to the left, and then to the right again).

(48) The capture trajectory component 104 may be configured to determine a capture trajectory of the image capture device/housing of the image capture device based on a subsequent portion of the observed trajectory and/or other information. The determination of the capture trajectory may be referred to as trajectory generation/capture trajectory generation. The capture trajectory may refer to one or more paths and/or progression to be used in determining which portions of the visual content of the images (punch-outs) may be used to generate a video. The capture trajectory may reflect actual and/or virtual positions of the image capture device/housing of the image capture device at different moments within the capture duration. An actual position may refer to a position that was taken by the image capture device/housing of the image capture. A virtual position may refer to a position that was not taken by the image capture device/housing of the image capture. A virtual position may be offset (rotationally and/or translationally) from the actual position of the image capture

device/housing of the image capture device. The capture trajectory may have smoother changes in the positions of the image capture device/housing of the image capture device than the observed trajectory. That is, the capture trajectory may have less jitters (slight irregular movement/variation), less abrupt changes, and/or less discontinuous changes in the positions of the image capture device/housing of the image capture device than the observed trajectory.

(49) Determining a capture trajectory (capture trajectory generation) based on a subsequent portion of an observed trajectory may include determining a portion of the capture trajectory corresponding to a given moment within the capture duration based on one or more portions of the observed trajectory corresponding to one or more subsequent moments (moment(s) past the given moment) within the capture duration. That is, the capture trajectory component 104 may "look ahead" in time to determine a portion of the capture trajectory. A look ahead may include use of one or more subsequent portions of an observed trajectory to determine a preceding portion of the capture trajectory. Such generation of trajectory may be referred to as a look head trajectory generation. A subsequent moment within the duration may be adjacent to the given moment or not adjacent to the given moment. Using the subsequent portion(s) of the observed trajectory may enable the capture trajectory component 104 to determine a capture trajectory that preserves a user's intended motion for the image capture device. The user's intended motion may refer to the motion of the image capture device that the user planned/meant to carry out.

(50) The positions/motions of the image capture device in the "future" may be analyzed (look ahead) to determine whether particular position(s)/motion(s) of the image capture device at a moment is an intended motion or an unintended motion (e.g., shaking due to vibration, rotation due to bumping/mishandling the image capture device). For example, when determining the capture trajectory for a moment (e.g., corresponding to the 1000th video frame) within the capture duration, the position(s)/motion(s) of the image capture device for a duration subsequent to the moment (e.g., corresponding to the next 30 video frames) may be analyzed to determine whether the position/motion of the image capture device at the moment was intended or not. In some implementations, the capture trajectory component 104 may determine a capture trajectory of the image capture device/housing of the image capture device further based on one or more prior portions of the observed trajectory. The past position/motion information of the image capture device may supply context for the intended motion.

(51) FIG. 5C illustrates an example capture trajectory determined by the capture trajectory component 104. The capture trajectory may include a capture yaw trajectory 532. The capture yaw trajectory 532 may reflect yaw angle positions (e.g., rotational positions defined with respect to a yaw axis, rotation to the left or right) of the image capture device/housing of the image capture device to be used in determining which portions of the visual content of the images (punch-outs) may be used to generate a video. For example, the capture yaw trajectory 532 may include a zero-rotation about

the yaw axis (front-direction) for durations 522, 524, 526 and then a smooth rotation to the right for durations 528, 530. Other types of capture trajectory (e.g., capture pitch trajectory, capture roll trajectory, capture translational trajectory) are contemplated.

(52) The capture yaw trajectory 532 may be determined such that a portion of the capture yaw trajectory 532 corresponding to the portion of the observed yaw trajectory 400 is determined based on a subsequent portion of the observed yaw trajectory 400. For example, the portion of the capture yaw trajectory 532 for one or more portions of the duration A 522 may be determined based on the portion(s) of the observed yaw trajectory 400 within the duration B 524 and/or the duration C 526 (look ahead to the duration B 524 and/or the duration C 526). The portion(s) of the observed yaw trajectory 400 for the duration B 524 and/or the duration C 526 may be used to determine in what direction and/or by what amount the capture yaw trajectory 532 for portion(s) of the duration A 522 may differ from the observed yaw trajectory 400. The capture yaw trajectory 532 may be determined based on subsequent portion(s) of the observed trajectory 400 such that the capture yaw trajectory 532 preserves a user's intended motion for the image capture device. For example, based on the subsequent portion(s) (look ahead) of the observed trajectory 400, the capture trajectory component 104 may determine that the rotation of the image capture device to the right and left during durations 522, 524 were unintended motions (e.g., the image capture device being unintentionally rotated to the right and the user overcorrecting the rotation to the left), and may determine the capture yaw trajectory 532 to be directed to the front during

durations 522, 524. Based on the subsequent portion(s) (look ahead) of the observed trajectory 400, the capture trajectory component 104 may determine that the staggered rotation of the image capture device to the right during durations 528, 530 included unintended motions (non-continuous rotation to the right), and may determine the capture yaw trajectory 532 to include continuous rotation to the right during durations 528, 530. Other determinations of capture trajectory are contemplated.

(53) In some implementations, the capture trajectory may be determined based on minimization of a rotational velocity of the image capture device/housing of the image capture device and a rotational acceleration of the image capture device/housing of the image capture device while respecting a set of constraints. For example, the capture trajectory may be determined by generating a smooth path that respects the set of constraints, rather than by modifying the observed trajectory. For instance, a smooth path defining yaw angle position, pitch angle position, and/or roll angle position may be generated by finding a path of the image capture device/housing of the image capture device that minimizes a combination of a time derivative, a second time derivative, and/or other time derivative(s) of the yaw angle position, pitch angle position, and/or roll angle position while respecting the set of constraints:

(54) $$\min\left(\left\|\frac{d}{dt}\theta\right\|^2+\left\|\frac{d^2}{dt^2}\theta\right\|^2+\dots\right)$$

(55) In some implementations, one or more of the portions of the minimization calculation may be changed. For example, one or more portions of the minimization calculation (e.g., the first time derivative) may be changed to have a greater affect or a lesser affect than other portion(s) of the minimization calculation (e.g., the second time derivative), and/or other factors may be introduced into the calculation.

(56) In some implementations, information on high frequencies (jitters) of image capture may be used to improve visual characteristics of generated video content. Certain portion of high frequencies in the input may be kept based on the image capture configuration, such as exposure start time and exposure duration time, the position information (e.g., position sensor readings), and/or other information. For example, motion of the image capture device/image sensor during a frame exposure may be analyzed and used to generate/modify a capture trajectory that minimizes inter-frame motion (e.g., smooths inter-frame motion) while preserving the intra-frame motion, which may contain the high frequencies. This may provide for improved visual characteristics of the generated video content, such as by compensating for motion blur and/or lowlight image capture conditions.

(57) For example, image capture may not happen instantaneously. Rather, it may take a certain amount of time for image sensor pixel sites to gather light. This may lead to splitting of the image sensor motion in time in two phases: inter-frame motion which may not be captured and may be suppressed, and intra-frame motion which may be "encrusted" in the image and may not be removed. Better visual characteristics (e.g.,

impression) may be provided when the intra-frame motion is taken into account so that the capture trajectory is smooth for inter-frame phases while corresponding to the original motion for intra-frame phases. That is, the capture trajectory may move/follow in the same direction and with the same speed as during the frame exposure phase, so that its motion is aligned with the motion blur in the image.

(58) The set of constraints may include one or more constraints that provide limitations/restrictions/rules on how the smooth path is generated. For example, the set of constraints may include a margin constraint that provide limitation(s)/restriction(s)/rule(s) on how far from the observed trajectory the smooth path may be generated. The margin constraint may be determined based on a difference between the optical field of view and the capture field of view, and/or other information. The optical field of view may refer to the field of view of a scene captured within the image. That is, the optical field of view may refer to the spatial extent/angle of the scene captured within the image. The capture field of view may refer to the field of view used to generate a video based on visual content of the images. That is, a video may be generated based on visual content of the images within the capture field of view. The capture field of view may be defined in terms of shape and/or size.

(59) For example, FIG. 6A illustrates an example optical field of view 602 and an example capture field of view 604 for an image A 600. The image A 600 may include capture of a scene within an angle defined by the optical field of view 602. The capture field of view 604 may provide a punch-out of the image A 600 to be used for video

generation. The amount and/or direction from which the smooth path may deviate from the observed trajectory may depend on the difference between the optical field of view 602 and the capture field of view 604. The difference between the optical field of view 602 and the capture field of view 604 (e.g., 10%) may define a margin 606 within which the capture field of view 604 may move with respect to the optical field of view 602. For example, referring to FIG. 6B, a capture field of view 614 may be rotated with respect to the optical field of view 612 while not going beyond the pixels captured within an image B 610, and a capture field of view 624 may be laterally moved with respect to a optical field of view 622 while not going beyond the pixels captured within an image C 620.

(60) Larger difference between the optical field of view 602 and the capture field of view 604 may enable larger movement of the capture field of view 604 with respect to the optical field of view 602 while smaller difference between the optical field of view 602 and the capture field of view 604 may enable smaller movement of the capture field of view 604 with respect to the optical field of view 602. However, the larger margin 606 may result in waste of pixel space and computing resources (e.g., processor power and/or battery consumption to capture images with larger optical field of view than needed to generate a video).

(61) In some implementations, the set of constraints may include a trajectory constraint that provide limitation(s)/restriction(s)/rule(s) on how the smooth path may be generated based on subsequent portions of the observed trajectory. The trajectory constraint may be determined based on a subsequent portion of the observed trajectory

and/or other information. That is, the trajectory constraint may include one or more constraints relating to shape of the observed trajectory in the "future." The trajectory constraint may preserve the intended motion for the image capture device in the generated path.

(62) In some implementations, the set of constraints may include a target constraint that provide limitation(s)/restriction(s)/rule(s) on how the smooth path may be generated based on a target within the images. A target may refer to a person, an object, and/or a thing that may be selected for inclusion in a video. For example, the images captured by the image capture device may include one or more view of a person (e.g., a person of interest) and a user may wish to create a video that includes the person. The target constraint may include one or more constraints relating to the location of the target within the images such that the images are stabilized around the location of the target within the images. That is, the target constraint may affect the generation of the smooth path so that the target is within one or more of the punch-outs for the images. Other constraints are contemplated.

(63) The orientation component 106 may be configured to determine orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the image capture device/housing of the image capture device and/or other information. The orientations of the capture field of view for the images with respect to the optical field of view of the images may determine which portions of the visual content of the images (punch-outs) may be used to

generate a video. That is, the orientation component 106 may determine how the punch-outs for the images may be oriented with respect to the capture field of view for the images. The capture trajectory may be used to determine how much and in what direction the capture field of view is rotated with respect to the optical field of view. In some implementations, the orientation component 106 may determine how the punch-outs for the images may be laterally and/or vertically positioned with respect to the capture field of view for the images. The capture trajectory may determine how much and in what direction the capture field of view is rotated with respect to the optical field of view. The capture trajectory may be used to determine how much and in what direction the capture field of view is laterally/vertically positioned with respect to the optical field of view.

(64) For example, referring to FIG. 6B, the orientation component 106 may determine the orientation of the capture field of view 614 with respect to the optical field of view 612 for the image B 610 based on the capture trajectory at a particular moment. The capture field of view 614 may be oriented with respect to the optical field of view 612 to provide a punch-out of the image B 610 that is stable with respect to a prior and/or next punch-out of the images (e.g., stable with the punch-out of the image A 600 using the capture field of view 604 for the image A 600, shown in FIG. 6A). The orientation component 106 may determine the orientation of the capture field of view 624 with respect to the optical field of view 622 for the image C 620 based on the capture trajectory at a particular moment. The capture field of view 624 may be oriented with

respect to the optical field of view 622 to provide a punch-out of the image C 620 that is stable with respect to a prior and/or next punch-out of the images (e.g., stable with the punch-out of the image B 610 using the capture field of view 614 for the image B 610).

(65) The generation component 108 may be configured to generate video content based on visual content of the images within the capture field of view and/or other information. Video content may refer media content that may be consumed as one or more videos/video clips. Video content may include one or more videos/video clips stored in one or more formats/containers, and/or other video content. A format may refer to one or more ways in which the information defining video content is arranged/laid out (*e.g.*, file format). A container may refer to one or more ways in which information defining video content is arranged/laid out in association with other information (*e.g.*, wrapper format). Video content may define visual content viewable as a function of progress through a progress length of the video content. Video content may include video frames that define visual content. That is, visual content of the video content may be included within video frames of the video content.

(66) The video frames of the video content may be determined based on visual content of the images within the capture field of view and/or other information. The video frames of the video content may be determined based on a punch-out of the images in accordance with the capture trajectory, the capture field of view, and/or other information. For example, referring to FIGS. 6A-6B, the video frames of the video content may be determined based on the visual content of the image A 600 within the

capture field of view 604, the visual content of the image B 610 within the capture field of view 614, the visual content of the image C 620 within the capture field of view 624, and/or other information. Such determination of visual content of images for inclusion in video content may effectuate stabilization of the video content.

(67) In some implementations, the video frames of the video content may be determined based on warping of images (e.g., one or more portions of the visual content of the images). The warping of the images may provide for different perspectives of content captured within the images, with the different perspectives corresponding to how the content would have look had the images been captured from the image capture device on the capture trajectory.

(68) In some implementations, one or more of the images and/or one or more of the portions of images used to generate video content may be stored in a buffer (e.g., 1s buffer). The buffer may be used to store images/portions of images including visual content that will be included in the visual content and/or images/portions of images including visual content that will be transformed (e.g., warped) for inclusion in the visual content. The buffer may be used to store image information, position information, and/or other information for look ahead and/or trajectory generation, For example, the buffer may be used to store images for which trajectory generation is being performed using look ahead. After corresponding portion of the capture trajectory is generated, the relevant portions of the images (visual content of the images within the capture field of view) in the buffer may be used to generate the video content.

(69) The video content generated by the generation component 108 may be defined by video information. Video information defining video content may define an encoded version/copy of the video content and/or instructions for rendering the video content. For example, the video information may define an encoded version/copy of the video content, and the video information (e.g., video file) may be opened in a video player for presentation of the video content. The video information may define instructions to render the video content for presentation. For example, the video information may define a director track that includes information as to which visual portions of the images should be included within the presentation of the video content. The director track may include information on the location and/or shape of the punch-out of images to be used to as a function progress through the video content to provide a stabilized view of the images. A video player may use the director track to retrieve the relevant visual portions of the images when the video content is opened/to be presented.

(70) The generation component 108 may be configured effectuate storage of the video information and/or other information in one or more storage media. For example, the video information may be stored in the electronic storage 13, remote storage locations (storage media located at/accessible through a server), and/or other locations. In some implementations, the generation component 108 may effectuate storage of the video information through one or more intermediary devices. For example, the processor 11 may be located within a computing device without a connection to the storage device (e.g., the computing device lacks WiFi/cellular connection to the storage

device). The generation component 108 may effectuate storage of the video information through another device that has the necessary connection (e.g., the computing device using a WiFi/cellular connection of a paired mobile device, such as a smartphone, tablet, laptop, to store information in one or more storage media). Other storage locations for and storage of the video information are contemplated.

(71) While the description herein may be directed to images and videos, one or more other implementations of the system/method described herein may be configured for other types media content. Other types of media content may include one or more of audio content (e.g., music, podcasts, audiobooks, and/or other audio content), multimedia presentations, images, slideshows, visual content (e.g., one or more images and/or videos), and/or other media content.

(72) Implementations of the disclosure may be made in hardware, firmware, software, or any suitable combination thereof. Aspects of the disclosure may be implemented as instructions stored on a machine-readable medium, which may be read and executed by one or more processors. A machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computing device). For example, a tangible computer-readable storage medium may include read-only memory, random access memory, magnetic disk storage media, optical storage media, flash memory devices, and others, and a machine-readable transmission media may include forms of propagated signals, such as carrier waves, infrared signals, digital signals, and others. Firmware, software, routines, or instructions

may be described herein in terms of specific exemplary aspects and implementations of the disclosure, and performing certain actions.

(73) In some implementations, some or all of the functionalities attributed herein to the system 10 may be provided by external resources not included in the system 10. External resources may include hosts/sources of information, computing, and/or processing and/or other providers of information, computing, and/or processing outside of the system 10.

(74) Although the processor 11 and the electronic storage 13 are shown to be connected to the interface 12 in FIG. 1, any communication medium may be used to facilitate interaction between any components of the system 10. One or more components of the system 10 may communicate with each other through hard-wired communication, wireless communication, or both. For example, one or more components of the system 10 may communicate with each other through a network. For example, the processor 11 may wirelessly communicate with the electronic storage 13. By way of non-limiting example, wireless communication may include one or more of radio communication, Bluetooth communication, Wi-Fi communication, cellular communication, infrared communication, Li-Fi communication, or other wireless communication. Other types of communications are contemplated by the present disclosure.

(75) Although the processor 11 is shown in FIG. 1 as a single entity, this is for illustrative purposes only. In some implementations, the processor 11 may comprise a

plurality of processing units. These processing units may be physically located within the same device, or the processor 11 may represent processing functionality of a plurality of devices operating in coordination. The processor 11 may be configured to execute one or more components by software; hardware; firmware; some combination of software, hardware, and/or firmware; and/or other mechanisms for configuring processing capabilities on the processor 11.

(76) It should be appreciated that although computer components are illustrated in FIG. 1 as being co-located within a single processing unit, in implementations in which processor 11 comprises multiple processing units, one or more of computer program components may be located remotely from the other computer program components.

(77) While computer program components are described herein as being implemented via processor 11 through machine-readable instructions 100, this is merely for ease of reference and is not meant to be limiting. In some implementations, one or more functions of computer program components described herein may be implemented via hardware (e.g., dedicated chip, field-programmable gate array) rather than software. One or more functions of computer program components described herein may be software-implemented, hardware-implemented, or software and hardware-implemented

(78) The description of the functionality provided by the different computer program components described herein is for illustrative purposes, and is not intended to be limiting, as any of computer program components may provide more or less functionality

than is described. For example, one or more of computer program components may be eliminated, and some or all of its functionality may be provided by other computer program components. As another example, processor 11 may be configured to execute one or more additional computer program components that may perform some or all of the functionality attributed to one or more of computer program components described herein.

(79) The electronic storage media of the electronic storage 13 may be provided integrally (i.e., substantially non-removable) with one or more components of the system 10 and/or removable storage that is connectable to one or more components of the system 10 via, for example, a port (e.g., a USB port, a Firewire port, etc.) or a drive (e.g., a disk drive, etc.). The electronic storage 13 may include one or more of optically readable storage media (e.g., optical disks, etc.), magnetically readable storage media (e.g., magnetic tape, magnetic hard drive, floppy drive, etc.), electrical charge-based storage media (e.g., EPROM, EEPROM, RAM, etc.), solid-state storage media (e.g., flash drive, etc.), and/or other electronically readable storage media. The electronic storage 13 may be a separate component within the system 10, or the electronic storage 13 may be provided integrally with one or more other components of the system 10 (e.g., the processor 11). Although the electronic storage 13 is shown in FIG. 1 as a single entity, this is for illustrative purposes only. In some implementations, the electronic storage 13 may comprise a plurality of storage units. These storage units

may be physically located within the same device, or the electronic storage 13 may represent storage functionality of a plurality of devices operating in coordination.

(80) FIG. 2 illustrates method 200 for stabilizing videos. The operations of method 200 presented below are intended to be illustrative. In some implementations, method 200 may be accomplished with one or more additional operations not described, and/or without one or more of the operations discussed. In some implementations, two or more of the operations may occur substantially simultaneously.

(81) In some implementations, method 200 may be implemented in one or more processing devices (e.g., a digital processor, an analog processor, a digital circuit designed to process information, a central processing unit, a graphics processing unit, a microcontroller, an analog circuit designed to process information, a state machine, and/or other mechanisms for electronically processing information). The one or more processing devices may include one or more devices executing some or all of the operation of method 200 in response to instructions stored electronically on one or more electronic storage mediums. The one or more processing devices may include one or more devices configured through hardware, firmware, and/or software to be specifically designed for execution of one or more of the operation of method 200.

(82) Referring to FIG. 2 and method 200, at operation 201, an image output signal may be generated. The image output signal may convey image information that defines images with an optical field of view. In some implementation, operation 201 may be

performed by a component the same as or similar to the image sensor 306 (Shown in FIG. 3 and described herein).

(83) At operation 202, a position output signal may be generated. The position output signal may convey position information that characterizes positions of an image capture device at different moments within a capture duration. In some implementation, operation 202 may be performed by a processor component the same as or similar to the positions sensor 308 (Shown in FIG. 3 and described herein).

(84) At operation 203, an observed trajectory of the image capture device during the capture duration may be determined based on the position information. In some implementation, operation 203 may be performed by a processor component the same as or similar to the observed trajectory component 102 (Shown in FIG. 1 and described herein).

(85) At operation 204, a capture trajectory of the image capture device may be determined based on a subsequent portion of the observed trajectory. In some implementation, operation 204 may be performed by a processor component the same as or similar to the capture trajectory component 104 (Shown in FIG. 1 and described herein).

(86) At operation 205, orientations of a capture field of view for the image may be determined with respect to the optical field of view based on the capture trajectory. In some implementation, operation 205 may be performed by a processor component the

same as or similar to the orientation component 106 (Shown in FIG. 1 and described herein).

(87) At operation 206, video content may be generated based on visual content of the images within the capture field of view. In some implementation, operation 206 may be performed by a processor component the same as or similar to the generation component 108 (Shown in FIG. 1 and described herein).

(88) Although the system(s) and/or method(s) of this disclosure have been described in detail for the purpose of illustration based on what is currently considered to be the most practical and preferred implementations, it is to be understood that such detail is solely for that purpose and that the disclosure is not limited to the disclosed implementations, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present disclosure contemplates that, to the extent possible, one or more features of any implementation can be combined with one or more features of any other implementation.

What is claimed is:

1. A system that stabilizes videos, the system comprising:

a housing of an image capture device;

an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content;

the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;

a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; and

one or more physical processors configured by machine-readable instructions to:

determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within

the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;

determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory;

determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and

generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.

2. The system of claim 1, wherein the determination of the capture trajectory of the housing based on the look ahead of the observed trajectory preserves a user's intended motion of the image capture device during the capture duration.

3. The system of claim 2, wherein past positions of the image capture device supply context for the user's intended motion of the image capture device.

4. The system of claim 1, wherein the positions of the housing further include translational positions of the housing, and at least some of the virtual positions of the housing are translationally offset from the actual positions of the housing.

5. The system of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.

6. The system of claim 1, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing.

7. The system of claim 1, wherein the capture trajectory of the housing is determined to minimize inter-frame motion while preserving intra-frame motion.

8. The system of claim 1, wherein the images are stored in a buffer during capture trajectory generation.

9. The system of claim 8, wherein the images are stored in the buffer during the capture trajectory generation such that individual ones of the images corresponding to the portion of the capture trajectory are stored in the buffer during the determination of the portion of the capture trajectory using the lookahead of the observed trajectory, and the visual content of the individual ones of the images stored in the buffer are used after the determination of the portion of the capture trajectory to generate the video content.

10. The system of claim 9, wherein the one or more physical processors are, to generate the video content based on the punch-out of the visual content of the images within the capture field of view, further configured by machine-readable instructions to crop the visual content of the images based on the capture field of view.

11. A method for stabilizing videos, the method performed by an image capture device including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to

guide light within an optical field of view to the image sensor, the optical field of view being greater than a capture field of view for generating video content, the method comprising:

generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;

generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing;

determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;

determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look

ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory;

determining, by the one or more processors, the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and

generating, by the one or more processors, the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.

12. The method of claim 11, wherein determining the capture trajectory of the housing based on the look ahead of the observed trajectory preserves a user's intended motion of the image capture device during the capture duration.

13. The method of claim 12, wherein past positions of the image capture device supply context for the user's intended motion of the image capture device.

14. The method of claim 11, wherein the positions of the housing further include translational positions of the housing, and at least some of the virtual positions of the housing are translationally offset from the actual positions of the housing.

15. The method of claim 11, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.

16. The method of claim 11, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing.

17. The method of claim 11, wherein the capture trajectory of the housing is determined to minimize inter-frame motion while preserving intra-frame motion.

18. The method of claim 11, wherein the images are stored in a buffer during capture trajectory generation.

19. The method of claim 18, wherein the images are stored in the buffer during the capture trajectory generation such that individual ones of the images corresponding to the portion of the capture trajectory are stored in the buffer during the determination of the portion of the capture trajectory using the lookahead of the observed trajectory, and the visual content of the individual ones of the images stored in the buffer are used after the determination of the portion of the capture trajectory to generate the video content.

20. The method of claim 19, wherein generating the video content based on the punch-out of the visual content of the images within the capture field of view includes cropping the visual content of the images based on the capture field of view.

ABSTRACT

Images with an optical field of view are captured by an image capture device. An observed trajectory of the image capture device reflects the positions of the image capture device at different moments may be determined. A capture trajectory of the image capture device reflects virtual positions of the image capture device from which video content may be generated. The capture trajectory is determined based on a subsequent portion of the observed trajectory such that a portion of the capture trajectory corresponding to a portion of the observed trajectory is determined based on a subsequent portion of the observed trajectory. Orientations of punch-outs for the images are determined based on the capture trajectory. Video content is generated based on visual content of the images within the punch-outs.

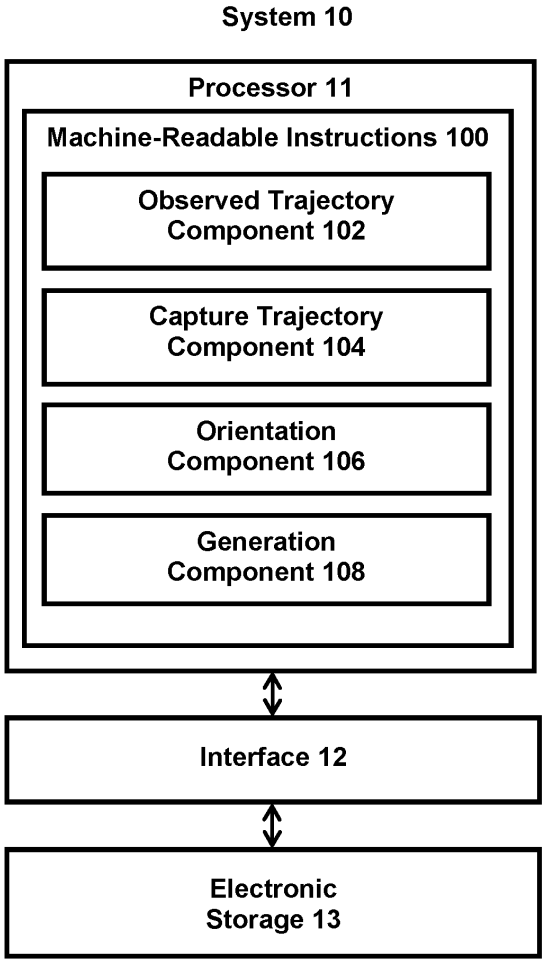

System 10
Processor 11
Machine-Readable Instructions 100
Observed Trajectory Component 102
Capture Trajectory Component 104
Orientation Component 106
Generation Component 108
Interface 12
Electronic Storage 13

FIG. 1

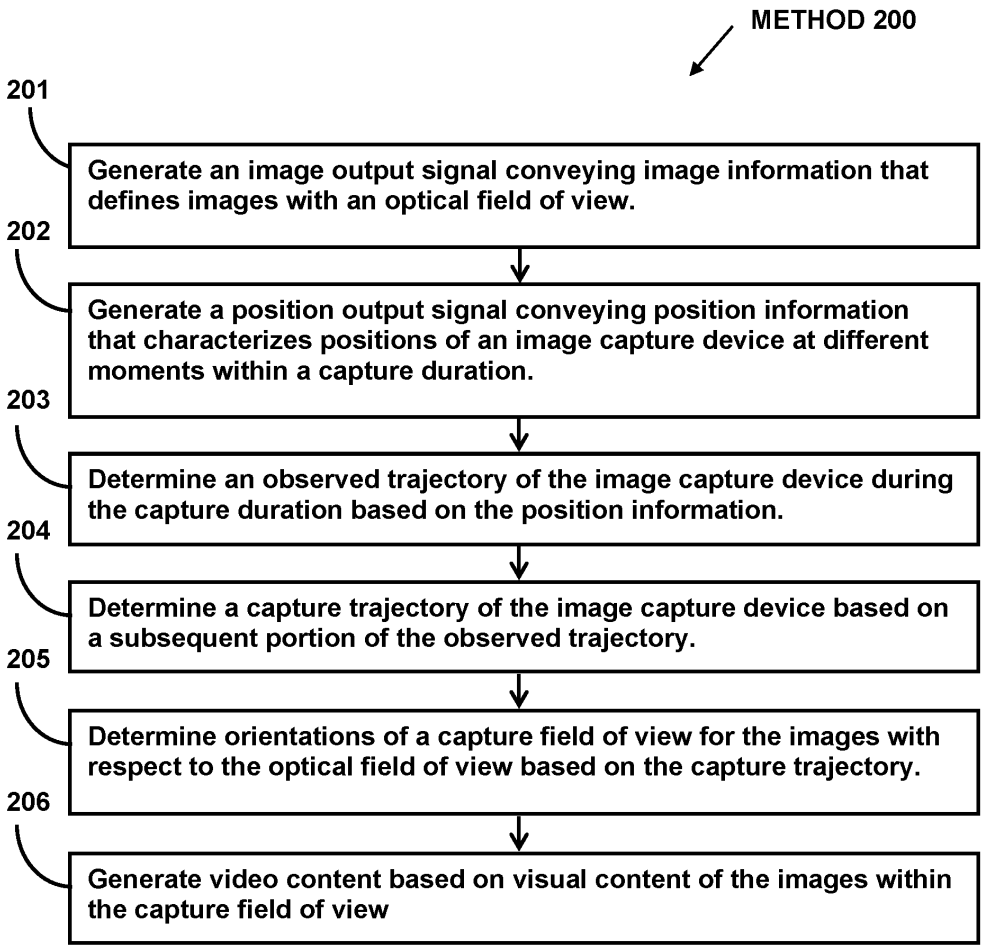

METHOD 200
201
Generate an image output signal conveying image information that defines images with an optical field of view.
202
Generate a position output signal conveying position information that characterizes positions of an image capture device at different moments within a capture duration.
203
Determine an observed trajectory of the image capture device during the capture duration based on the position information.
204
Determine a capture trajectory of the image capture device based on a subsequent portion of the observed trajectory.
205
Determine orientations of a capture field of view for the images with respect to the optical field of view based on the capture trajectory.
206
Generate video content based on visual content of the images within the capture field of view

FIG. 2

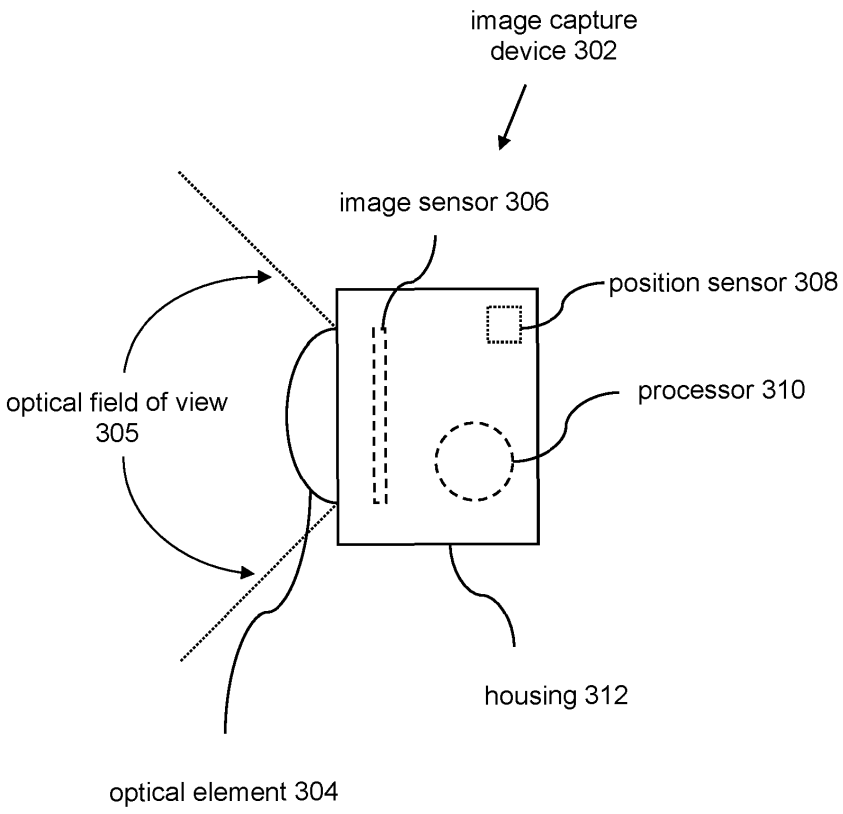

image capture device 302
image sensor 306
position sensor 308
processor 310
optical field of view 305
housing 312
optical element 304

FIG. 3

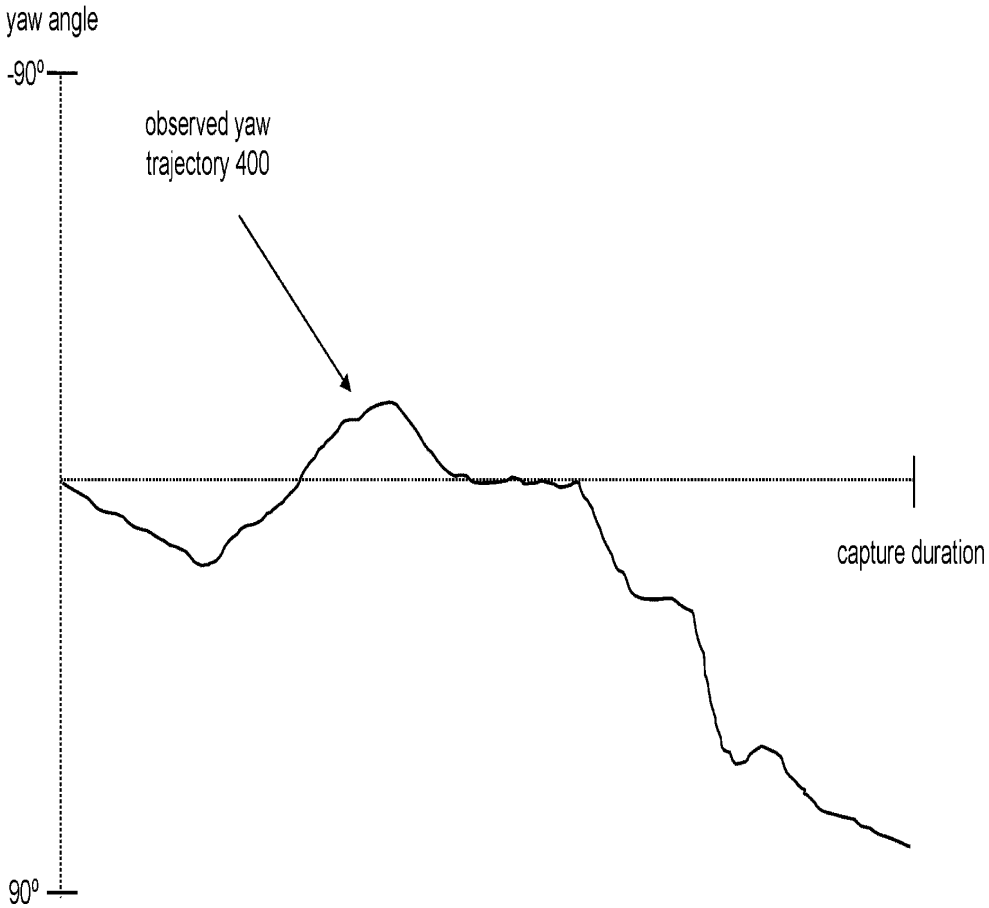

yaw angle
-90°
observed yaw
trajectory 400
capture duration
90°

FIG. 4

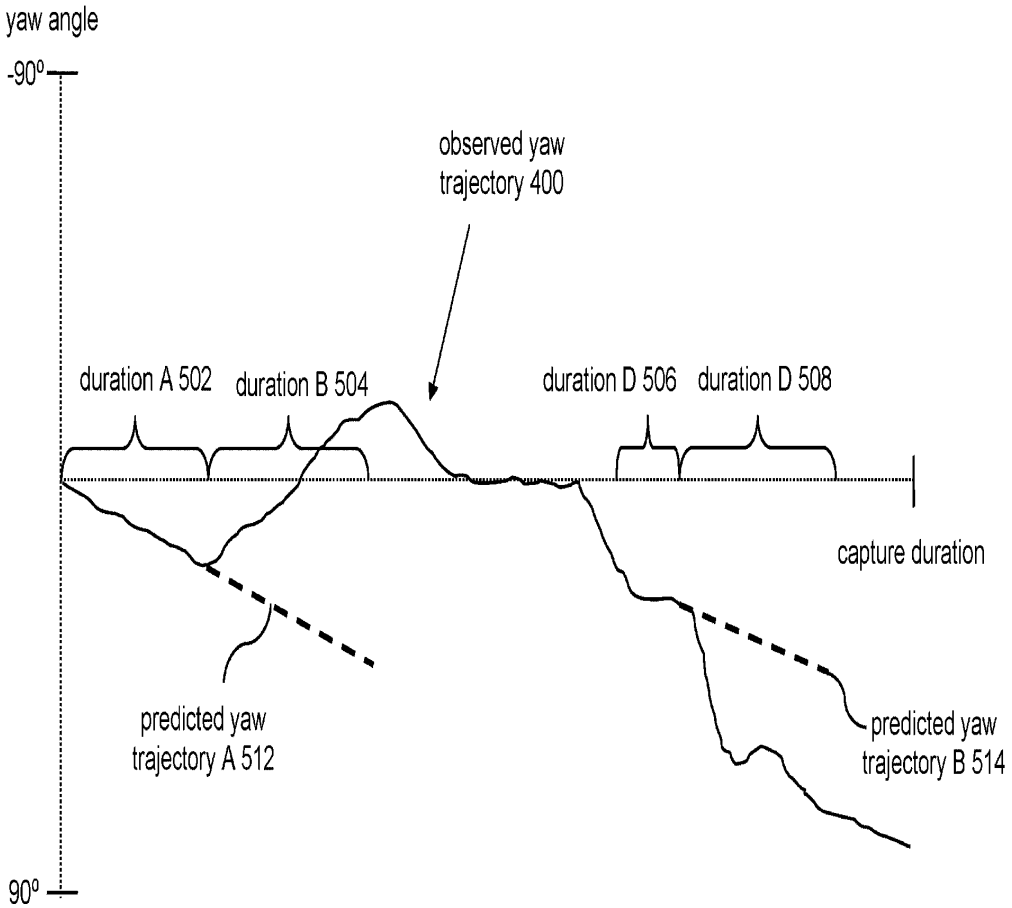

yaw angle
-90°
observed yaw
trajectory 400
duration A 502
duration B 504
duration D 506
duration D 508
capture duration
predicted yaw
trajectory A 512
predicted yaw
trajectory B 514
90°

FIG. 5A

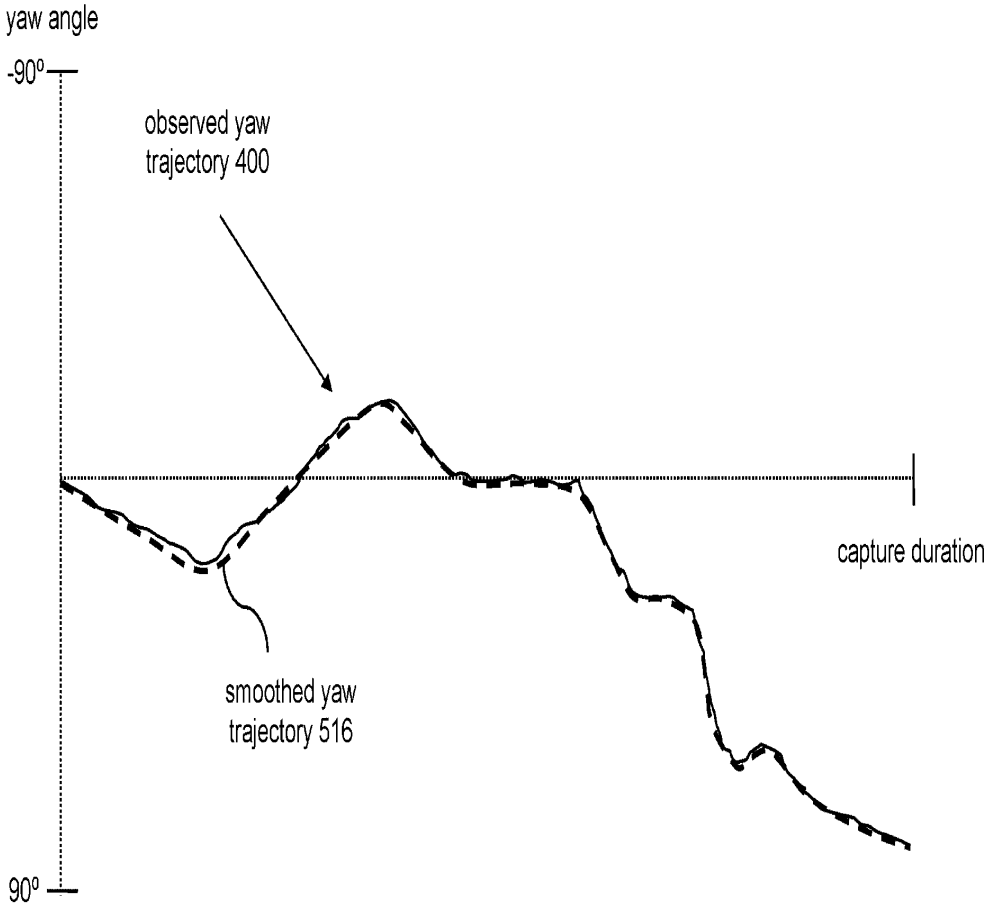

yaw angle
-90°
observed yaw
trajectory 400
capture duration
smoothed yaw
trajectory 516
90°

FIG. 5B

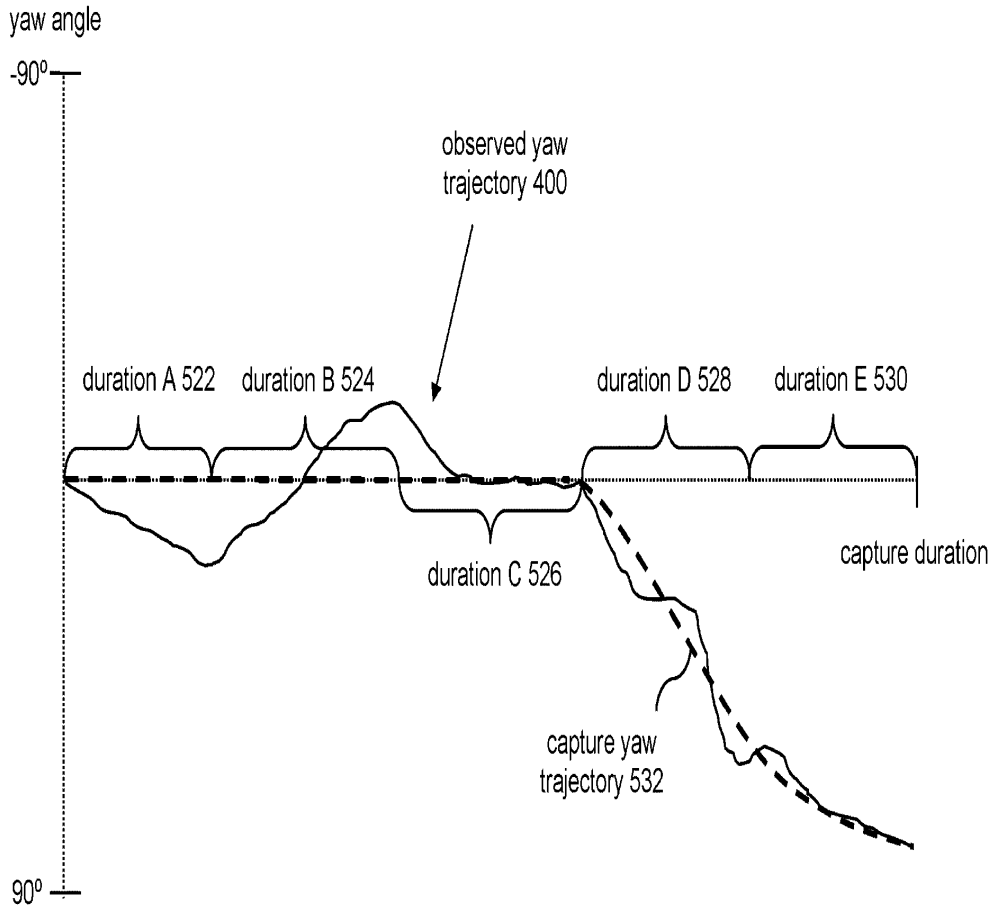

yaw angle
-90°
observed yaw
trajectory 400
duration A 522
duration B 524
duration C 526
duration D 528
duration E 530
capture duration
capture yaw
trajectory 532
90°

FIG. 5C

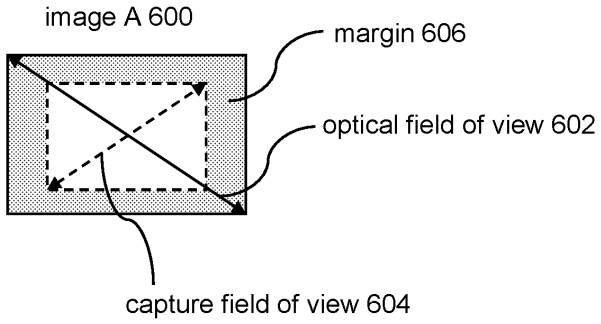

image A 600
margin 606
optical field of view 602
capture field of view 604

FIG. 6A

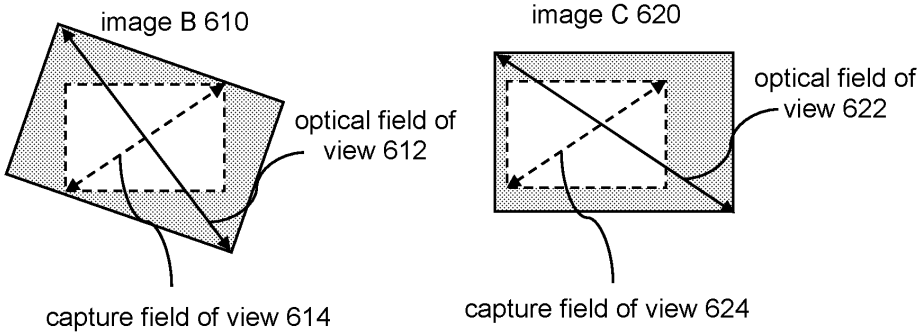

image B 610
optical field of view 612
capture field of view 614
image C 620
optical field of view 622
capture field of view 624

FIG. 6B

ATTORNEY DOCKET NUMBER: **46DG-274956**
GP2018025US1

DECLARATION (37 C.F.R. 1.63) FOR UTILITY PATENT APPLICATION USING AN APPLICATION DATA SHEET (37 C.F.R. 1.76) AND ASSIGNMENT

Title of Invention: **SYSTEMS AND METHODS FOR STABILIZING VIDEOS**

As a below named inventor, I hereby declare that:

This declaration is directed to the attached application, or (if following box is checked):

[X] United States application number 15/987,786 filed on May 23, 2018.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the application, including the claims.

I am aware of the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in 37 CFR Section 1.56.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WHEREAS, the undersigned inventor(s) (hereinafter "Assignor"), has/have made an invention entitled **"SYSTEMS AND METHODS FOR STABILIZING VIDEOS"** disclosed in the above-identified patent application and further identified by the Attorney Docket Number provided in the header of this document, and

WHEREAS, **GOPRO, INC.**, (hereinafter "Assignee"), a corporation of Delaware, having a place of business at 3000 Clearview Way, San Mateo, California 94402 USA, is desirous of acquiring the entire right, title and interest in and to the aforesaid invention, application and all Letters Patent of the United States or any foreign country, including continuations, continuations-in-part, reissues, reexaminations, extensions, substitutes, and divisions which may be granted therefor;

NOW THEREFORE, in consideration of the sum of One Dollar ($1.00) and other good and valuable consideration, the receipt of which is hereby acknowledged, I, the said Assignor, by these presents do sell, assign and transfer unto Assignee, its successors, legal representatives and assigns, the full and exclusive right in and to the said invention as described in the said application, and in and to any Letters Patent of the United States or any foreign country, including continuations, continuations-in-part, reissues, reexaminations, extensions, substitutes, and divisions which may be granted therefor and all rights to claim priority on the basis of said application; and I further grant to Assignee the sole right to sue and collect damages for past infringement;

AND I HEREBY authorize and request the Commissioner of Patents and Trademarks or any other proper officer or agency of any country to issue all said Letters Patent to said Assignee;

AND I HEREBY warrant and covenant that I have the full right to convey the entire interest herein assigned and that I have not executed and will not execute any instrument or assignment in conflict herewith;

AND I HEREBY agree to communicate to said Assignee or its representatives any facts known to me respecting said invention, to execute all divisional, continuation, reissue, reexamination, extension, substitute, and foreign applications, sign all lawful documents and make all rightful oaths and declarations relating to said invention, execute and deliver any and all papers that may be necessary or desirable to perfect the title to this invention in said Assignee, its successors, legal representatives or assigns, and to testify in any judicial or administrative proceeding and generally do everything possible to aid the said Assignee to obtain and enforce said Letters Patent in the United States or any foreign country when requested so to do by said Assignee.

(1) Legal Name of Inventor: **Thomas Derbanne**

Signature: _____

Date: 08/24/2018

(2) Legal Name of Inventor: **César Douady-[redacted]** CD 09/28/2018

Signature: _____

Date: 08/24/2018

(3) Legal Name of Inventor: **Maxim Karpushin**

Signature: _____

Date: 08/24/2018

ASSIGNEE hereby agrees to the foregoing terms of this assignment.

GOPRO, INC.

Date: 12/17/2018 Signature: _____

By: Tyler J. Gee

Its: Associate General Counsel, Head of IP

CD Submission Review Results

Internal Worksheet Only - Do Not Scan

Application Number	16548453	Receipt Date	Aug 22, 2019

X	New Application		Response To Notice	Date Of Response

☐ Jumbo – Large tables are included on the CD

X **There are no problems with the CDs in the submission.**

Items checked below are to be selected in the PALM Pre-Exam CD problem list.

Omitted Items

	Files on compact disc are unreadable:
	Disc(s) of either set not readable:
	Disc(s) do not contain file names listed:
	Amended CD missing unamended files
	Missing compact discs

Missing Parts

	Disc(s) do not contain file names listed
	Discs contains files that are non-ASCII files:
	Only one copy of the CD, no duplicate:
	Wrong media type, e.g., CD-RW:
	The transmittal letter and specification do not list information:
	Both disc(s) contain unreadable files:
	One disc(s) contain unreadable files:
	Compact disc(s) contain viruses, but are still readable:
	EFS/Paper Submission:
	Table does not maintain data in proper alignment:
	Not proper subject matter for CD's:

Informality

	No statement in transmittal letter that CD's are the same:
	No incorporation by reference statement for the CD's:
	CD's not labeled "Copy 1" and "Copy 2":
	Deficient CD packaging:
	Deficient Labeling on CD's:
	The transmittal letter does not list information:
	The specification does not list information:
	Table less than 51 pages submitted on CD:

File Directory Attachment

	Copy of file directory listing is attached and should be mailed to applicant
	Copy of file directory listing is not attached
	Copy of file directory listing is not attached because it is over one page long

Additional Comments

Internal Worksheet Only - Do Not Scan

C:\Users\sleng\Desktop\ScoreModule\20190829\16548453\46DG-026061_Drawings.pdf

DocCode – SCORE

SCORE Placeholder Sheet for IFW Content

Application Number: 16548453 Document Date: 08/22/2019

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

- Drawing

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- External customers may access SCORE content via PAIR using the Supplemental Content tab.

Form Revision Date: March 1, 2019

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/548,453

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	300
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	660
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	760
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*			OR	x 100 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	2 minus 3 =	*				x 460 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1720

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
16/548,453	08/22/2019		1720	46DG-026061	20	2

CONFIRMATION NO. 2987

FILING RECEIPT

137002
Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008



Date Mailed: 09/04/2019

Receipt is acknowledged of this non-provisional utility patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF FIRST INVENTOR, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection.

Please verify the accuracy of the data presented on this receipt. If an error is noted on this Filing Receipt, please submit a written request for a corrected Filing Receipt, including a properly marked-up ADS showing the changes with strike-through for deletions and underlining for additions. If you received a "Notice to File Missing Parts" or other Notice requiring a response for this application, please submit any request for correction to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections provided that the request is grantable.

Inventor(s)

Thomas Derbanne, Paris, FRANCE;
César Douady, Les Molieres, FRANCE;
Maxim Karpushin, Paris, FRANCE;

Applicant(s)

GoPro, Inc., San Mateo, CA;

Power of Attorney: The patent practitioners associated with Customer Number 137002

Domestic Priority data as claimed by applicant

This application is a CON of 16/418,203 05/21/2019
which is a CON of 16/150,066 10/02/2018 PAT 10341564
which is a CON of 15/987,786 05/23/2018
which claims benefit of 62/673,388 05/18/2018

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 09/03/2019
The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/548,453**
Projected Publication Date: 12/12/2019
Non-Publication Request: No
Early Publication Request: No
Title

SYSTEMS AND METHODS FOR STABILIZING VIDEOS

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

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Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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To: docketing@esplin.legal,,
From: PAIR_eOfficeAction@uspto.gov
Cc: PAIR_eOfficeAction@uspto.gov
Subject: Private PAIR Correspondence Notification for Customer Number 137002

Sep 04, 2019 03:40:31 AM

Dear PAIR Customer:

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

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Application	Document	Mailroom Date	Attorney Docket No.
16548453	APP.FILE.REC	09/04/2019	46DG-026061

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Monday - Friday 6:00 a.m. to 12:00 a.m.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/548,453	08/22/2019	Thomas Derbanne	46DG-026061	2987

137002 7590 09/13/2019

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Carlsbad, CA 92008

EXAMINER	
SEGURA, CYNTHIA	

ART UNIT	PAPER NUMBER
2698	

NOTIFICATION DATE	DELIVERY MODE
09/13/2019	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

docketing@esplin.legal

PTOL-90A (Rev. 04/07)

Office Action Summary	**Application No.** 16/548,453	**Applicant(s)** Derbanne et al.	
	Examiner CYNTHIA SEGURA	**Art Unit** 2698	**AIA (FITF) Status** Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☑ Responsive to communication(s) filed on 8/22/2019.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL.** 2b) ☑ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☑ Claim(s) 1-20 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☐ Claim(s) _____ is/are allowed.

7) ☑ Claim(s) 1-20 is/are rejected.

8) ☐ Claim(s) _____ is/are objected to.

9) ☐ Claim(s) _____ are subject to restriction and/or election requirement

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☑ The drawing(s) filed on 8/22/2019 is/are: a)☑ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☑ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____.

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

CLAIM INTERPRETATION

2. The following is a quotation of 35 U.S.C. 112(f):

> (f) Element in Claim for a Combination. – An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

The following is a quotation of pre-AIA 35 U.S.C. 112, sixth paragraph:

> An element in a claim for a combination may be expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support thereof, and such claim shall be construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof.

3. The claims in this application are given their broadest reasonable interpretation using the plain meaning of the claim language in light of the specification as it would be understood by one of ordinary skill in the art. The broadest reasonable interpretation of a claim element (also commonly referred to as a claim limitation) is limited by the description in the specification when 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, is invoked.

As explained in MPEP § 2181, subsection I, claim limitations that meet the following three-prong test will be interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph:

(A) the claim limitation uses the term "means" or "step" **or a term used as a substitute for "means" that is a generic placeholder (also called a nonce term or a non-structural term having no specific structural meaning)** for performing the claimed function;

(B) the term "means" or "step" or the generic placeholder is modified by functional language, typically, but not always linked by the transition word "for" (e.g., "means for") or another linking word or phrase, such as "configured to" or "so that"; and

(C) the term "means" or "step" or the generic placeholder is not modified by sufficient structure, material, or acts for performing the claimed function.

Use of the word "means" (or "step") in a claim with functional language creates a rebuttable presumption that the claim limitation is to be treated in accordance with 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. The presumption that the claim limitation is interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, is rebutted when the claim limitation recites sufficient structure, material, or acts to entirely perform the recited function.

Absence of the word "means" (or "step") in a claim creates a rebuttable presumption that the claim limitation is not to be treated in accordance with 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. The presumption that the claim limitation is not interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, is rebutted when the claim limitation recites function without reciting sufficient structure, material or acts to entirely perform the recited function.

Claim limitations in this application that use the word “means” (or “step”) are being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, except as otherwise indicated in an Office action. Conversely, claim limitations in this application that do not use the word “means” (or “step”) are not being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, except as otherwise indicated in an Office action.

4. This application includes one or more claim limitations that do not use the word “means,” but are nonetheless being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, because the claim limitation(s) uses a generic placeholder that is coupled with functional language without reciting sufficient structure to perform the recited function and the generic placeholder is not preceded by a structural modifier. **Such claim limitation is: “an optical element" in claims 1-20.**

Because these claim limitations are being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, they are being interpreted to cover the corresponding structure described in the specification as performing the claimed function, and equivalents thereof.

a) “an optical element” corresponds one or more of lens, mirror or prism; see paragraph 0031 of the specification of the instant application.

If applicant does not intend to have this/these limitation(s) interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph, applicant may: (1) amend the claim limitation(s) to avoid it/them being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph (e.g., by reciting sufficient structure to perform the

claimed function); or (2) present a sufficient showing that the claim limitation(s) recite(s) sufficient structure to perform the claimed function so as to avoid it/them being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph.

Double Patenting

5. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on nonstatutory double patenting provided the reference application or patent either is shown to be commonly owned with the examined application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. See MPEP § 717.02 for applications subject to examination under the first inventor to file

provisions of the AIA as explained in MPEP § 2159. See MPEP §§ 706.02(l)(1) - 706.02(l)(3) for applications not subject to examination under the first inventor to file provisions of the AIA. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The USPTO Internet website contains terminal disclaimer forms which may be used. Please visit www.uspto.gov/patent/patents-forms. The filing date of the application in which the form is filed determines what form (e.g., PTO/SB/25, PTO/SB/26, PTO/AIA/25, or PTO/AIA/26) should be used. A web-based eTerminal Disclaimer may be filled out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to www.uspto.gov/patents/process/file/efs/guidance/eTD-info-I.jsp.

6. Claims 1-20 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-20 of **U.S. Patent No. 10,341,564**.

Although the claims at issue are not identical, they are not patentably distinct from each other because they are both claiming substantially the same features.

For example, note the following similarities between the application claims and patent claims.

Instant Application No. 16/548,453	**US Patent 10,341,564**
Claim 1 A system that stabilizes videos, the system comprising: a housing of an image capture device;	Claim 1 An image capture device that stabilizes videos, the image capture device comprising: a housing;

an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content;	an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content;
the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;	the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;
a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; and	a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes positions of the housing at different moments within the capture duration, the characterized positions of the housing including rotational positions of the housing, the position information being conveyed by the position output signal of the position sensor independent of the image information; and
one or more physical processors configured by machine-readable instructions to:	one or more physical processors configured by machine-readable instructions to:
determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;	determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;
determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the	determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view are determined, the look head of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having

capture duration, the capture trajectory having smoother changes than the observed trajectory; determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.	smoother changes in the positions of the housing than the observed trajectory; determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing, the capture field of view including a smaller field of view within the optical field of view; and generate the video content based on a punch-out of visual content of the images within the capture field of view.
Claim 5 The system of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.	Claim 3 The image capture device of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit.
Claim 6 The system of claim 1, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing.	Claim 6 The image capture device of claim 1, wherein the capture trajectory of the housing is determined based on minimizing a combination of a rotational velocity of the housing and a rotational acceleration of the housing while respecting a set of constraints.
Claim 10 The system of claim 9, wherein the one or more physical processors are, to generate the video content based on the punch-out of the visual content of the images within the capture field of view, further configured by machine-readable instructions to crop the visual content of the images based on the capture field of view.	Claim 10 The image capture device of claim 1, wherein the one or more physical processors are, to generate the video content based on the punch-out of the visual content of the images within the capture field of view, further configured by machine-readable instructions to crop the visual content of the images within the capture field of view.
Claim 11 A method for stabilizing videos, the method performed by an image capture device including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to guide light within an optical field of view to the	Claim 11 A method for stabilizing videos, the method performed by an image capture device including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to guide light within an optical field of view to the

image sensor, the optical field of view being greater than a capture field of view for generating video content, the method comprising:	image sensor, the optical field of view being greater than a capture field of view for generating video content, the method comprising:
generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;	generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;
generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing;	generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes positions of the housing at different moments within the capture duration, the characterized positions of the housing including rotational positions of the housing, the position information being conveyed by the position output signal of the position sensor independent of the image information;
determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;	determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;
determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory;	determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view are determined, the look head of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes in the positions of the housing than the observed trajectory;
determining, by the one or more processors, the orientations of the capture field of view for the	determining, by the one or more processors, the orientations of the capture field of view for the

images with respect to the optical field of view of the images based on the capture trajectory of the housing; and generating, by the one or more processors, the video content based on a punch- out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.	images with respect to the optical field of view of the images based on the capture trajectory of the housing, the capture field of view including a smaller field of view within the optical field of view; and generating, by the one or more processors, the video content based on a punch-out of visual content of the images within the capture field of view.
Claim 15 The method of claim 11, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.	Claim 13 The method of claim 11, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit.
Claim 16 The method of claim 11, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing.	Claim 16 The method of claim 11, wherein the capture trajectory of the housing is determined based on minimizing a combination of a rotational velocity of the housing and a rotational acceleration of the housing while respecting a set of constraints.
Claim 20 The method of claim 19, wherein generating the video content based on the punch-out of the visual content of the images within the capture field of view includes cropping the visual content of the images based on the capture field of view.	Claim 20 The method of claim 11, wherein generating the video content based on the punch-out of the visual content of the images within the capture field of view includes cropping the visual content of the images within the capture field of view.

7. Claims 1-20 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-20 of **Co-pending Application No. 15/987,786.**

Although the claims at issue are not identical, they are not patentably distinct from each other because they are both claiming substantially the same features.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

For example, note the following similarities between the application claims and patent claims.

Instant Application No. 16/548,453	**Co-pending Application No. 15/987,786.**
Claim 1 A system that stabilizes videos, the system comprising: a housing of an image capture device; an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content; the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view; a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; and one or more physical processors configured by machine-readable instructions to: determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments	Claim 1 A system that stabilizes videos, the system comprising: a housing; an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content; the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view; a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes positions of the housing at different moments within the capture duration; and Claim 2 The system of claim 1, wherein the positions of the housing include rotational positions of the housing. Cont. 1 one or more physical processors configured by machine-readable instructions to: determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments

within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;	within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;
determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory;	determine a capture trajectory of the housing based on a subsequent portion of the observed trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory is determined based on the second portion of the observed trajectory, the capture trajectory having smoother changes in the positions of the housing than the observed trajectory;
determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and	determine orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and
generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.	generate the video content based on visual content of the images within the capture field of view.
Claim 5 The system of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.	Claim 4 The system of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.
Claim 6 The system of claim 1, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational	Claim 6 The system of claim 1, wherein the capture trajectory of the housing is determined based on minimization of a rotational velocity of the housing

velocity of the housing and a rotational acceleration of the housing.	and a rotational acceleration of the housing while respecting a set of constraints.
Claim 11 A method for stabilizing videos, the method performed by an image capture device including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to guide light within an optical field of view to the image sensor, the optical field of view being greater than a capture field of view for generating video content, the method comprising: generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view; generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration; determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the	Claim 10 A method for stabilizing videos, the method performed by a system including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to guide light within an optical field of view to the image sensor, the optical field of view being greater than a capture field of view for generating video content, the method comprising: generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view; generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes positions of the housing at different moments within the capture duration; Claim 11 The method of claim 10, wherein the positions of the housing include rotational positions of the housing. Cont. 10 determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration; determining, by the one or more processors, a capture trajectory of the housing based on a subsequent portion of the observed trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed

capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory; determining, by the one or more processors, the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and generating, by the one or more processors, the video content based on a punch- out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.	trajectory is determined based on the second portion of the observed trajectory, the capture trajectory having smoother changes in the positions of the housing than the observed trajectory; determining, by the one or more processors, orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and generating, by the one or more processors, the video content based on visual content of the images within the capture field of view.
Claim 15 The method of claim 11, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.	Claim 13 The method of claim 10, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.
Claim 16 The method of claim 11, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing.	Claim 15 The method of claim 10, wherein the capture trajectory of the housing is determined based on minimization of a rotational velocity of the housing and a rotational acceleration of the housing while respecting a set of constraints.

8. Claims 1-20 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-20 of **Co-pending Application No. 16/418,203.**

Although the claims at issue are not identical, they are not patentably distinct from each other because they are both claiming substantially the same features.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

For example, note the following similarities between the application claims and patent claims.

Instant Application No. 16/548,453	**Co-pending Application No. 16/418,203**
Claim 1 A system that stabilizes videos, the system comprising: a housing of an image capture device; an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content; the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view; a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; and	Claim 1 An image capture device that stabilizes videos, the image capture device comprising: a housing; an optical element carried by the housing and configured to guide light to an image sensor; the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with a field of view; a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes rotational positions of the housing at different moments within the capture duration; and

one or more physical processors configured by machine-readable instructions to: determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration; determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory; determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.	one or more physical processors configured by machine-readable instructions to: determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the rotational positions of the housing at the different moments within the capture duration; determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of a capture field of view with respect to the field of view of the images are determined, the look head of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to a first moment within the capture duration is determined based on a portion of the observed trajectory corresponding to a second moment subsequent to the first moment within the capture duration; determine the orientations of the capture field of view with respect to the field of view of the images based on the capture trajectory of the housing; and generate stabilized video content based on a punch-out of visual content of the images within the capture field of view.
Claim 5 The system of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.	Claim 3 The image capture device of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit.

Claim 6 The system of claim 1, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing.	Claim 6 The image capture device of claim 1, wherein the capture trajectory of the housing is determined further based on minimizing a combination of a rotational velocity of the housing and a rotational acceleration of the housing while respecting a set of constraints.
Claim 11 A method for stabilizing videos, the method performed by an image capture device including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to guide light within an optical field of view to the image sensor, the optical field of view being greater than a capture field of view for generating video content, the method comprising: generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view; generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration; determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the	Claim 11 A method for stabilizing videos, the method performed by an image capture device including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to guide light to the image sensor, the method comprising: generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with a field of view; generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes rotational positions of the housing at different moments within the capture duration; determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the rotational positions of the housing at the different moments within the capture duration; determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of a

capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory; determining, by the one or more processors, the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and generating, by the one or more processors, the video content based on a punch- out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.	capture field of view with respect to the field of view of the images are determined, the look head of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to a first moment within the capture duration is determined based on a portion of the observed trajectory corresponding to a second moment subsequent to the first moment within the capture duration; determining, by the one or more processors, the orientations of the capture field of view with respect to the field of view of the images based on the capture trajectory of the housing; and generating, by the one or more processors, stabilized video content based on a punch-out of visual content of the images within the capture field of view.
Claim 15 The method of claim 11, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.	Claim 13 The method of claim 11, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit.
Claim 16 The method of claim 11, wherein the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing.	Claim 16 The method of claim 11, wherein the capture trajectory of the housing is determined further based on minimizing a combination of a rotational velocity of the housing and a rotational acceleration of the housing while respecting a set of constraints.
Claim 20 The method of claim 19, wherein generating the video content based on the punch-out of the visual content of the images within the capture field of view includes cropping the visual content of the images based on the capture field of view.	Claim 20 The method of claim 11, wherein generating the stabilized video content based on the punch-out of the visual content of the images within the capture field of view includes cropping the visual content of the images within the capture field of view.

Claim Rejections - 35 USC § 102

9. In the event the determination of the status of the application as subject to AIA 35 U.S.C. 102 and 103 (or as subject to pre-AIA 35 U.S.C. 102 and 103) is incorrect, any correction of the statutory basis for the rejection will not be considered a new ground of rejection if the prior art relied upon, and the rationale supporting the rejection, would be the same under either status.

10. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (a)(2) the claimed invention was described in a patent issued under section 151, or in an application for patent published or deemed published under section 122(b), in which the patent or application, as the case may be, names another inventor and was effectively filed before the effective filing date of the claimed invention.

11. Claims 1-20 are rejected under 35 U.S.C. 102(a)(2) as being anticipated by Beysserie et al. (US Patent 9,787,902).

Regarding **claim 1**, Beysserie discloses a system that stabilizes videos (Electronic device 1000; see fig. 10 and col. 21, line 58 to col. 22, line 40), the system comprising:

a housing of an image capture device (Housing of electronic device 1000 enclosing the elements shown in fig. 10, see col. 21, to col. 58 to col. 22, line 40);

an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content (Lens; see col. 9, lines 23-27; col. 21, lines 51-57 and figs. 4 and 9);

the image sensor (Image capture circuit or unit 1050; see fig. 10) carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view (see col. 21, lines 58; col. 22, lines 1-3 and lines 41-51 and figs. 4 and 9);

a position sensor (Device sensors 1025: accelerometer and/or gyroscope; see fig. 10 and col. 21, lines 58-67) carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing (Each image has a capture time and motion data provided by one or more motion sensors such as gyroscopes or accelerometers; see col. 2, lines 19-27; col. 5, line 65-67; col. 6, lines 1-2. Video can be stabilized using gyroscope output against rotation artifacts; see col. 9, lines 12-34; col. 12, lines 65-67 and col. 21, lines 58-67); and

one or more physical processors (Processor 1005; see fig. 10 and col. 22, lines 6-40) configured by machine-readable instructions to:

determine an observed trajectory of the housing during the capture duration based on the position information (Past frames 604; see figs. 6A, 6B, 6D), the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration (Video stabilization

described herein monitors the motion data of each frame, adjusting a stabilization tuning value based on that motion data and the motion data of a specified number of "future" and "past" frames. Video image stabilization takes into account specific stabilization constraints placed upon certain "selected" image frames in the incoming time-sequenced set of images; see col. 5, lines 14-50; from col. 14, line 63 to col. 15, lines 38; col 18, lines 31-55);

determine a capture trajectory (Current frames 600; see figs. 6A-6D) of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory (Intelligently and gradually steer the trajectory of the video stabilization towards specific selected future frames, so that desired stabilization constraints may be met in a resultant stabilized video sequence, without producing any jarring visual jumps when the selected image(s) are reached during the playback of the stabilized video sequence; col. 5, lines 43-50. For each current frame, video stabilization operation 100 may determine the stabilized motion trajectory based on past /future motion data, and may determine the correction

(difference) that needs to be applied to the frame (e.g., based the frame's respective motion data) to make it equal the stabilized trajectory; see col. 9, lines 18-34);

determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing (The higher the value of the video stabilization strength parameter, σ, the smoother the trajectory of the stabilized video sequence will be. Operation 100's ability to look into the "future" provides it with the ability to anticipate abrupt movements in the future and begin adjusting the strength value of images before the abruptness occurs so that visible jumps or glitches in the final video sequence may be reduced or eliminated; col. 12, lines 38-58 and figs. 7A-8); and

generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images (The visible frame of one or more of the captured video frames may be `pushed into` the overscan region by the stabilization algorithm, in order to account for motion of the device between the capture of the video frames. If a user's hand shakes upwardly by the equivalent of ten pixels between the capture of two video frames, a video stabilization algorithm may move the visible frame of the second captured frame (i.e., what a user will see for the second frame in a resultant stabilized video sequence) downward by ten pixels, so that there is no noticeable movement of the camera in the stabilized video sequence between the two frames; see col. 2, lines 42-67).

Regarding **claim 2**, Beysserie discloses everything claimed as applied above (see claim 1). In addition, Beysserie discloses the determination of the capture trajectory of the housing based on the look ahead of the observed trajectory preserves a user's intended motion of the image capture device during the capture duration (A user may simply wish to designate certain moments (i.e., frames) in the captured video sequence as 'points of interest' towards which the user desires that the stabilization trajectory of the video sequence be steered, such that the resultant stabilized video sequence is particularly stable at and around the designated point of interest frames in the video sequence; see col. 16, lines 42-50; col. 4, lines 31-47; from col. 17, line 66 to col. 18, lines 1-7).

Regarding **claim 3**, Beysserie discloses everything claimed as applied above (see claim 2). In addition, Beysserie discloses past positions (Past frames 604; see figs. 6A, 6B, 6D) of the image capture device supply context for the user's intended motion of the image capture device (selected frames; see fig. 6D and col. 16, lines 42-50).

Regarding **claim 4**, Beysserie discloses everything claimed as applied above (see claim 1). In addition, Beysserie discloses the positions of the housing further include translational positions of the housing, and at least some of the virtual positions of the housing are translationally offset from the actual positions of the housing (The stabilization motion values may take the form of two-dimensional translations, e.g., an adjustment in an 'x-direction' and an adjustment in a 'y-direction; see col. 3, lines 1-3; col. 9, lines 8-27).

Regarding **claim 5**, Beysserie discloses everything claimed as applied above (see claim 1). In addition, Beysserie discloses the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information (Device sensors 1025: accelerometer and/or gyroscope; see fig. 10 and col. 21, lines 58-67. Each image has a capture time and motion data provided by one or more motion sensors such as gyroscopes or accelerometers; see col. 2, lines 19-27; col. 5, line 65-67; col. 6, lines 1-2. Video can be stabilized using gyroscope output against rotation artifacts; see col. 9, lines 12-34; col. 12, lines 65-67 and col. 21, lines 58-67).

Regarding **claim 6**, Beysserie discloses everything claimed as applied above (see claim 1). In addition, Beysserie discloses the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing (Operation 100's ability to look into the "future" provides it with the ability to anticipate abrupt movements in the future and begin adjusting the strength value of images before the abruptness occurs so that visible jumps or glitches in the final video sequence may be reduced or eliminated; see col. 12, lines 28-43. Video may be stabilized using gyroscope output against rotation; see col. 9, lines 12-27 and col. 20, lines 42-44. Preserving the look of constant speed motion in the stabilized video sequence as the video is stabilized according to the calculated stabilized trajectory; see col. 8, lines 1-34).

Regarding **claim 7**, Beysserie discloses everything claimed as applied above (see claim 1). In addition, Beysserie discloses the capture trajectory of the housing is determined to minimize inter-frame motion while preserving intra-frame motion (Operation 100's ability to look into the "future" provides it with the ability to anticipate abrupt movements in the future and begin adjusting the strength value of images before the abruptness occurs so that visible jumps or glitches in the final video sequence may be reduced or eliminated; see col. 12, lines 28-43).

Regarding **claim 8**, Beysserie discloses everything claimed as applied above (see claim 1). In addition, Beysserie discloses the images are stored in a buffer during capture trajectory generation (Look-ahead buffer comprising a number of video input frames; see col. 4, lines 1-2. Buffer system; see col. 5, line 51 to col. 6, line 61; col. 8, lines 59-61 and col. 13, line 6 to col. 14, line 35).

Regarding **claim 9**, Beysserie discloses everything claimed as applied above (see claim 8). In addition, Beysserie discloses the images are stored in the buffer during the capture trajectory generation such that individual ones of the images corresponding to the portion of the capture trajectory are stored in the buffer during the determination of the portion of the capture trajectory using the lookahead of the observed trajectory (Look-ahead buffer comprising a number of video input frames; see col. 4, lines 1-2), and the visual content of the individual ones of the images stored in the buffer are used after the determination of the portion of the capture trajectory to generate the video content (Buffer system; see col. 5, line 51 to col. 6, line 61; col. 8, lines 59-61 and col. 13, line 6 to col. 14, line 35).

Regarding **claim 10**, Beysserie discloses everything claimed as applied above (see claim 9). In addition, Beysserie discloses the one or more physical processors are, to generate the video content based on the punch-out of the visual content of the images within the capture field of view, further configured by machine-readable instructions to crop the visual content of the images based on the capture field of view (Frame 910 represents the stabilized version of video frame 905 that has been cropped to maintain the same POV with original unstabilized frame 900; see col. 20, lines 64-66).

Regarding **claim 11**, Beysserie discloses a method for stabilizing videos (see figs. 1A-1D), the method performed by an image capture device including a housing (Housing of electronic device 1000 enclosing the elements shown in fig. 10, see col. 21, to col. 58 to col. 22, line 40) and one or more processors (Processor 1005; see fig. 10 and col. 22, lines 6-40), the housing carrying an optical element (Lens; see col. 9, lines 23-27; col. 21, lines 51-57 and figs. 4 and 9), an image sensor (Image capture circuit or unit 1050; see fig. 10), and a position sensor (Device sensors 1025: accelerometer and/or gyroscope; see fig. 10 and col. 21, lines 58-67), the optical element configured to guide light within an optical field of view to the image sensor, the optical field of view being greater than a capture field of view for generating video content (Lens; see col. 9, lines 23-27; col. 21, lines 51-57 and figs. 4 and 9), the method comprising:

generating, by the image sensor (Image capture circuit or unit 1050; see fig. 10), an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with

the optical field of view (see col. 21, lines 58; col. 22, lines 1-3 and lines 41-51 and figs. 4 and 9);

generating, by the position sensor (Device sensors 1025: accelerometer and/or gyroscope; see fig. 10 and col. 21, lines 58-67), a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing (Each image has a capture time and motion data provided by one or more motion sensors such as gyroscopes or accelerometers; see col. 2, lines 19-27; col. 5, line 65-67; col. 6, lines 1-2. Video can be stabilized using gyroscope output against rotation artifacts; see col. 9, lines 12-34; col. 12, lines 65-67 and col. 21, lines 58-67);

determining, by the one or more processors (Processor 1005; see fig. 10 and col. 22, lines 6-40), an observed trajectory (Past frames 604; see figs. 6A, 6B, 6D) of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration (Video stabilization described herein monitors the motion data of each frame, adjusting a stabilization tuning value based on that motion data and the motion data of a specified number of "future" and "past" frames. Video image stabilization takes into account specific stabilization constraints placed upon certain "selected" image frames in the incoming time-

sequenced set of images; see col. 5, lines 14-50; from col. 14, line 63 to col. 15, lines 38; col 18, lines 31-55);

determining, by the one or more processors, a capture trajectory (Current frames 600; see figs. 6A-6D) of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory (Intelligently and gradually steer the trajectory of the video stabilization towards specific selected future frames, so that desired stabilization constraints may be met in a resultant stabilized video sequence, without producing any jarring visual jumps when the selected image(s) are reached during the playback of the stabilized video sequence; col. 5, lines 43-50. For each current frame, video stabilization operation 100 may determine the stabilized motion trajectory based on past /future motion data, and may determine the correction (difference) that needs to be applied to the frame (e.g., based the frame's respective motion data) to make it equal the stabilized trajectory; see col. 9, lines 18-34);

determining, by the one or more processors, the orientations of the capture field of view for the images with respect to the optical field of view of the images based on

the capture trajectory of the housing (The higher the value of the video stabilization strength parameter, σ, the smoother the trajectory of the stabilized video sequence will be. Operation 100's ability to look into the " future" provides it with the ability to anticipate abrupt movements in the future and begin adjusting the strength value of images before the abruptness occurs so that visible jumps or glitches in the final video sequence may be reduced or eliminated; col. 12, lines 38-58 and figs. 7A-8); and

generating, by the one or more processors, the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images (The visible frame of one or more of the captured video frames may be `pushed into` the overscan region by the stabilization algorithm, in order to account for motion of the device between the capture of the video frames. If a user's hand shakes upwardly by the equivalent of ten pixels between the capture of two video frames, a video stabilization algorithm may move the visible frame of the second captured frame (i.e., what a user will see for the second frame in a resultant stabilized video sequence) downward by ten pixels, so that there is no noticeable movement of the camera in the stabilized video sequence between the two frames; see col. 2, lines 42-67).

Regarding **claim 12**, Beysserie discloses everything claimed as applied above (see claim 11). In addition, Beysserie discloses determining the capture trajectory of the housing based on the look ahead of the observed trajectory preserves a user's intended

motion of the image capture device during the capture duration (A user may simply wish to designate certain moments (i.e., frames) in the captured video sequence as 'points of interest' towards which the user desires that the stabilization trajectory of the video sequence be steered, such that the resultant stabilized video sequence is particularly stable at and around the designated point of interest frames in the video sequence; see col. 16, lines 42-50; col. 4, lines 31-47; from col. 17, line 66 to col. 18, lines 1-7).

Regarding **claim 13**, Beysserie discloses everything claimed as applied above (see claim 12). In addition, Beysserie discloses past positions (Past frames 604; see figs. 6A, 6B, 6D) of the image capture device supply context for the user's intended motion of the image capture device (selected frames; see fig. 6D and col. 16, lines 42-50).

Regarding **claim 14**, Beysserie discloses everything claimed as applied above (see claim 11). In addition, Beysserie discloses the positions of the housing further include translational positions of the housing, and at least some of the virtual positions of the housing are translationally offset from the actual positions of the housing (The stabilization motion values may take the form of two-dimensional translations, e.g., an adjustment in an 'x-direction' and an adjustment in a 'y-direction; see col. 3, lines 1-3; col. 9, lines 8-27).

Regarding **claim 15**, Beysserie discloses everything claimed as applied above (see claim 11). In addition, Beysserie discloses the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information (Device sensors 1025: accelerometer and/or gyroscope; see fig. 10 and col. 21, lines 58-67. Each image has a capture time and motion data provided by one or more motion sensors such as gyroscopes or accelerometers; see col. 2, lines 19-27; col. 5, line 65-67; col. 6, lines 1-2. Video can be stabilized using gyroscope output against rotation artifacts; see col. 9, lines 12-34; col. 12, lines 65-67 and col. 21, lines 58-67).

Regarding **claim 16**, Beysserie discloses everything claimed as applied above (see claim 11). In addition, Beysserie discloses the capture trajectory of the housing is determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing (Operation 100's ability to look into the "future" provides it with the ability to anticipate abrupt movements in the future and begin adjusting the strength value of images before the abruptness occurs so that visible jumps or glitches in the final video sequence may be reduced or eliminated; see col. 12, lines 28-43. Video may be stabilized using gyroscope output against rotation; see col. 9, lines 12-27 and col. 20, lines 42-44. Preserving the look of constant speed motion in the stabilized video sequence as the video is stabilized according to the calculated stabilized trajectory; see col. 8, lines 1-34).

Regarding **claim 17**, Beysserie discloses everything claimed as applied above (see claim 11). In addition, Beysserie discloses the capture trajectory of the housing is determined to minimize inter-frame motion while preserving intra-frame motion (Operation 100's ability to look into the "future" provides it with the ability to anticipate abrupt movements in the future and begin adjusting the strength value of images before the abruptness occurs so that visible jumps or glitches in the final video sequence may be reduced or eliminated; see col. 12, lines 28-43).

Regarding **claim 18**, Beysserie discloses everything claimed as applied above (see claim 11). In addition, Beysserie discloses the images are stored in a buffer during capture trajectory generation (Look-ahead buffer comprising a number of video input frames; see col. 4, lines 1-2. Buffer system; see col. 5, line 51 to col. 6, line 61; col. 8, lines 59-61 and col. 13, line 6 to col. 14, line 35).

Regarding **claim 19**, Beysserie discloses everything claimed as applied above (see claim 18). In addition, Beysserie discloses the images are stored in the buffer during the capture trajectory generation such that individual ones of the images corresponding to the portion of the capture trajectory are stored in the buffer during the determination of the portion of the capture trajectory using the lookahead of the observed trajectory (Look-ahead buffer comprising a number of video input frames; see col. 4, lines 1-2), and the visual content of the individual ones of the images stored in the buffer are used after the determination of the portion of the capture trajectory to

generate the video content (Buffer system; see col. 5, line 51 to col. 6, line 61; col. 8, lines 59-61 and col. 13, line 6 to col. 14, line 35).

Regarding **claim 20**, Beysserie discloses everything claimed as applied above (see claim 19). In addition, Beysserie discloses generating the video content based on the punch-out of the visual content of the images within the capture field of view includes cropping the visual content of the images based on the capture field of view (Frame 910 represents the stabilized version of video frame 905 that has been cropped to maintain the same POV with original unstabilized frame 900; see col. 20, lines 64-66).

Contact Information

12. Any inquiry concerning this communication or earlier communications from the examiner should be directed to CYNTHIA SEGURA whose telephone number is (571)270-3580. The examiner can normally be reached on Monday - Friday; 9:00am to 6:00pm.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Twyler L Haskins can be reached on (571)272-7406. The fax phone

number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/CYNTHIA SEGURA/
Primary Examiner, Art Unit 2698
09/10/2019

Notice of References Cited	Application/Control No. 16/548,453	Applicant(s)/Patent Under Reexamination Derbanne et al.	
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U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-9787902-B1	10-2017	Beysserie; Sebastien X.	H04N5/23258	1/1
*	B	US-20150350548-A1	12-2015	Beysserie; Sebastien X.	H04N5/23254	348/208.6
*	C	US-20160006935-A1	01-2016	Zhou; Jianping	H04N5/23254	348/208.1
	D					
	E					
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	**Art Unit**
	CYNTHIA SEGURA	2698

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	09/10/2019								
	1	✓								
	2	✓								
	3	✓								
	4	✓								
	5	✓								
	6	✓								
	7	✓								
	8	✓								
	9	✓								
	10	✓								
	11	✓								
	12	✓								
	13	✓								
	14	✓								
	15	✓								
	16	✓								
	17	✓								
	18	✓								
	19	✓								
	20	✓								

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	Art Unit
	CYNTHIA SEGURA	2698

CPC - Searched*		
Symbol	Date	Examiner

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
Inventor search	09/06/2019	CS
East search: H04N5/23258; H04N5/23267; H04N5/2252 plus key words	09/06/2019	CS
East text search	09/06/2019	CS
East text search	09/10/2019	CS
Refs checked: applns 15987786, 16150066, 16418203	09/06/2019	CS

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner

/CYNTHIA SEGURA/ Primary Examiner, Art Unit 2698	

Insta360
Exhibit 1003 Page 123

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	0	16/548453.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 16:57
S2	0	15/987786.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 16:58
S3	1	16/150066.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 16:59
S4	0	16/418203.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 16:59
S5	31	("20030160862" | "20030210327" | "20040010804" | "20040125133" | "20060291841" | "20090278917" | "20100277617" | "20100281375" | "20100299630" | "20110013778" | "20120206565" | "20130058535" | "20130177168" | "20130210563" | "20130250047" | "20140039884" | "20140266773" | "20140267586" | "20160360109" | "20170084086" | "20170085964" | "20170289454" | "20180324358" | "6654019" | "8022948" | "8237787" | "9144714" | "9279983" | "9363569" | "9374532" | "9426430").PN. OR ("10341564").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/09/06 16:59
S6	135	Derbanne-Thomas.in. Douady-Cesar.in. Karpushin-Maxim.in.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 17:00
S7	1	(observed near4 trajectory).clm. and S6	US-	OR	ON	2019/09/06

			PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB			17:00
S8	1	(look$4 near2 ahead).clm. and S6	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 17:01
S9	24474	(H04N5/23258 or H04N5/23267 or H04N5/2252).cpc.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 17:02
S10	0	((housing enclosure casing) with (translat$4 rotat$4) with (position$4 movements motion) with ("ahead" futur$4 preceding) with (path trajectory course)) and S9	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 17:03
S11	15	((stabilization stabilizing ((movement shak$4 jitter$4) near4 (correct$4 adjustment adjusting compensat$4 remov$4 cancel$4))) with ("ahead" futur$4 preceding) with (path trajectory course)) and S9	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 17:06
S12	25	("20040001147" | "20060257042" | "20100124379" | "20110037861" | "20110096179" | "20110234825" | "20120120265" | "20130135430" | "20130141602" | "20130294655" | "20140132784" | "20140160309" | "7359563" | "7705667" | "7817187" | "8134603" | "8335350" | "8520084" | "8711233" | "8749644" | "8786716" | "8947529" | "9100575" | "9413963").PN. OR ("9787902").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2019/09/06 17:29
S13	192	((stabilization stabilizing ((movement shak$4 jitter$4) near4 (correct$4 adjustment adjusting compensat$4 remov$4 cancel$4))) with ("ahead" futur$4 preceding) with (path trajectory course))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/06 17:30
S15	1	15/992053.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/09 10:31
S16	4	"20140110809"	US-PGPUB;	OR	ON	2019/09/09 12:13

			USPAT; FPRS; EPO; JPO; IBM_TDB			
S17	1	16/251531.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/09 12:44
S18	6	(reduc$4 minimize) with (inter-frame interframe) with (maintain$4 keep kept preserv$4) with (intra-frame intraframe) with (motion movement jitter)	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/09/10 17:09

9/ 10/ 2019 6:21:20 PM
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CONFIRMATION NO. 2987

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
16/548,453	08/22/2019	348	2698	46DG-026061

APPLICANTS
GoPro, Inc., San Mateo, CA;

INVENTORS
Thomas Derbanne, Paris, FRANCE;
César Douady, Les Molieres, FRANCE;
Maxim Karpushin, Paris, FRANCE;

**** CONTINUING DATA **************************
This application is a CON of 16/418,203 05/21/2019
which is a CON of 16/150,066 10/02/2018 PAT 10341564
which is a CON of 15/987,786 05/23/2018
which claims benefit of 62/673,388 05/18/2018

**** FOREIGN APPLICATIONS **************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****
09/03/2019

Foreign Priority claimed ❑ Yes ☑ No 35 USC 119(a-d) conditions met ❑ Yes ☑ No Verified and Acknowledged /CYNTHIA SEGURA/ Examiner's Signature	❑ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		FRANCE	8	20	2

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5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

TITLE
SYSTEMS AND METHODS FOR STABILIZING VIDEOS

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16548453	CTNF	09/13/2019	46DG-026061
	892	09/13/2019	46DG-026061

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PATENT APPLICATION INFORMATION RETRIEVAL SYSTEM

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 1 of 3	**Matter Number**	46DG-026061

U.S. PATENT/PUBLICATION DOCUMENTS					
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	4	9144714	09/29/2015	HOLLINGER STEVEN J	
	5	9279983	03/08/2016	DAVIS BENJAMIN	
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	7	9374532	06/21/2016	GRUNDMANN MATTHIAS	
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	9	10262691	04/16/2019	GILMOUR NICHOLAS RYAN	
	10	10284794	05/07/2019	FRANCOIS BRUNO	
	11	10341564	07/02/2019	DERBANNE THOMAS	
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	28	20130329132	12/12/2013	TICO MARIUS	
	29	20140028876	01/30/2014	MILLS CHRISTOPHER L	

Examiner Signature		**Date Considered**	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 2 of 3	Matter Number	46DG-026061

U.S. PATENT/PUBLICATION DOCUMENTS					
Initials	Cite No.	Document Number	Issue/Publication Date	First Named Inventor	Relevant Pages, Columns, etc.
	30	20140039884	02/06/2014	Wei-ge Chen	
	31	20140266773	09/18/2014	AGUILAR FRANCISCO	
	32	20140267586	09/18/2014	AGUILAR FRANCISCO	
	33	20140267590	09/18/2014	MCCLATCHIE IAIN RICHARD TYRONE	
	34	20150146014	05/28/2015	BLACK ROBERT A	
	35	20150159846	06/11/2015	HOLLINGER STEVEN J	
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	49	International Search Report and Written Opinion for Application No. PCT/US2019/020241, date of mailing June 3, 2019, 12 pages.	

Examiner Signature		Date Considered	
Examiner: Please initial if citation considered, whether or not citation is in conformance with MPEP Section 609. Please draw a line through the citation if it is not in conformance and it is not considered. Please include a copy of this form with the next communication to the applicant.			

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
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	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 3 of 3	**Matter Number**	46DG-026061

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	50	International Search Report and Written Opinion for Application No. PCT/US2019/031591, date of mailing June 18, 2019, 7 pages.	
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	52	KOPF et al., "First-person Hyper-Lapse Videos" ACM Transactions on Graphics (Proceedings of SIGGRAPH 2014), 33(4), Article No. 78, 2014 (10 pages).	
	53	O'DONOVAN, A., et al., "Audio-Visual Panoramas and Spherical Audio Analysis using the Audio Camera," C1 Proceedings of the 16th International Conference on Auditory Display, June 9-15, 2010, Pages ICAD-167- 168, can be retrieved at <URL: https://smartech.gatech.edu/bitstream/handle/1853/49858/0%27DonovanDuraiswami201 O.pdf?sequence=1 >	
	54	O'DONOVAN, A., et al., "Real Time Capture of Audio Images and their Use with Video," 2007 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics, October 21-24, 2007, Pages 10-13.	
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	56	United States Office Action, U.S. Application No. 14/789,706, June 7, 2016, ten pages.	

Examiner Signature		**Date Considered**	
Examiner: Please initial if citation considered, whether or not citation is in conformance with MPEP Section 609. Please draw a line through the citation if it is not in conformance and it is not considered. Please include a copy of this form with the next communication to the applicant.			

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 1 of 1	**Matter Number**	46DG-026061

GENERAL

Pursuant to 37 C.F.R. 1.97 and 1.98 and to the duty of disclosure set forth in 37 C.F.R. 1.56, the Examiner in charge of the above-identified application is requested to consider and make of record the references listed herewith. A copy of each listed reference, other than U.S. patents/applications and references cited in a parent application, is enclosed.

Although the information submitted herewith may be "material" to the Examiner's consideration of the subject application, this submission is not intended to constitute an admission that such information is "prior art" as to the claimed invention.

In accordance with 37 C.F.R. 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made.

TIMING

In accordance with 37 CFR 1.97(c), this Information Disclosure Statement is being filed after the period specified in 37 CFR 1.97(b) and before the mailing date of a Final Action under 37 CFR 1.113, a Notice of Allowance under 37 CFR 1.311, or an Action that otherwise closes prosecution in the application.

CERTIFICATION STATEMENT

No certification statement is required. This Information Disclosure Statement is being filed in accordance with 37 CFR 1.97(c) and is accompanied by the fee set forth in 37 CFR 1.17(p).

FEE

The Director is hereby authorized to charge $240 (large entity) to Deposit Account No. 601896. Please reference attorney docket number 46DG-026061 for this transaction.

This Information Disclosure Statement is being filed in accordance with 37 CFR 1.97(c), and is not accompanied by one of the certification statements of 37 CFR 1.97(e). Therefore, this Information Disclosure Statement is subject to the $240 (large entity) fee set forth in 37 CFR 1.17(p).

ADDITIONAL COMMENTS

SIGNATURE

Signature	/ Vadim Polonichko /	**Date**	2019-09-23
Name	Vadim Polonichko	**Registration Number**	62769

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 April 2009 (16.04.2009)

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(51) International Patent Classification:
H04N 5/262 (2006.01) *H04N 5/232* (2006.01)

(21) International Application Number:
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20080100618 29 September 2008 (29.09.2008) GR

(71) Applicant *(for all designated States except US)*: **ANALYSIS SYSTEMS RESEARCH HIGH-TECH S.A.** [GR/GR]; 88 Argyroupoleos Str., GR-164 51 Argyroupolis Attikis (GR).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **KARYDIS, Antonios** [GR/GR]; 32 Sofokleous Str., GR-166 73 Voula Attikis (GR).

(74) Agent: **PAPASTERGIOU, Vassilios**; 120 Harilaou Trikoupi Str., GR-114 72 Athens (GR).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
- *with international search report*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(54) Title: INTEGRATED SYSTEM, METHOD AND APPLICATION FOR THE SYNCHRONIZED INTERACTIVE PLAY-BACK OF MULTIPLE SPHERICAL VIDEO CONTENT AND AUTONOMOUS PRODUCT FOR THE INTERACTIVE PLAY-BACK OF PRERECORDED EVENTS.

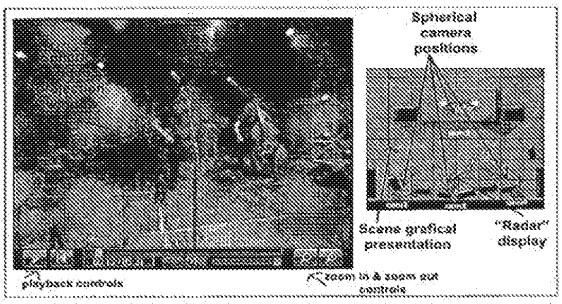


Figure 8:
Drawing presenting the Application of the Method for the synchronized interactive play-back of multiple spherical videos.

(57) Abstract: The Integrated system, method and application for the synchronized interactive play-back of multiple spherical videos, captures in spherical video format of 360°x360° angle of view events from different positions in space and allows their interactive play-back on a computer or through the internet. The autonomous product allows the interactive play-back of prerecorded events from a DVD. The viewer, during play-back, without interrupting or disrupting it, interactively, can alter the position from which the event is viewed by choosing which one he/she wishes to watch, among several available spherical videos, corresponding to different places in the area where the event took place, alter direction and angle of viewing from the full 360°x360° angle of view, rotate (turn around) his/her viewing window, approach (zoom-in) and retreat (zoom- out) while the corresponding sound remains synchronized with the projected images.

WO 2009/047572 A1

DESCRIPTION

Integrated system, method and application for the synchronized interactive play-back of multiple spherical video content and autonomous product for the interactive play-back of prerecorded events.

The Integrated system, method and application for the synchronized interactive play-back of multiple spherical video content on a computer or through the internet, involves the synchronous recording of events in multiple spherical videos from different positions in the area where the event takes place, the interactive play-back on the recorded event on a computer or through the internet by means of an interactive application for the synchronized play-back of multiple spherical videos, which offers to the viewer, during the play-back and without interrupting or disrupting it, the capability to interactively choose whichever spherical video they wish to watch from the available alternatives. This choice of a different spherical video corresponds to a virtual shift of the viewer to a different physical viewing position as each spherical video corresponds to a different spherical camera which had been positioned on a predetermined position in the area in which the event took place. In addition to choosing the position from which the event is viewed, the viewer, during the play-back of the event and without interrupting or disrupting it, can interactively alter the angle and direction of viewing as if they were turning their head to whichever direction they wished, as well as approach and move away from the point of interest (zoom-in and zoom-out).

The autonomous product for the interactive play-back of prerecorded events refers to a product in the form of a DVD which operates autonomously in a computer and allows the interactive play-back of an event that has been recorded and produced with the above integrated system. It utilizes an interactive application for the synchronized play-back of multiple spherical videos, in association with a graphical interface. The viewer, during the play-back and without interrupting or disrupting it, is offered the capability to interactively choose whichever spherical video they wish to watch from the available alternatives. This choice of a different spherical video corresponds to a virtual shift of the viewer to a different physical viewing position as each spherical video corresponds to a different spherical camera which had been positioned on a predetermined position in the area in which the event took place. In addition to choosing the position from which the event is viewed, the viewer, during the play-back of the event and without interrupting or disrupting it, can interactively alter the angle and direction of viewing as if they were turning their head to whichever direction they wished, as well as approach and move away from the point of interest (zoom-in and zoom-out).

For the complete recording of an event using conventional video technologies, usually a number of video cameras are required. Those cameras are either stationary, positioned in preselected positions of perceived increased interest or movable. They can be moved and rotated around the vertical and lateral

horizontal axis either by trained personnel (cameramen) or by mechanical means, in order to focus and approach selected points of interest. In all circumstances, the width of view that the video cameras can record is limited despite the availability of a wide range of different lenses, from extreme zooms to extreme wide angles.

Although usually a great number of conventional video cameras is used to record an event it is practically not feasible to record everything that takes place. After the recording of the event, specific sections (scenes) considered to be the most interesting or characteristic from each one of the individual videos from each camera are selected and edited to produce a linear video sequence which finally represents the recorded event. The finished content can be replicated on a variety of media in order to be distributed and reproduced on specific players, transmitted or streamed through the internet and viewed on a suitable screen e.g. a TV.

When an event is transmitted live, the responsible event-director, while the event takes place watches all the available images corresponding to all the available cameras on the event and chooses on the spot which image is transmitted at any time, usually the view from one camera at any given time. This is the view that the viewer watches in a passive way on their TV screen or on their computer screen streamed through the internet.

In both above scenarios, due to both the limitation in the angle of view that conventional video cameras transmit or record, as well as the manner in which the subject to be transmitted or edited at any time is chosen, many aspects of the event are lost, even though viewers might wish to view them. As an example, if it is assumed that the event recorded or transmitted is a concert, the director has to select what to show at any time, from all the different activities taking place at the same time, excluding the rest. As a result, for as long as the director chooses to focus on the singer of the group, a viewer that might have liked wish to watch the guitarist or drummer has no option to do so.

Further still, as it often happens especially in sports, when something of special interest happens, if none of the available cameras is focused on the specific location, the incident is not recorded at all. In car racing, where instances of interest are unpredictable, often such incidents are missed. In conclusion, in the viewing of conventional video content either live or prerecorded, the viewer is presented with a predetermined sequence of images which they can only view passively without any capability to influence the play-back. The view point is predetermined by the positioning of the cameras and the content and subject presented at any time is preselected by the director or the editor.

With the Integrated system, the method and application for the synchronized interactive play-back of multiple spherical videos on a computer or through the internet and the autonomous product for the interactive play-back of

prerecorded events in the form of a DVD, every activity and individual happening which take place during an event are recorded in very high resolution digital video format by means of two or more digital spherical video recording devices covering a angle of view of 360°x360° (spherical cameras). These devices record digitally on a single image a full sphere surrounding their position. Each such device produces a different spherical representation of the event. Spherical video consists of a sequence of single spherical images (frames) each capturing an angle of view of 360°x360° (Figure 1). Therefore, each frame of the spherical video constitutes a panoramic image which represents 360° on the horizontal and 360° on the vertical axis. Depending on the physical dimensions of the area where an event takes place, it is possible that two or more spherical cameras are used, positioned on pre-determined and preselected positions aiming to cover every aspect of the event area and as a result, capture totally every happening, activity and instance that takes place during the event. With two or more spherical cameras (typically four), placed in strategically chosen positions of the event area, 100% of the activities happening on any point of the event area at any time during the event are recorded. At the same time, the sound from the event is recorded in digital format. The spherical videos from every spherical camera and the corresponding sound are played-back synchronized with full interactive user control on a computer or through the internet and are projected in a normalized projection with a rate of 25 or 30 frames per second (depending on the local video system standard, PAL or NTSC) on a computer screen.

The viewer has the capability and freedom, at any point in time during the play-back, with out interrupting or disrupting the play-back, with full control using his/her mouse or any other pointing/navigation device, to alter interactively the position from which the event is viewed, by choosing which spherical video he/she wishes to watch at any given time, selecting among the several spherical videos available, each one corresponding to any of the several different spherical cameras, which had been placed on preselected positions in the area where the event took place. In this way, the viewer selects to virtually move between the places where the cameras were positioned and watch the event from these points. At the same time, the viewer has total freedom to choose the direction and width (angle) of viewing from the available full angle of view of 360°x360° and also total freedom to rotate (turn around) his/her viewing window, approach (zoom-in) and retreat (zoom-out), while maintaining full interactive control of the spherical video play-back. Irrespective of the interactive alterations in viewing position, angle, direction or virtual distance, the corresponding sound remains synchronized with the projected images.

Comparing the Integrated system, the method and application for the synchronized interactive play-back of multiple spherical videos of 360°x360° angle of view on a computer or through the internet and the autonomous product for the interactive play-back of prerecorded events in the form of a DVD to conventional event recording, transmission and play-back

technologies, in the former the viewer has at his/her disposal locally or through the internet, multiple alternative full spherical video sequences from an event, each one of which represents a full surrounding sphere and as a result every action, instance or happening in all the area where the event takes place is captured or transmitted during the full duration of the event, each sequence corresponding to one of the several spherical cameras that had been used to capture the event. In contrast, in a conventional event recording, transmission of the same event, the viewer would have at his disposal only the linear sequence of individual and by necessity partial scenes-instances which the event director would have chosen to include in the final presentation of the event.

During the synchronized play-back of an event and without interrupting or disrupting this play-back, the viewer has the ability, whenever he/she chooses, to interactively select any one among the available spherical videos, each one of which has captured the full event duration and watch the event from the position corresponding to the particular place where the particular spherical camera had been positioned. He/she may watch the event from the selected point for as long as he/she wishes, having the capability to focus his/her attention to any particular point or subject in space, by interactively altering his/her direction of view (look around), by turning left or right, up or down, in a range of 360° in all directions (both y- and z- axes) using the interactive rotation controls, approach or retreat using the interactive zoom-in and zoom out controls (moving along the x-axis). In this way, he/she alters interactively the direction and angle of view of the viewing window. In contrast, in a conventional play-back of video material, the viewer would have had no choice with regards to the image presented to him, apart from moving forward or backward in time by means of controls such as rewind, fast forward, previous and next. Even in the restricted cases that the viewer is offered control of alternative angles (e.g. multi-angle DVDs) he/she still has no choice on the actual camera movements which dictate the viewing direction and angle of view as all these would have been fixed during the recording of the event.

With the method and the application for the synchronized interactive play-back of multiple spherical video content of 360°x360° angle of view on a computer or through the internet and the autonomous product for the interactive play-back of prerecorded events in the form of a DVD, the viewer has full freedom to repeat the play-back of an event while choosing to watch it from a completely different view point (choosing a spherical video from a different spherical camera) but also from a different viewing angle as he/she has tha freedom to control interactively the direction and angle of view presented to him/her. In this way, the viewer in every repetition of the play-back of the event has the option to focus on a different point of interest of the same event. In contrast, in a conventional video play-back, the viewer, no matter how many times watched the video, he/she would have watched the same material as the content is fixed and offers no capability of interactive viewpoint control. All camera movements, no matter how elaborate, would have been fixed and the

image content and focus would also have been predetermined with no option to alter. If a particular action or happening was not within the viewing range of one of the available conventional cameras, then it would have not been recorded and there would have been no way to recreate it.

During the synchronized play-back of an event and without interrupting or disrupting this play-back, the viewer has the ability, whenever he/she chooses, to interactively select a different spherical video to be projected to him/her. In this way he/she is moving his/her position in space and is transferred virtually to the place where the chosen spherical camera was positioned during the event, while the time-continuity of the play-back is not disrupted. In contrast in a conventional video play-back, the viewer would have no ability to alter his/her position as this would have been fixed by the event director who decides which image from which camera is included in the final linear sequence that is presented to the viewer.

Therefore, with the integrated system, the method and the application for the synchronized interactive play-back of multiple spherical videos of 360°x360° angle of view on a computer or through the internet and the autonomous product for the interactive play-back of prerecorded events in the form of a DVD, the viewer has total freedom to choose what he/she will watch, from which point in space and towards which direction to focus his/her attention as he/she has total freedom to choose, interactively, at any time, to move to a different position in space (by selecting a different spherical video), to turn his/her viewpoint around at any direction, to approach or retreat, while maintaining control of the temporal play-back. The experience offered to the viewer by watching an event using an application based on the method and for the synchronized interactive play-back of multiple spherical video content of 360°x360° angle of view on a computer or through the internet or by using the autonomous product for the interactive play-back of prerecorded events in the form of a DVD, approximates the experience of him/her being actually in the area where the event took place and being free to move around at the same time turning his/her view to focus on points of interest at will. The viewer is not anymore a passive viewer of an event but interacts with and controls the reenaction of the event through the use of an interactive application. The viewer is no more dependent on the choices made by somebody else (the director) regarding what to watch and what not to watch, as in conventional video play-back but instead, he/she assumes actively the role of the director.

The integrated system for the synchronized interactive play-back of multiple spherical videos on a computer or through the internet is based on the method that utilizes multiple digital video sensors arranged in a predefined pattern for the capture of individual conventional videos that are then combined (stitched) together to produce a spherical video. Such a device is the LadyBug 2 spherical camera from Point Grey Research Inc. (Figure 2). Each spherical camera integrates six digital video sensors (the LadyBug 2 integrates six Sony ICX204AQ 1/3" 1024x768 progressive scan CCDs). Each individual sensor captures images with a resolution of 1024 x 768 pixels at a rate of up to 30

frames per second (fps), with sensitivity (gain) between 0dB and 25dB and with shutter speeds between 0.06ms and 34ms. Five sensors are arranged around a horizontal circular pattern in a portrait orientation. In this configuration each sensor covers an angle of view wider that 72° in the horizontal axis and produces images of 1024 pixels vertical by 768 pixels horizontal resolution. The five sensors together produce a composite image with a horizontal resolution of 3840 pixels (768 pixels x 5 images). Due to the arrangement of the five sensors, parts of the neighbouring images, along the vertical edges are common and therefore some overlap is allowed which results in better stitched video images. Stitching together the five individual video images from the five radial sensors, allowing for the necessary overlap, results in composite video images with an angle of view of 360° on the horizontal axis and horizontal resolution of 3500 pixels. The sixth sensor is positioned to aim vertically and produces the top portion (dome) of the spherical image. The bottom part of the image does not present imagery of any interest as it would record the support of the camera and therefore is not captured. The stitched video images at a rate up to 30 fps are sent from the spherical video camera via optical fiber with a transmission speed of 1,2Gbps to a compressor unit where they are compressed in real time in the JPEG standard with variable compression rate and the compressed spherical images are transmitted via a FireWire 1394b connection with a transmission speed of 800Mbps, to a computer where they are either stored in a native RAW format or converted to digital video format, stored and transmitted. When spherical video is captured for PAL countries, 35fps are captured while for NTSC the rate is set to 30fps. The individual spherical RAW images are combined into 5-second long AVI video sequences with an image aspect of 2:1 and 3500 x 1750 pixels horizontal to vertical resolution. These images represent the full surrounding sphere on an orthogonal projection. In parallel to the capture of the spherical video images, the sound of the event is recorded using digital recording technologies in either two or more discreete channels and stored in WAV format. The sound is synchronized with the images and is combined with the images to produce spherical videos with embedded audio which is stored in Quicktime format encoded with the Sorenson 3 algorithm. The audio is also stored separately in MP3 format at 128 kbps, 44.1 Hz stereo.

In order to use the spherical video sequences in the method for synchronized interactive play-back of multiple spherical videos they are converted into FLV format and their resolution is reduced to 1024x512 Pixels with quality setting at 1000 kbps with a key frame every 30 (or 25) frames. The resulting spherical videos (one from each spherical camera) in order to be played back have to be stored on a computer or a removable medium (DVD) or be made available for streaming through the internet. These spherical videos are played-back in a normalized projection, in a similar way as conventional videos projecting part of the sphere in a viewing window and offering the viewer interactive of which part of the sphere to view at any point in time. The application for the synchronized interactive play-back of multiple spherical videos offers the viewer the capability to select interactively which spherical video he/she

wishes to be projected, to select alternative spherical videos while play-back is taking place while all the time during play-back the sound remains synchronized to the projected spherical video images.

The application for synchronized interactive play-back of multiple spherical videos, presents to the viewer a navigational/control interface (Figure 8), with a window in which the selected spherical video is played-back in a normalized projection, in a similar fashion as a conventional video at a frame rate of 30 or 25 frames per second, depending on territorial video standard (PAL or NTSC). By positioning his/her pointing device (e.g. computer mouse) within this projection window, the viewer may control interactively what is projected. He/she may turn around, altering the direction of viewing towards any point in any direction in a 360 degree range. He/she may alter the angle of viewing using zoom-in and zoom-out controls. This is similar to having the capability to move a virtual camera around its position within a 3D real space. Adjacent to the actual spherical video projection window the application interface presents the viewer with a graphical representation of the actual area where the event took place. This graphical representation of the actual scene of the event may be from very simple to very elaborate, without affecting the operation and performance of the application. On this scene graphical representation the positions of the spherical cameras which were used to record the event are shown. By clicking on any of these cameras, the viewer selects it and play-back in the main projection window continues synchronized to the sound but now displaying the spherical video corresponding to the selected camera. Video play-back always remains synchronized to the sound and play-back following change of cameras continues from the correct point in time. When a camera is selected, this is indicated also on the scene graphical representation by means of a colour change and by displaying an additional radar-like graphic that depicts the direction and angle of viewing of the selected camera. This graphic is interactively changing with every change effected by the viewer. When the direction is changed, the radar cone moves to show the new direction. When the angle of viewing changes, the radar cone becomes wider or narrower, depending on the alteration effected. Moreover, the viewer, using his/her pointing devise on this representation may interactively and directly alter the direction of viewing by dragging this graphic towards the desired point on the scene graphical representation. The image projected in the main projection window follows every change in real time without any disruption or interruption in the play-back. In this way, the graphical representation offers an additional and very useful and viewer friendly navigational and control tool. The application has the capability to highlight the positions of the spherical cameras also on the projection window, superimposing graphical elements on the actual projected spherical video that is played back. Therefore, as the viewer rotates his/her view, when the position of another spherical camera comes within his/her viewport, a graphic element will make this apparent to the viewer by highlighting its relative position. This graphic element will also offer a control link to the viewer who may, by clicking on this graphic, move his/her position to the point where the

corresponding selected camera was placed, altering the projected spherical video accordingly.

As a result, the viewer, from within the application for synchronized interactive play-back of multiple spherical videos, may continuously alter his/her viewing position, direction and angle of view, in a direct and interactive fashion not offered by any other technology currently in use for the play-back of recorded events.

The application for synchronized interactive play-back of multiple spherical videos, undertakes and controls the play-back of spherical video on a computer by feeding the projection system with the corresponding spherical video images. As spherical videos have a much higher resolution compared to conventional video content, the play-back system poses increased load to the computer compared to conventional video play-back applications. Yet, spherical videos of reduced resolution (e.g. (1024x512 pixels) can be played back on medium-powered computers of current technology. As computer technology will undoubtedly continue advancing, the method and application for synchronized interactive play-back of multiple spherical videos is not dependent on nor restricted by the resolution of the spherical videos involved.

The application based on the method for synchronized interactive play-back of multiple spherical videos utilizes the Adobe FLASH libraries to implement the play-back of spherical videos locally on a computer or through the internet using Adobe Flash Media Server or similar. The application for synchronized interactive play-back of multiple spherical videos receives as input all the available spherical videos in FLV format as produced by the available spherical cameras on an event and digital audio in MP3 format. The spherical videos may be stored locally on the computer, in a removable magnetic or optical medium (Hard Disk or DVD) or in a Web Server which makes them available for viewing through Adobe Flash Media Server. The application for synchronized interactive play-back of multiple spherical videos implements the necessary graphics engine using the Sandy3D "open source" 3D graphics library for Flash objects in association to the Flash video play-back libraries of Adobe Flash. The encoding of the complete application for synchronized interactive play-back of multiple spherical videos is based on the ActionScript 3.0 programming language through Adobe Flash. These technologies enable the application for synchronized interactive play-back of multiple spherical videos to be executed locally or by means of a removable medium (HD or DVD) or, embedded in the web pages of a web site, on any computer that connects to this site.

The graphics engine generates a sphere and projects, in real time, at 30 or 25 fps, on its internal surface, as texture the spherical image that is supplies by the video play-back system. This is implemented with the "*sphere = new Sphere('sphere', radius, segmentsW, segmentsH)*" command of the "primitive" library of the Sandy 3D graphics engine. This command generates a sphere with a given radius and polygonal count (Figure 3) which constitute the sphere

geometry (segments). The sphere radius is estimated based on the width of the available spherical video image. The polygonal count of the sphere geometry is usually set to 30. The bigger this number, the better the quality of the projected image but at the same time the generation of the sphere will become slower and this will inevitably lead to delays in the projection, therefore, the value chosen constitutes an acceptable compromise for the given parameters of computer power, and spherical image resolution. Using the "*material = new VideoMaterial(video, UpdateMS)*" command of the "materials" library of the Sandy 3D graphics engine, the spherical video to be projected is assigned as material (VideoMaterial) for the sphere and with the "*app = new Appearance(material)*" and the "*sphere.appearance = app*" commands of the "materials" library of the Sandy 3D graphics engine, the spherical image is assigned as texture for the sphere.

Next, the Sandy 3D graphics engine creates a virtual camera using the command "*camera = new Camera3D(width, height, fov)*", where "*width*" and "*height*" are the relative dimensions of the projection window and "*fov*" is the field of view (angle of view) of the virtual camera in degrees. The virtual camera is positioned in the centre of the sphere (Figure 3), using the command "*camera.x = camera.y = camera.z = 0*" of the Sandy 3D graphics engine (values of zero are assigned to all the virtual camera co-ordinates (x,y,z)).

The image projected on the projection window becomes thereafter the image as viewed by the camera based on the above settings, all of which may be altered interactively by the viewer during play-back of the spherical video. The viewer as a result is given the view of the selected virtual camera and is therefore virtually placed on the same position as the position from which the virtual camera looks towards the spherical image. The viewer may rotate the virtual camera interactively to point to any direction inside the sphere, using his/her pointing device and in so doing his/her field of view is altered to reflect the movement of the virtual camera.

The co-ordinate system used by the Sandy 3D graphics engine assigns x to the axis going through the camera lens, y to the axis vertical with respect to the camera and z to the lateral axis, sideways from the camera. This distinction is necessary because there is a discrepancy between the projection window and the camera/sphere co-ordinate system (Figure 4). As a result, the x-axis of the projection window corresponds to the z-axis of the camera/sphere co-ordinate system, while the y-axis in both systems refers to the vertical axis. As the projection window is two dimensional, there is no need to reference the third axis which is the x-axis on the camera/sphere co-ordinate system and refers to forward/backward movement of the camera. Such movements are not allowed in the current application.

The viewer watches always the spherical video in a normalized projection, which in effect is the projection of the part of the spherical surface that corresponds to the virtual camera field of view, on a rectangle with the

dimensions given above. The viewer may interactively stop or fast forward the play-back of the spherical video, rewind or even start play-back from the beginning using the controls available on the navigational interface. These controls execute the corresponding Flash commands. The PLAY control executes the Flash *"play()"* command, and commences play-back of whichever spherical video is currently selected. The PAUSE control executes the Flash "*pause()*" command, which pauses play-back of whichever spherical video is currently selected at the point in time where the control was pressed. The STOP control executes the Flash "*stop()*" command, which stops play-back of whichever spherical video is currently selected. There is also a SEEK BAR control which executes the Flash "*seek()*" command, which moves whichever spherical video is currently selected forward and or backward in time, in relation to where the pointing device is placed. The control/navigation interface of the application for synchronized interactive play-back of multiple spherical videos is shown in Figure 7.

At the same time, the graphics engine allows the viewer to move his/her view towards any direction, up, down, left or right and to widen or narrow his/her angle of view. These movements are implemented by the co-ordination of two distinct and independent movements/rotations, one of the virtual camera, the other of the sphere itself. Which rotation is activated depends on the movements of the pointing device by the viewer. Left clicking the pointing device inside the projection window area stores the initial values of the x- and y- axes co-ordinates of the pointing device, using the "*mousePosition.x = stage.mouseX*" and "*mousePosition.y = stage.mouseY*" commands of the Flash library. As the pointing device moves on a 2 dimensional plane (the viewing window on the computer screen, there is no movement on the Z axis Every subsequent movement of the pointing device by the viewer, while the left click is maintained (click and drag), results in continuous calculation of the differences from the initial co-ordinate values, with the *"((mousePosition.y - stage.mouseY)"* and "*(mousePosition.x - stage.mouseX)*" commands where *mousePosition.x* and mousePosition.y are the initial co-ordinate values while *stage.mouseX* and *stage.mouseY* are the final (current) co-ordinate values. The resulting differences lead to the corresponding rotation of either the virtual camera or the sphere. The sphere and/or the virtual camera are rotated by means of the "*rotate*" command of the Flash library, depending on the kind of movement of the pointing device by the viewer. If the pointing device is moved upwards or downwards, along the y-axis of the projection window co-ordinates, then the projection system rotates the virtual camera accordingly around the X-axis of the sphere 3D space co-ordinates, with the "*camera.rotateZ*" command (Figure 5). If the pointing device is moved to the left or right, along the x-axis of the projection window co-ordinates, then the projection system rotates the sphere accordingly around the Y-axis of the sphere 3D space co-ordinates, with the "*sphere.rotateY*" command (Figure 6).

When the viewer activates the ZOOM-IN or ZOOM-OUT controls, aiming to widen or narrow his/her angle of view, the projection system alters the field of view of the virtual camera with the "*camera.fov*" command of the "scenegraph"

library of the Sandy 3D graphics engine. Activating the "camera.fov++" command, the angle of view becomes wider and the viewer appears to move away from the point of interest while activating the "camera.fov--" command, the angle of view becomes narrower and the viewer appears to move closer to the point of interest.

The graphical representation of the area where the event took place, (scene graphical representation), incorporating the positions of the available spherical cameras with the associated links to the corresponding spherical videos, and the radar-like graphical representation of the angle of view and direction of the selected camera, is initially designed using a graphics package such as Adobe Photoshop. The interactive controls are generated in Flash and are connected to the corresponding spherical video files. Therefore, whenever the viewer selects a different camera by clicking on its image on the scene graphical representation, the corresponding spherical video is assigned as texture for the inside surface of the sphere and the portion of it that corresponds to the selected direction and angle of view of the virtual camera is projected on the projection window. At the same time, the selected camera image on the scene graphical representation is highlighted and the radar-like display depicts the direction and angle of viewing. Every pixel on the scene graphical representation diagram constitutes an interactive point and therefore the relative position of the pointing device whenever this is positioned within the scene graphical representation diagram screen area is recorded with the "*MouseEvent.MOUSE_UP*" command of the Flash "event" library, its colour is altered to indicate that it is an active point. If the viewer clicks over the position of a camera other than the currently selected, this action is recognized in real time with the "*MouseEvent.MOUSE_DOWN*" command of the Flash "event" library, and the projection system, ceases the projection of the spherical video that was being played back until this moment and starts projecting on the projection window, the spherical video corresponding to the selected camera, from the current position in time, thereby maintaining temporal continuity and synchronization with the sound. These actions are implemented using the "*ns.stop()*" and "*ns.play(video2)*" commands and at the same time invokes the command "*(randar.visible = true)*" to make the radar graphic visible and active for the newly selected camera on the scene graphical representation window. This radar graphic follows and recognizes any movement of the pointing device within the spherical video projection window and is rotated around the corresponding camera image to reflect any changes in the direction and viewing angle. In addition to moving the pointing device within the projection window area, the viewer can alter the viewing direction by click and dragging the pointing device inside the scene graphical representation window to indicate the direction towards which he/she wishes the camera to be turned to. Such movements interactively result in rotations of either the sphere or the virtual camera or both at the same time, in real time and are based on the calculation in real time of the x,y co-ordinates of the position of the pointing device and the differences between initial and final values, in a way similar to the approach described above. When the viewer moves the pointing device within the spherical video projection window, not only the view is altered

accordingly to his/her movements but the radar graphic in the scene graphical representation window rotates accordingly to reflect these changes. When the viewer moves the pointing device within the scene graphical representation window, the radar graphic follows his/her movements while at the same time, the projected view in the spherical video projection window is altered by directing the sphere or the virtual camera or both at the same time, to rotate in real time, according to these movements.

With this capability, the viewer, during play-back and without interrupting or disrupting it, can interactively choose among different cameras, alter viewing direction and angle of viewing. The viewer using the application based on the method for synchronized interactive play-back of multiple spherical videos or the autonomous product for the interactive play-back of one or more prerecorded events in a computer, acts more like a director and not as a passive viewer, having the freedom to control every aspect of his/her viewing experience.

Using Flash commands, the application based on the method for synchronized interactive play-back of multiple spherical videos controls play-back of several spherical videos and synchronized audio at the same time. Initially the application commences play-back of the first assigned spherical video with the command "*(play(video1))*" synchronized with the corresponding sound which is played back using the command "*(sound.play())*". When the viewer chooses to move to another camera position, the point in running time based on the sound play-back is recorded in fractions of a second using the "*time = channel.position*" Flash command, where *channel* is the corresponding audio channel. Play-back of the spherical video corresponding to the newly selected camera commences from this point in time using the "*ns.seek(time/1000)*" command where *ns* is the NetStream to which the video is connected. The key to the method for establishing and maintaining synchronization in the play-back of multiple spherical videos and the corresponding sound is to commence play-back of the new spherical video not from the point in time where the previous spherical video was paused but from the point in time which the sound has reached when play-back of the newly selected spherical video is ready to commence. The performance of the application based on the method for synchronized interactive play-back of multiple spherical videos depends on the capabilities of the computer which runs the application, the characteristics and performance of the graphics card, the amount of available memory and several other factors which influence the play-back of the spherical videos and sound and to varying levels introduce delays in the play-back process which would inevitably lead to synchronization loss. For this reason, the application in predetermined time intervals re-synchronizes the spherical video projected at these particular times with the sound by jumping to the spherical video frame corresponding to the sound.

The autonomous product for the interactive play-back of prerecorded events offers to the viewer the ability to repeatedly play-back an event produced

using the method for synchronized interactive play-back of multiple spherical videos, on any suitable computer without the need to be connected to the internet. Each product is produced for one or more specific events and include all the spherical videos and the digital audio corresponding to the particular event(s), the application for synchronized interactive play-back of multiple spherical videos and a graphical interface for navigation and control of the application, designed especially for the particular event(s).

The viewer through this interface interactively controls the play-back of the event which is projected on his/her computer screen. The viewer watches the play-back while at the same time he/she is given a graphical overview of the event area, by means of the scene graphical representations described above. During the play-back and without interrupting or disrupting it, the viewer has the capability to interactively choose whichever spherical video they wish to watch from the available alternatives. This choice of a different spherical video corresponds to a virtual shift of the viewer to a different physical viewing position as each spherical video corresponds to a different spherical camera which had been positioned on a predetermined position in the area in which the event took place. In addition to choosing the position from which the event is viewed, the viewer, during the play-back of the event and without interrupting or disrupting it, can interactively alter the angle and direction of viewing as if they were turning their head to whichever direction they wished, as well as approach and move away from the point of interest (zoom-in and zoom-out). The viewer using the autonomous product for the interactive play-back of one or more prerecorded events in a computer, acts more like a director and not as a passive viewer, having the freedom to control every aspect of his/her viewing experience.

An example of the use of the integrated system, method and application for the synchronized interactive play-back of multiple spherical video content of 360°x360^{o} angle of view and the autonomous product for the interactive play-back of prerecorded events, is the recording and reproduction of a concert.

For the complete capture of such an event, several spherical cameras, typically four, are placed in carefully chosen positions ton and around the concert stage. These cameras record full spheres around them, thereby capturing 100% of the event. In parallel, a digital audio recording system is used to record the sound of the event in uncompressed high quality WAV format. The spherical video sequences are stored in large capacity and high reliability hard disks in the native RAW spherical video format. After the event is over, the spherical videos are converted to AVI format, while the audio is converted to MP3 format. The AVI files are converted to FLV format and thei resolution reduced to 1024 x 512 pixels. The FLV files are uploaded to a WEB server where Flash Media Server is installed. The viewer connects to the web site where the event is uploaded and is presented with the application for the synchronized interactive play-back of multiple spherical video content, using

which he/she may watch the event play-back with full interactive control as described earlier, from within his/her web browser application.

During the event play-back, the viewer has total freedom to decide on which aspect of the concert he/she wishes to focus on. He/she may move his/her view point continuously in order to follow one particular performer, or even choose to assess the reactions of the crowd. He/she may focus on one musician in order to study and analyze his/her technique for as long as he/she wishes. Moreover, the viewer may choose to watch the event from different positions by virtually moving to different places in the area. While he/she applies such control, play-back remains continuous and synchronized to the sound and the flow of activity is not disrupted nor interrupted in any sense. The viewer is no longer passive but interacts with the play-back through an interactive application that gives the impression that the viewer's experience of the event is not restricted by the decisions of others. If the viewer decides to repeat the play-back of any part or even the full event, he/she may choose to watch it in a completely different way every time.

If the event is to be published as an autonomous product for interactive play-back of the concert in DVD format, the corresponding control and navigational interface is designed to suit the particular event. The scene graphical representation is also designed to reflect the scent of the event and the full application is encoded in HTML to create a fully integrated interactive application. The application for the synchronized interactive play-back of multiple spherical video content and all the corresponding spherical video and digital audio files are also included and a Master of the DVD is produced which then may be reproduced (replicated) in whatever quantity is desired by standard industrial processes. The resulting product could be distributed on its own or in combination with other products (e.g combined with a CD or conventional DVD of the event). The owner of the product may play it on any computer with full interactive control and freedom as described above.

CLAIMS

1. Integrated system for the recording and interactive play-back of events by means of spherical video in which events are recorded with digital spherical video recording devices capable of capturing an angle of view of 360°x360°, the corresponding sound of the event is recorded and synchronized with the spherical videos and the unified sequences of digital spherical videos and sound are played-back under interactive user control on a computer or through the internet and are projected in a normalized projection at a rate of 25 or 30 frames per second on a computer screen, characterized by the synchronized and interactive play-back of multiple spherical videos and the corresponding sound, and the ability to offer to the viewer the capability, at any point in time during the play-back, without interrupting or disrupting the play-back, with full control using his/her mouse or any other pointing/navigation device, to alter interactively the position from which the event is viewed by choosing which spherical video he/she wishes to watch at any given time, selecting among the several available spherical videos, each one corresponding to any of the several different spherical cameras which had been placed on preselected positions in the area where the event took place, choosing in this way to virtually move to the view-points where the spherical cameras had been placed and watch the event from these points, while at the same time he/she maintains total freedom to choose the direction and angle of viewing from the available full 360°x360° angle of view and total freedom to rotate (turn around) his/her viewing window, approach (zoom-in) and retreat (zoom-out), while also maintaining full interactive control of the spherical video play-back. Irrespective of the interactive alterations in viewing position, angle, direction or virtual distance, the corresponding sound remains synchronized with the projected images.

2. Method for synchronized interactive play-back on a computer or through the internet of multiple spherical videos and the corresponding sound which are projected in a normalized projection at a rate of 25 or 30 frames per second on a computer screen characterized by the synchronized and interactive play-back of multiple spherical videos and the corresponding sound, offers to the viewer the capability, at any point in time during the play-back, without interrupting or disrupting the play-back, with full control using his/her mouse or any other pointing/navigation device, to alter interactively the position from which the event is viewed by choosing which spherical video he/she wishes to watch at any given time, selecting among the several available spherical videos, each one corresponding to any of the several different spherical cameras which had been placed on preselected positions in the area where the event took place, choosing in this way to virtually move to the view-points where the spherical cameras had been placed and watch the event from these points, while at the same time he/she maintains total freedom to choose the direction and angle of viewing from the available full 360°x360° angle of view and total freedom to rotate (turn around) his/her viewing window, approach (zoom-in) and retreat (zoom-out), while also maintaining full interactive control of the spherical video play-back. Irrespective of the interactive alterations in

viewing position, angle, direction or virtual distance, the corresponding sound remains synchronized with the projected images.

3. Application for synchronized interactive play-back on a computer or through the internet of multiple spherical videos and the corresponding sound which are stored locally on the play-back computer or are made available for streaming through the internet or are stored in an autonomous optical medium (DVD), are projected in a normalized projection at a rate of 25 or 30 frames per second on a computer screen, characterized by the synchronized and interactive play-back of multiple spherical videos and the corresponding sound, offers to the viewer the capability, at any point in time during the play-back, without interrupting or disrupting the play-back, with full control using his/her mouse or any other pointing/navigation device, to alter interactively the position from which the event is viewed by choosing which spherical video he/she wishes to watch at any given time, selecting among the several available spherical videos, each one corresponding to any of the several different spherical cameras which had been placed on preselected positions in the area where the event took place, choosing in this way to virtually move to the view-points where the spherical cameras had been placed and watch the event from these points, while at the same time he/she maintains total freedom to choose the direction and angle of viewing from the available full 360°x360^{o} angle of view and total freedom to rotate (turn around) his/her viewing window, approach (zoom-in) and retreat (zoom-out), while also maintaining full interactive control of the spherical video play-back. Irrespective of the interactive alterations in viewing position, angle, direction or virtual distance, the corresponding sound remains synchronized with the projected images.

4. Autonomous product for the interactive play-back of one or more prerecorded events in a computer, which is available in the form of one or more optical media (DVD), operates locally in the computer of the viewer, offers control and navigational interfaces which enable the viewer to choose freely which part of the event or events wishes to watch in a normalized projection at a rate of 25 or 30 frames per second on the screen of the computer of the viewer, characterized by the synchronized and interactive play-back of multiple spherical videos and the corresponding sound, which are stored in the same optical media (DVD) that constitutes the product, are projected in a normalized projection at a rate of 25 or 30 frames per second on the screen of the computer of the viewer, offers to the viewer the capability, at any point in time during the play-back, without interrupting or disrupting the play-back, with full control using his/her mouse or any other pointing/navigation device, to alter interactively the position from which the event is viewed by choosing which spherical video he/she wishes to watch at any given time, selecting among the several available spherical videos, each one corresponding to any of the several different spherical cameras which had been placed on preselected positions in the area where the event took place, choosing in this way to virtually move to the view-points where the spherical cameras had been placed and watch the event from these points, while at the

same time he/she maintains total freedom to choose the direction and angle of viewing from the available full 360°x360° angle of view and total freedom to rotate (turn around) his/her viewing window, approach (zoom-in) and retreat (zoom-out), while also maintaining full interactive control of the spherical video play-back. Irrespective of the interactive alterations in viewing position, angle, direction or virtual distance, the corresponding sound remains synchronized with the projected images.



Figure 1:
Spherical Image (Corresponds to one frame of a spherical video sequence).

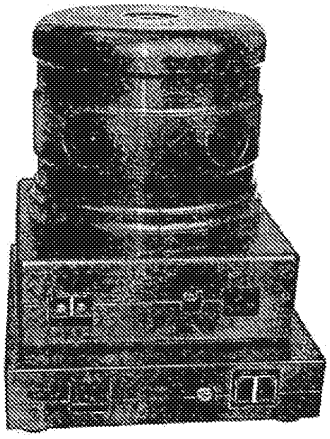


Figure 2:
Spherical Video Capture Device (Spherical Camera) and Compression Unit (Lower box)

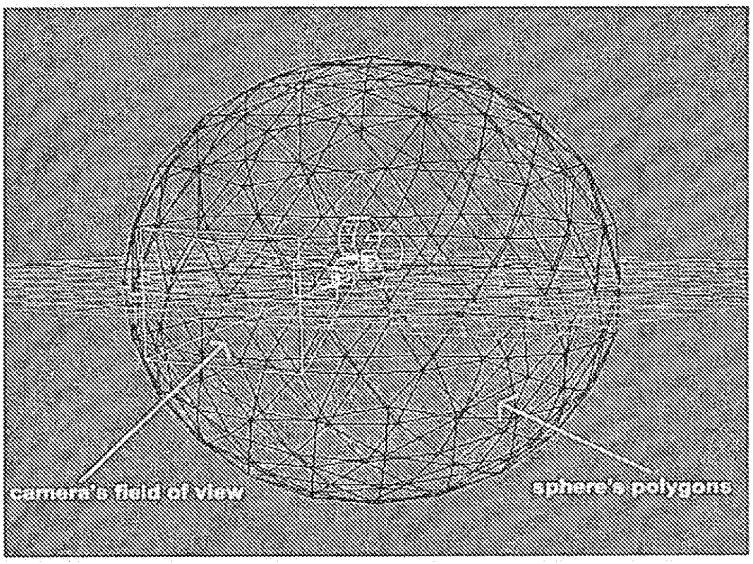


Figure 3:
The Sphere and virtual camera generated by the Graphics Engine.

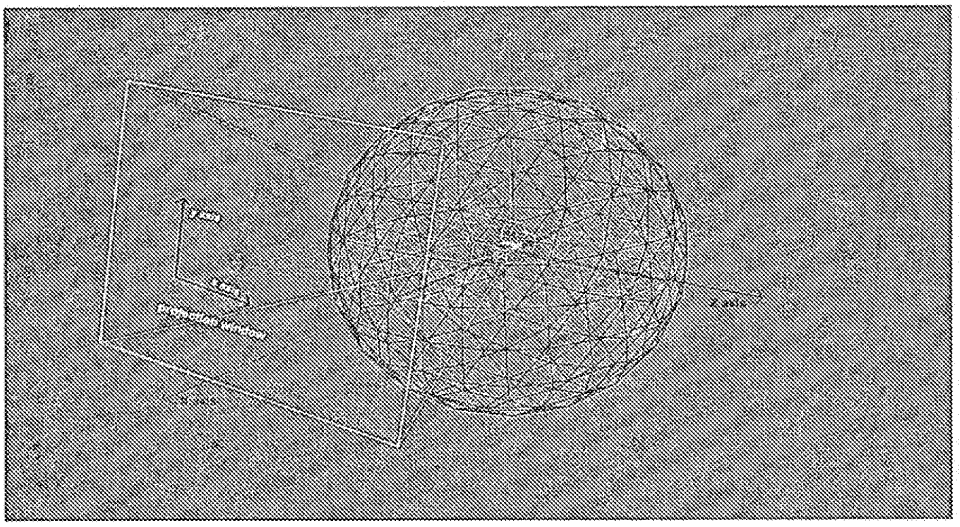


Figure 4:
Correspondence of the Projection Window and the Camera/Sphere Co-ordinate systems.

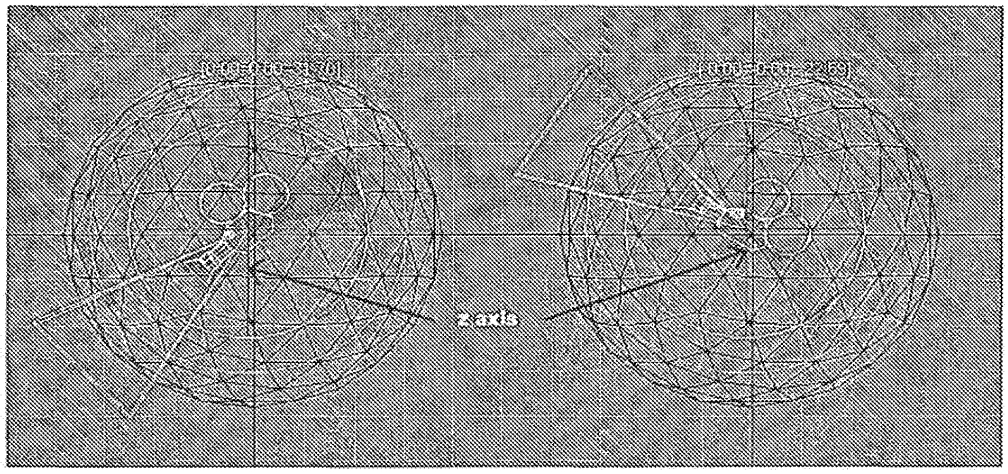


Figure 5:
Camera movement around the z-axis (up and down).

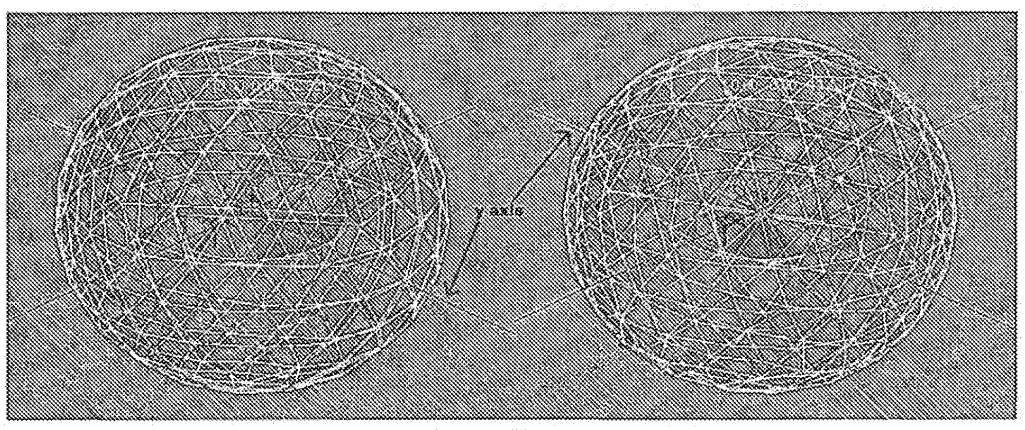


Figure 6:
Camera movement around the y-axis (left or right).

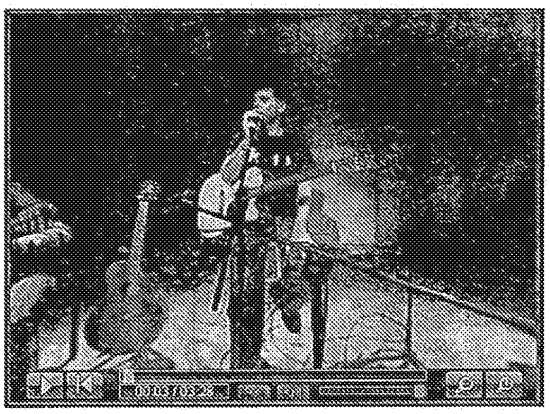


Figure 7:

The viewing window for the normalized projection of spherical video in the application for the synchronized interactive play-back of multiple spherical videos.

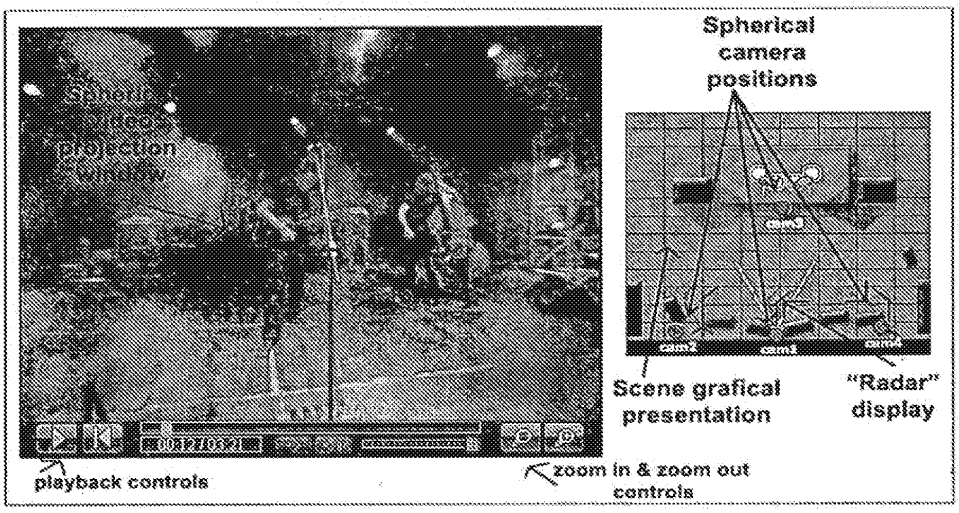


Figure 8:

Drawing presenting the Application of the Method for the synchronized interactive play-back of multiple spherical videos.

INTERNATIONAL SEARCH REPORT

International application No
PCT/GR2008/000060

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04N5/262 H04N5/232

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2004/075738 A1 (BURKE SEAN [US] ET AL) 22 April 2004 (2004-04-22) abstract paragraphs [0004], [0158] - [0168]; figures 12-14	1-4
Y	MORITA S ET AL: "Networked video surveillance using multiple omnidirectional cameras" COMPUTATIONAL INTELLIGENCE IN ROBOTICS AND AUTOMATION, 2003. PROCEEDIN GS. 2003 IEEE INTERNATIONAL SYMPOSIUM ON JULY 16 - 20, 2003, PISCATAWAY, NJ, USA,IEEE, vol. 3, 16 July 2003 (2003-07-16), pages 1245-1250, XP010650320 ISBN: 978-0-7803-7866-7 Section 3.3	1-4

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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 January 2009	06/02/2009

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Tillier, Christophe

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/GR2008/000060

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2005 244410 A (NIPPON TELEGRAPH & TELEPHONE) 8 September 2005 (2005-09-08) the whole document	1-4
A	HEID J: "VR: QUICKTIME'S NEW EDGE" MACWORLD, PC WORLD COMMUNICATIONS, SAN FRANCISCO, CA, US, 1 July 1995 (1995-07-01), pages 1-74, XP002924983 ISSN: 0741-8647 the whole document	1-4

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GR2008/000060

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2004075738 A1	22-04-2004	NONE	
JP 2005244410 A	08-09-2005	NONE	

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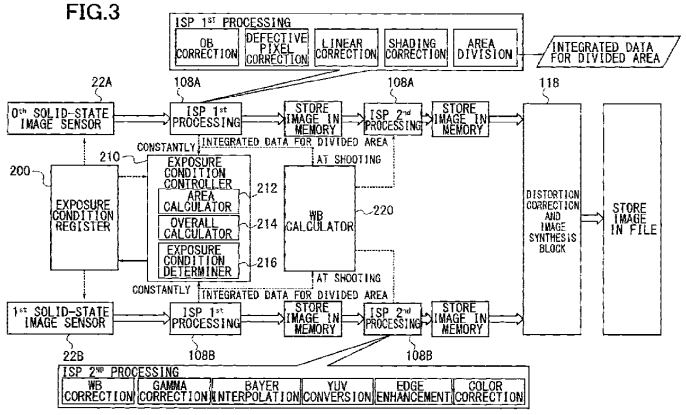
(74) Agent: **NISHIWAKI, Tamio**; Tokyo Tatemono Yaesu Bldg. 2F, 4-16, Yaesu 1-chome, Chuo-ku, Tokyo, 1030028 (JP).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

[Continued on next page]

(54) Title: IMAGING CONTROLLER AND IMAGING CONTROL METHOD AND PROGRAM

FIG.3



(57) Abstract: An imaging controller includes an index calculator to calculate an index value for each of divided areas of images captured by a plurality of imaging units, the index value for evaluating a photographic state of each of the divided areas, an evaluation value calculator to evaluate the images and an overlapping area between the images on the basis of the index value of each divided area calculated by the index calculator and calculate an overall evaluation value, and a condition determiner to determine an imaging condition for each of the imaging units on the basis of the overall evaluation value calculated by the evaluation value calculator.

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Published:

— *with international search report (Art. 21(3))*

DESCRIPTION

IMAGING CONTROLLER AND IMAGING CONTROL METHOD AND PROGRAM

CROSS REFERENCE TO RELATED APPLICATION

The present application is based on and claims priority from Japanese Patent Application No. 2012-199622, filed on September 11, 2012.

Technical Field

[0001]

The present invention relates to an imaging controller which can provide appropriate imaging conditions to multiple imaging units, and an imaging control method executed by the imaging controller and a program for realizing the imaging control method.

Background Art

[0002]

There is a known omnidirectional imaging system which includes multiple wide-angle lenses such as fisheye lens or super wide-angle lens to capture an image in omnidirections at once. It is configured to project images from the lenses onto a sensor surface and combine the images through image processing to thereby generate an omnidirectional image. For example, by use of two wide-angle lenses with angle of view of over 180 degrees, omnidirectional images can be generated. In the image processing a partial image captured by each lens system is subjected to distortion correction and projection conversion on the basis of a certain projection model with a distortion from an ideal model taken into account. Then, the partial images are connected on the basis of an overlapping portion of the partial images to form a single omnidirectional image.

[0003]

In related art an exposure correction technique of a digital camera to acquire a proper exposure from a captured image is known. For instance, Japanese Patent Application Publication No. 2007-329555 discloses an imaging system including multiple imaging units arranged to have an overlapping imaging area to extract an overlapping area from each of the images captured by the imaging units. It is configured to adjust at least one of the exposure and white balance of the imaging units according to each image of the extracted overlapping areas to reduce a difference in the brightness or color of the captured images, for the purpose of abating workloads of post-processing such as synthesis.

[0004]

However, it is difficult for the omnidirectional imaging system to acquire a proper exposure by such a related-art exposure correction technique because the optical conditions or photographic circumstances of the imaging units thereof differ. The related art disclosed in the above document only concerns an overlapping area so that it cannot obtain appropriate exposure correction values under an unbalanced exposure condition if the overlapping area is small relative to the entire image. In particular, since the imaging area of the omnidirectional imaging system is omnidirectional, a high-brightness subject as the sun is often captured on a sensor, which may cause a flare and an increase in image offset value. A proper exposure can be obtained for each sensor, however, it may cause a difference in brightness between the connecting portions of the images and impair the quality of an omnidirectional image.

Disclosure of the Invention

[0005]

The present invention aims to provide an imaging controller and imaging control method and program which can provide to each of imaging units a proper imaging condition to abate a discontinuity at the connecting points of the images captured by the imaging units in synthesizing the images.

[0006]

According to one aspect of the present invention, an imaging controller comprises an index calculator to calculate an index value for each of divided areas of images captured by a plurality of imaging units, the index value for evaluating a photographic state of each of the divided areas, an evaluation value calculator to evaluate the images and an overlapping area between the images on the basis of the index value of each divided area calculated by the index calculator and calculate an overall evaluation value, and a condition determiner to determine an imaging condition for each of the imaging units on the basis of the overall evaluation value calculated by the evaluation value calculator.

Brief Description of the Drawings

[0007]

Features, embodiments, and advantages of the present invention will become apparent from the following detailed description with reference to the accompanying drawings:

FIG. 1 is a cross section view of an omnidirectional imaging system according to the present embodiment;

FIG. 2 shows the hardware configuration of the omnidirectional imaging system in FIG. 1;

FIG. 3 shows a flow of the entire image processing of the omnidirectional imaging system in FIG. 1;

FIGs. 4A, 4B show 0th and 1st images captured by two fisheye lenses, respectively and FIG. 4C shows a synthetic image of the 0th and 1st captured images by way of example;

FIG. 5A, 5B show an area division method according to the present embodiment;

FIG. 6 is a flowchart for exposure control executed by the omnidirectional imaging system according to the present embodiment; and

FIG. 7 is a flowchart for exposure calculation executed by the omnidirectional imaging system according to the present embodiment.

Description of Embodiments

[0008]

Hereinafter, an embodiment of an imaging controller and an imaging system will be described in detail with reference to the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. By way of example, the present embodiment describes an omnidirectional imaging system which comprises a camera unit including two fisheye lenses and a function to decide an imaging condition on the basis of images captured by the two fisheye lenses. However, the present embodiment should not be limited to such an example. Alternatively, the omnidirectional imaging system can comprise a camera unit including three or more fisheye lenses to determine an imaging condition according to the images captured by the fisheye lenses. Herein, a fisheye lens can include a wide-angle lens or a super wide-angle lens.

[0009]

Referring to FIGs. 1 to 2, the overall configuration of an omnidirectional imaging system 10 is described. FIG. 1 is a cross section view of the

omnidirectional imaging system 10 (hereinafter, simply imaging system). It comprises a camera unit 12, a housing 14 accommodating the camera unit 12 and elements as controller, batteries, and a shutter button 18 provided on the housing 14.

[0010]

The camera unit 12 in FIG. 1 comprises two lens systems 20A, 20B and two solid-state image sensors 22A, 22B as CCD (charge coupled device) sensor or CMOS (complementary metal oxide semiconductor). Herein, each of the pairs of the lens systems 20 and solid-state image sensors 22 are referred to as imaging unit. The lens systems 20A, 20B are each comprised of 6 groups of 7 lenses as a fisheye lens, for instance. In the present embodiment the fisheye lens has total angle of view of 180 degrees (360 degrees/n, n = 2) or more, preferably 185 degrees or more, more preferably 190 degrees or more.

[0011]

The optical elements as lenses, prisms, filters, aperture stops of the lens systems 20A, 20B are positioned relative to the solid-state image sensors 22A, 22B so that the optical axes of the optical elements are orthogonal to the centers of the light receiving areas of the corresponding solid-state image sensors 22 as well as the light receiving areas become the imaging planes of the corresponding fisheye lenses. The solid-state image sensors 22 are area image sensors on which photodiodes are two-dimensionally arranged, to convert light gathered by the lens systems 20 to image signals.

[0012]

In the present embodiment the lens systems 20A, 20B are the same and disposed opposite to each other so that their optical axes coincide. The solid-state image sensors 22A, 22B convert light distribution to image signals and output them to a not-shown image processor on the controller. The image

processor combines partial images from the solid-state image sensors 22A, 22B to generate a synthetic image with solid angle of 4π in radian or an omnidirectional image. The omnidirectional image is captured in all the directions which can be seen from a shooting point. Instead of the omnidirectional image, a panorama image which is captured in a 360-degree range only on a horizontal plane can be generated.

[0013]

To form an omnidirectional image with use of the fisheye lenses with total angle of view of more than 180 degrees, an overlapping portion of the captured images by the imaging units is used for connecting images as reference data representing the same image. Generated omnidirectional images are output to, for instance, a display provided in or connected to the camera unit 12, a printer or an external storage medium such as SD card®, compact flash®.

[0014]

FIG. 2 shows the structure of hardware of the imaging system 10 according to the present embodiment. The imaging system 10 comprises a digital still camera processor 100 (hereinafter, simply processor), a lens barrel unit 102, and various elements connected with the processor 100. The lens barrel unit 102 includes the two pairs of lens systems 20A, 20B and solid-state image sensors 22A, 22B. The solid-state image sensors 22A, 22B are controlled by a command from a CPU 130 of the processor 100.

[0015]

The processor 100 comprises ISPs (image signal processors) 108A, 108B, a DMAC (direct memory access controller) 110, an arbiter (ARBMEMC) 112 for memory access, a MEMC (memory controller) 114 for memory access, and a distortion correction and image synthesis block 118. The ISPs 108A, 108B

perform automatic exposure control to and set white balance and gamma balance of image data signal-processed by the solid-state image sensors 22A, 22B.

[0016]

The MEMC 114 is connected to an SDRAM 116 which temporarily stores data used in the processing of the ISP 108A, 108B and distortion correction and image synthesis block 118. The distortion correction and image synthesis block 118 performs distortion correction and vertical inclination correction on the two partial images from the two imaging units on the basis of information from a triaxial acceleration sensor 120 and synthesizes them.

[0017]

The processor 100 further comprises a DMAC 122, an image processing block 124, a CPU 130, an image data transferrer 126, an SDRAMC 128, a memory card control block 140, a USB block 146, a peripheral block 150, an audio unit 152, a serial block 158, an LCD (Liquid Crystal Display) driver 162, and a bridge 168.

[0018]

The CPU 130 controls the operations of the elements of the imaging system 10. The image processing block 124 performs various kinds of image processing on image data together with a resize block 132, a JPEG block 134, and an H. 264 block 136. The resize block 132 enlarges or shrinks the size of image data by interpolation. The JPEG block 134 is a codec block to compress and decompress image data in JPEG. The H. 264 block 136 is a codec block to compress and decompress video data in H.264. The image data transferrer 126 transfers the images processed by the image processing block 124. The SDRAMC 128 controls the SDRAM 138 connected to the processor 100 and temporarily storing image data during image processing by the processor 100.

[0019]

The memory card control block 140 controls data read and write to a memory card and a flash ROM 144 inserted to a memory card throttle 142 in which a memory card is detachably inserted. The USB block 146 controls USB communication with an external device such as personal computer connected via a USB connector 148. The peripheral block 150 is connected to a power switch 166.

[0020]

The audio unit 152 is connected to a microphone 156 for receiving an audio signal from a user and a speaker 154 for outputting the audio signal, to control audio input and output. The serial block 158 controls serial communication with the external device and is connected to a wireless NIC (network interface card) 160. The LCD driver 162 is a drive circuit for the LCD 164 and converts the image data to signals for displaying various kinds of information on an LCD 164.

[0021]

The flash ROM 144 contains a control program written in readable codes by the CPU 130 and various kinds of parameters. Upon power-on of the power switch 166, the control program is loaded onto a main memory. The CPU 130 controls the operations of the units and elements of the image processor in compliance with the control program on the main memory, and temporarily stores necessary control data in the SDRAM 138 and a not-shown local SRAM.

[0022]

FIG. 3 shows essential function blocks for controlling imaging condition and the flow of the entire image processing of the imaging system 10 according to the present embodiment. First, the solid-state image sensors 22A, 22B capture images under a certain exposure condition and output them. Then, the ISPs 108A, 108B in FIG. 2 perform optical black correction, defective pixel correction, linear

correction, shading correction and area division (collectively referred to as first processing) to the images from the solid-state image sensors 22A, 22B and store them in memory.

[0023]

The optical black correction is a processing in which an output signal from an effective pixel area is subjected to clamp correction, using the output signals of optical black areas of the solid-state image sensors as a black reference level. A solid-state image sensor such as CMOS may contain defective pixels from which pixels values are not obtainable because of impurities entering a semiconductor substrate in the manufacturing of the image sensor. The defective pixel correction is a processing in which the value of a defective pixel is corrected according to a combined signal from neighboring pixels of the defective pixel.

[0024]

The linear correction is for each of RGBs. The shading correction is to correct a distortion of shading in an effective pixel area by multiplying the output signal of the effective pixel area by a certain correction coefficient. The area division is to divide a captured image into small areas and calculate an integrated value or an integrated average value of brightness values for each divided area.

[0025]

Returning to FIG. 3, after the first processing the ISPs 108A, 108B further perform white balance, gamma correction, Bayer interpolation, YUV conversion, edge enhancement and color correction (collectively referred to as second processing) to the images, and the images are stored in the memory. The amount of light transmitting through the color filters of the image sensors changes depending on the color of the filter. The white balance correction is to correct a difference in sensitivity to the three colors R (red), G (green), and B (blue) and set a gain for appropriately representing white color in an image. A WB (white

balance) calculator 220 calculates a white balance parameter according to the RGB integrated value or integrated average value calculated in the area division process. The gamma correction is to correct a gamma value of an input signal so that the output linearity of an output device is maintained with the characteristic thereof taken into account.

[0026]

Further, in the CMOS each pixel is attached with any of RGB color filters. The Bayer interpolation is to interpolate insufficient two colors from neighboring pixels. The YUV conversion is to convert RAW data in RGB format to data in YUV format of a brightness signal Y and a color difference signal UV. The edge enhancement is to extract the edges of an image according to a brightness signal, apply a gain to the edges, and remove noise in the image in parallel to the edge extraction. The color correction includes chroma setting, hue setting, partial hue change, and color suppression.

[0027]

After the various kinds of processing to the captured images under a certain exposure parameter, the images are subjected to distortion correction and image synthesis. A generated omnidirectional image is added with a tag properly and stored in a file in the internal memory or an external storage. Inclination correction can be additionally performed on the basis of the information from the triaxial acceleration sensor 120 or a stored image file can be subjected to compression when appropriate. A thumb-nail image can be generated by cropping or cutting out the center area of an image.

[0028]

In the above-described image processing the exposure parameter for the solid-state image sensors 22A, 22B is determined and set in an exposure condition register 200 by an exposure condition controller 210. The imaging system 10

according to the present embodiment does not need to include a photometer for measuring the brightness of a subject but uses the outputs of the solid-state image sensors 22A, 22B for exposure control. To display a captured image on a LCD or an EVF (electronic view finder), image signals are constantly read from the solid-state image sensors 22A, 22B. The exposure condition controller 210 repeatedly conducts a photometry on the basis of a read image signal and determines whether a brightness level is appropriate, to correct the exposure parameter such as F-value, exposure time (shutter speed), amplifier gain (ISO sensitivity) and obtain a proper exposure.

[0029]

In omnidirectional photographing with the omnidirectional imaging system 10, the two imaging units generate two images. In a photographic scene including a high-brightness object as the sun, a flare may occur in one of the images as shown in FIGs. 4A, 4B and spread over the entire image from the high-brightness object. In such a case a synthetic image of the two images or omnidirectional image may be impaired in quality because an increased offset of the one of the images causes a difference in brightness at the connecting portions. Further, no proper object for exposure correction but an extremely white or black object will appear in an overlapping area of the two images.

[0030]

In the imaging unit using fisheye lenses with total angle of view of over 180 degrees, most of photographic areas do not overlap except for partial overlapping areas. Because of this, it is difficult to acquire a proper exposure for the above scene by exposure correction based only on the overlapping area. Further, even with the proper exposure obtained for the individual imaging units, a discontinuity of color attribute as brightness may occur at the connecting positions of a synthetic image.

[0031]

In view of avoiding insufficient exposure control, in the imaging system 10 the exposure condition controller 210 is configured to evaluate the level of exposure of all of the images with the overlapping area and non-overlapping areas of the images taken into consideration and decide exposure parameters as aperture a, exposure time t and amplifier gain g for the solid-state image sensors 22A, 22B to be set in the exposure condition register 200.

[0032]

Specifically, the exposure condition controller 210 includes an area calculator 212, an overall calculator 214 and an exposure condition determiner 216, and can be realized by the ISPs 108 and CPU 130. In the first processing the ISPs 108A, 108B calculate the integrated value or integrated average value for each divided area and outputs integrated data for each divided area, and the exposure condition controller 210 reads the integrated data.

[0033]

FIGs. 5A, 5B show how to divide an image into small areas by way of example. In the present embodiment incident light on the lens systems 20A, 20B is imaged on the light-receiving areas of the solid-state image sensors 22A, 22B in accordance with a certain projection model such as equidistant projection. Images are captured on the two-dimensional solid-state area image sensors and image data represented in a plane coordinate system. In the present embodiment a circular fisheye lens having an image circle diameter smaller than an image diagonal line is used and an obtained image is a planar image including the entire image circle in which the photographic areas in FIGs. 4A, 4B are projected.

[0034]

The entire image captured by each solid-state image sensor is divided into small areas in circular polar coordinate system with radius r and argument θ in FIG.

5A or small areas in planar orthogonal coordinate system with x and y coordinates in FIG. 5B. It is preferable to exclude the outside of the image circle from a subject of integration and averaging since it is a non-exposed outside area. In the area division of the ISPs 108, each image is divided into small areas as shown in FIGs. 5A, 5B and the integrated value or integrated average value of brightness is calculated for each divided area. The integrated value is obtained by integrating the brightness values of all the pixels in each divided area while the integrated average value is obtained by normalizing the integrated value with the size (number of pixels) of each divided area excluding the outside area.

[0035]

The area calculator 212 receives the integrated data for each divided area including the integrated average value and calculates an index value for each divided area to evaluate a photographic state thereof. In the present embodiment the index value is an area brightness level b for evaluating an absolute brightness of each divided area. The brightness level b(x, y) of a certain divided area is calculated for each solid-state image sensor 22 by the following equation:

$$b(x,y) = s(x,y)\frac{a^2}{t \cdot g} \quad \cdots (1)$$

where s(x,y) is an integrated average value for a certain divided area, a is an aperture, t is exposure time, and g is amplifier gain. The brightness level b(r, θ) of a divided area in a circular coordinate system can be calculated in the same manner.

[0036]

The brightness level b (x, y) is an index value to evaluate the brightness of a subject in each divided area and calculated from the brightness of a pixel value of an actual image according to a current exposure parameter (a, t, g).

[0037]

The overall calculator 214 evaluates the captured images including the overlapping area as a whole on the basis of the calculated brightness level $b^i(x, y)$ and calculates an overall evaluation value with weighting according to an overlapping portion between the photographic areas of the images. Herein, the solid-state image sensors 22A, 22B are referred to as 0th and 1st image sensors and their brightness levels are referred to as $b^0(x,y)$ and $b^1(x,y)$, respectively. In the present embodiment the overall evaluation value is an overall brightness level bT to evaluate the brightness of all the areas of the images or subject brightness as a whole with a certain weighting.

[0038]

The overall brightness level bT^i is calculated for an i-th solid-state image sensor by the following equation:

$$bT^i = \frac{\sum_{x,y} b^0(x,y) \times w^{0i}(x,y) + \sum_{x,y} b^1(x,y) \times w^{1i}(x,y)}{\sum_{x,y} w^{0i}(x,y) + \sum_{x,y} w^{1i}(x,y)} \quad \cdots (2)$$

where $b^j(x,y)$ is a brightness level for each divided area of each solid-state image sensor j ($j \in 0, 1$) and $w^{ji}(x, y)$ is a weighted value in weighted averaging for each divided area.

[0039]

As expressed by the above equation, different sets of weighted values $w^{ji}(x, y)$ are used for each solid-state image sensor. The weighted values $w^{ji}(x, y)$ can be adjusted so that a larger value is given to a solid-state image sensor with a lower brightness level to prevent receipt of an influence from a light source. Thus, weighting can be performed properly in accordance with a result of determination about a photographic scene. Further, the small areas (x, y) can be zoned into intermediate areas as overlapping area and non-overlapping area as

indicated by hatching in FIGs. 5A, 5B. The overall brightness level bT^i can be calculated by the following equation, using the brightness level and weighted values for each intermediate area.

$$bT^i = \frac{w1i \times bE^0 + w2i \times bE^1 + w3i \times bC^0 + w4i \times bC^1}{w1i + w2i + w3i + w4i} \quad \cdots (3)$$

where bE^0 is a brighteness level (average) of an edge area (overlapping area) of the 0th image, bC^0 is a brighteness level (average) of a center area (non-overlapping area) of the 0th image, bE^1 is a brightness level (average) of an edge area (overlapping area) of the 1st image, bC^1 is a brighteness level (average) of a center area (non-overlapping area) of the 1st image, and w1i to w4i are weighted values of weighted averaging set for each intermediate area of an i-th solid-state image sensor. The basic values of weighted values w1i to w4i can be calculated by the following equations (4):

$$W1i = W2i = Ae / (A0 + A1 + 2Ae)$$
$$W3i = A0 / (A0 + A1 + 2Ae)$$
$$W4i = A1 / (A0 + A1 + 2Ae)$$

where Ae is the size of the edge areas of the 0th and 1st images, and A0 and A1 are the sizes of the center areas of the 0th and 1st images. The calculated basis values can be corrected in accordance with a result of determination about a photographic scene such that a solid-state image sensor with a lower brightness level is given a larger weight.

[0040]

Preferably, the overall calculator 214 can include a weighting setter to set the weighted values $w^{ji}(x, y)$ according to a signal level of a captured image. The weighting setter is configured to create a brightness distribution (histogram) from the brightness levels $b^j(x, y)$ of all the divided areas and analyze a total average

value and brightness distribution for the scene determination. Then, according to a determined scene, it can change the weighted values $w^{ji}(x, y)$ for a certain divided area depending on the brightness level $b^{j}(x, y)$ for the divided area in question.

[0041]

For example, in a dark scene as night view, the weighting setter sets, by adding a predetermined amount to the area brightness level, the weighted value $w^{ji}(x, y)$ to a larger value for evaluating a divided area with a larger brightness level b(x, y) calculated. Thereby, a bright subject in a dark scene is highly evaluated for photometry and exposure can be properly controlled according to a result of the photometry. Meanwhile, in a bright scene the weighting setter sets a larger weighted value $w^{ji}(x, y)$ for a divided area with a smaller brightness level b(x, y) calculated. Thus, a dark subject in a bright scene is highly evaluated for photometry.

[0042]

Alternatively, a divided area containing an extremely black or white subject can be detected according to an upper limit threshold and a lower limit threshold to exclude the divided area for a subject of the photometry. For example, if a divided area or a white area with a brightness level equal to or over an upper limit threshold (b_{uth}) and/or a divided area or a black area with a brightness level equal to or below a lower limit threshold (b_{lth}) is/are detected, these areas can be given a smaller weight or zero. Thereby, it is possible to calculate the overall brightness level bT with the divided area unsuitable for exposure correction given a small weight or not taken into account.

[0043]

The weighting setter determines a scene of each the 0th and 1st images captured by the two solid-state image sensors 22A, 22B on the basis of a relation

of the brightness between the two images and sets weighted values appropriate for the scene for each of the solid-state image sensors 22A, 22B. For example, to prevent receipt of an influence from a light source, the weighted values $w^{ji}(x, y)$ can be adjusted so that a larger value is given to a solid-state image sensor with a lower brightness level.

[0044]

The exposure condition determiner 216 determines an exposure parameter (a, t, g) for each i-th solid-state image sensor on the basis of the overall brightness level bT^i calculated by the overall calculator 214. The overall brightness level bT is to evaluate the brightness of a subject in the images, and a condition for acquiring a proper exposure can be represented by the following conditions:

$$\frac{a^2}{t} = \frac{bT \cdot g}{K} \quad \cdots (4)$$

$$Bv + Sv = Av + Tv \quad \cdots (5)$$

where k is a constant, Bv is a brightness value, Sv is a sensitivity value, Av is an aperture value and Tv is a time value. The condition (5) is a transformation of the condition (4) taking 2 as a base of logarithm of each of the four parameters.

[0045]

The four parameters are calculated by the following equations:

$$Av = 2\log_2 a \quad \cdots (6)$$

$$Tv = \log_2 \frac{1}{t} \quad \cdots (7)$$

$$Bv = \log_2 (k_1 bT) \quad \cdots (8)$$

$$Sv = \log_2 (k_2 g) \quad \cdots (9)$$

In the equations (8), (9) k_1, k_2 are constants.

[0046]

Specifically, to satisfy the above exposure conditions, the exposure condition determiner 216 adjusts the aperture a, exposure time t and amplifier gain g for each i-th solid-state image sensors 22 according to a current exposure parameter and a measured subject brightness or overall brightness level and acquires a proper exposure. The corrected exposure parameter (a', t', g') can be obtained from the brightness level bT^i, referring to a table called a program diagram which is prepared in advance in accordance with the characteristic of the imaging system 10. Herein, the program diagram refers to a diagram or a table containing the combinations of the amplifier gain g and exposure time t with a fixed aperture a. Exposure values can be determined from the combinations.

[0047]

In the present embodiment an optimal combination of the aperture a, exposure time t and amplifier gain g is obtainable from the overall brightness level bT by a certain program diagram. Alternatively, at least one of the aperture a, exposure time t and amplifier gain g can be manually set and the rest of them can be found from the program diagram. Such automatic exposure mode exemplifies shutter priority mode in which exposure time t is manually set, aperture priority mode in which aperture a is manually set, and sensitivity priority mode in which amplifier gain g is manually set.

[0048]

Hereinafter, the exposure control by the imaging system 10 is described, referring to FIGs. 6, 7. FIG. 6 is a flowchart for the exposure control while FIG. 7 is a flowchart for exposure calculation process of the exposure control. The operation in FIG. 6 is repeatedly executed every time images are captured by the image sensors 22A, 22B. In step S101 the imaging system 10 calculates an integrated average value for each divided area of the two image sensors 22A, 22B

by integrating the pixel values thereof. In step S102 the exposure calculation in FIG. 7 is called up.

[0049]

In FIG. 7 in step S201 the imaging system 10 takes the statistics of integrated average values for the divided areas of each solid-state image sensor 22 to calculate an average and a dispersion (or a standard deviation) of the image. In step S202 the imaging system 10 determines whether a current exposure parameter is in an allowable range from the average and dispersion of the two images to sufficiently evaluate a subject brightness. For example, if the average of the images is close to zero and the dispersion is lower than a certain threshold, it is probable that black saturation occur in the captured images. In contrast, if the average is close to saturation and a dispersion is low, it is probable that white saturation occur in the captured images. The light amount of captured images with black or white saturation cannot be properly measured so that the exposure parameter indicating black or white saturation is determined to be outside the allowable range.

[0050]

With NO in step S202, the imaging system 10 proceeds to step S206 and adjusts an exposure parameter to acquire a proper exposure, and completes the operation in step S207. For instance, with the occurrence of black saturation, the exposure parameter is adjusted so that the aperture is opened and exposure time and sensitivity are increased. In contrast, with the occurrence of white saturation, the exposure parameter is adjusted so that the aperture is closed and exposure time and sensitivity are decreased. When the gain g is fixed, the exposure parameter (a', t') is adjusted by lowering an exposure value Ev by a predetermined number of steps in black saturation. In white saturation the exposure parameter (a', t') is adjusted by raising an exposure value Ev by a predetermined number of steps.

When the aperture a is fixed, the exposure parameter (t', g') is adjusted by increasing the exposure time t and amplifier gain g in black saturation and decreasing them in white saturation.

[0051]

With YES in step S202, the area calculator 212 calculates a brightness level $b^i(x,y)$ for each divided area of the 0th and 1st images on the basis of the integrated average value s(x, y) and a current exposure parameter (a, t, g).

[0052]

In step S204 the overall calculator 214 determines a scene of the images and reads a weighted value $w^{ji}(x, y)$ for the determined scene. In step S205 the overall calculator 214 calculates the weighted average of the brightness levels $b^0(x, y)$ and $b^1(x, y)$ and calculates the overall brightness level bT^i for each i-th solid-state image sensors by the equations (2) and (3). In step S206 the exposure condition determiner 216 adjusts the exposure according to the overall brightness level bT^i to satisfy the conditions (4) and (5) and determines the exposure parameter (a', t', g'). Then, the imaging system 10 completes the exposure calculation and returns to step S103 in FIG. 6.

[0053]

In step S103 the exposure parameter in the exposure condition register 200 is updated to the determined exposure parameter (a', t', g'), completing the exposure control operation. By repeating the operations in FIGs. 6, 7, the exposure condition is set to a proper exposure satisfying the above conditions (4), (5).

[0054]

In omnidirectional photographing with the omnidirectional imaging system 10, the same subject is captured in the overlapping area, therefore, the brightness levels b of the two images should be the same value. In view of the

occurrence of flares in one of the images as shown in FIGs. 4A, 4B, according to the present embodiment the overall exposure level of the captured images including the overlapping area and non-overlapping areas is evaluated to determine the exposure parameter (a, t, g) for each of the imaging units. Thereby, it is made possible to abate a discontinuity of the brightness at the connecting positions of a synthetic image and generate high-quality synthetic images.

[0055]

Thus, according to the above embodiment, it is possible to provide an imaging controller and imaging control method and program which can provide to each of imaging units a proper imaging condition to abate a discontinuity at the connecting points of the images captured by the imaging units in synthesizing the images.

[0056]

The above embodiment has described an example where two images captured with the lens systems having angle of view of over 180 degrees are overlapped for synthesis. Alternatively, three or more images captured with multiple imaging units can be overlapped for synthesis.

[0057]

Moreover, the above embodiment has described the imaging system 10 to capture an omnidirectional still image as an example of the imaging controller. The present invention should not be limited to such an example. Alternatively, the imaging controller can be configured as an omnidirectional video imaging system or unit, a portable data terminal such as a smart phone or tablet having an omnidirectional still or video shooting function, or a digital still camera processor or a controller to control a camera unit of an imaging system.

[0058]

The functions of the omnidirectional imaging system can be realized by a computer-executable program written in legacy programming language such as assembler, C, C++, C#, JAVA® or object-oriented programming language. Such a program can be stored in a storage medium such as ROM, EEPROM, EPROM, flash memory, flexible disc, CD-ROM, CD-RW, DVD-ROM, DVD-RAM, DVD-RW, blue ray disc, SD card, or MO and distributed through an electric communication line. Further, a part or all of the above functions can be implemented on, for example, a programmable device (PD) as field programmable gate array (FPGA) or implemented as application specific integrated circuit (ASIC). To realize the functions on the PD, circuit configuration data as bit stream data and data written in HDL (hardware description language), VHDL (very high speed integrated circuits hardware description language), and Verilog-HDL stored in a storage medium can be distributed.

[0059]

Although the present invention has been described in terms of exemplary embodiments, it is not limited thereto. It should be appreciated that variations or modifications may be made in the embodiments described by persons skilled in the art without departing from the scope of the present invention as defined by the following claims.

Claims

1. An imaging controller comprising:

an index calculator to calculate an index value for each of divided areas of images captured by a plurality of imaging units, the index value for evaluating a photographic state of each of the divided areas;

an evaluation value calculator to evaluate the images and an overlapping area between the images on the basis of the index value of each divided area calculated by the index calculator and calculate an overall evaluation value; and

a condition determiner to determine an imaging condition for each of the imaging units on the basis of the overall evaluation value calculated by the evaluation value calculator.

2. The imaging controller according to claim 1, wherein:

the imaging condition includes an exposure condition;

the index value of a certain divided area is a first brightness level to evaluate a brightness of the certain divided area;

the overall evaluation value is a second brightness level for each of the imaging units to evaluate a total brightness of the images by applying weighting to the overlapping area; and

the condition determiner is configured to determine an imaging condition for each of the imaging units on the basis of the second brightness level.

3. The imaging controller according to either claim 1 or 2, further comprising

a setter to set, for each of the imaging units, a set of weighted values for the divided areas according to a relation of brightness between the images captured by the imaging units.

4. The imaging controller according to any one of claims 1 to 3, further comprising

a weighting setter to apply weighting to a certain divided area in accordance with the index value calculated for the certain divided area.

5. The imaging controller according to claim 4, wherein

the weighting setter is configured to apply weighting to the divided areas such that in a dark scene a divided area for which a larger index value is calculated is given a larger weighting.

6. The imaging controller according to either claim 4 or 5, wherein

the weighting setter is configured to apply weighting to the divided areas such that in a bright scene a divided area for which a smaller index value is calculated is given a larger weighting.

7. The imaging controller according to any one of claims 4 to 6, wherein

the weighting setter is configured to apply weighting to the divided areas such that a divided area for which the index value as an upper limit threshold or more or a lower limit threshold or less is calculated is given a smaller weighting or zero.

8. The imaging controller according to any one of claims 1 to 7, wherein

the imaging condition includes at least one of an aperture, an exposure time and a gain.

9. An imaging control method comprising the steps of:

calculating an index value for each of divided areas of images captured by a plurarity of imaging units, the index value for evaluating a photographic state of each of the divided areas;

evaluating the images and an overlapping area between the images on the basis of the index value of each divided area calculated in the calculating step and calculating an overall evaluation value; and

determining an imaging condition for each of the imaging units on the basis of the overall evaluation value calculated in the evaluating step.

10. A non-transitory computer-readable storage medium storing a program for causing a computer to execute the steps of the imaging control method according to claim 9.

FIG.1

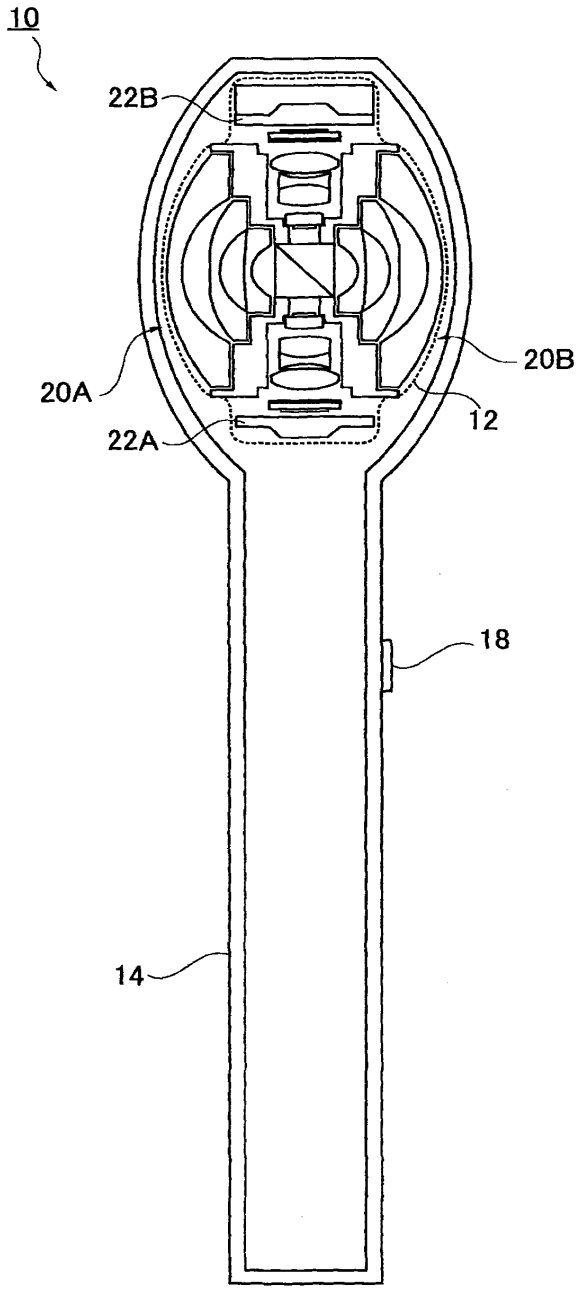


FIG.2

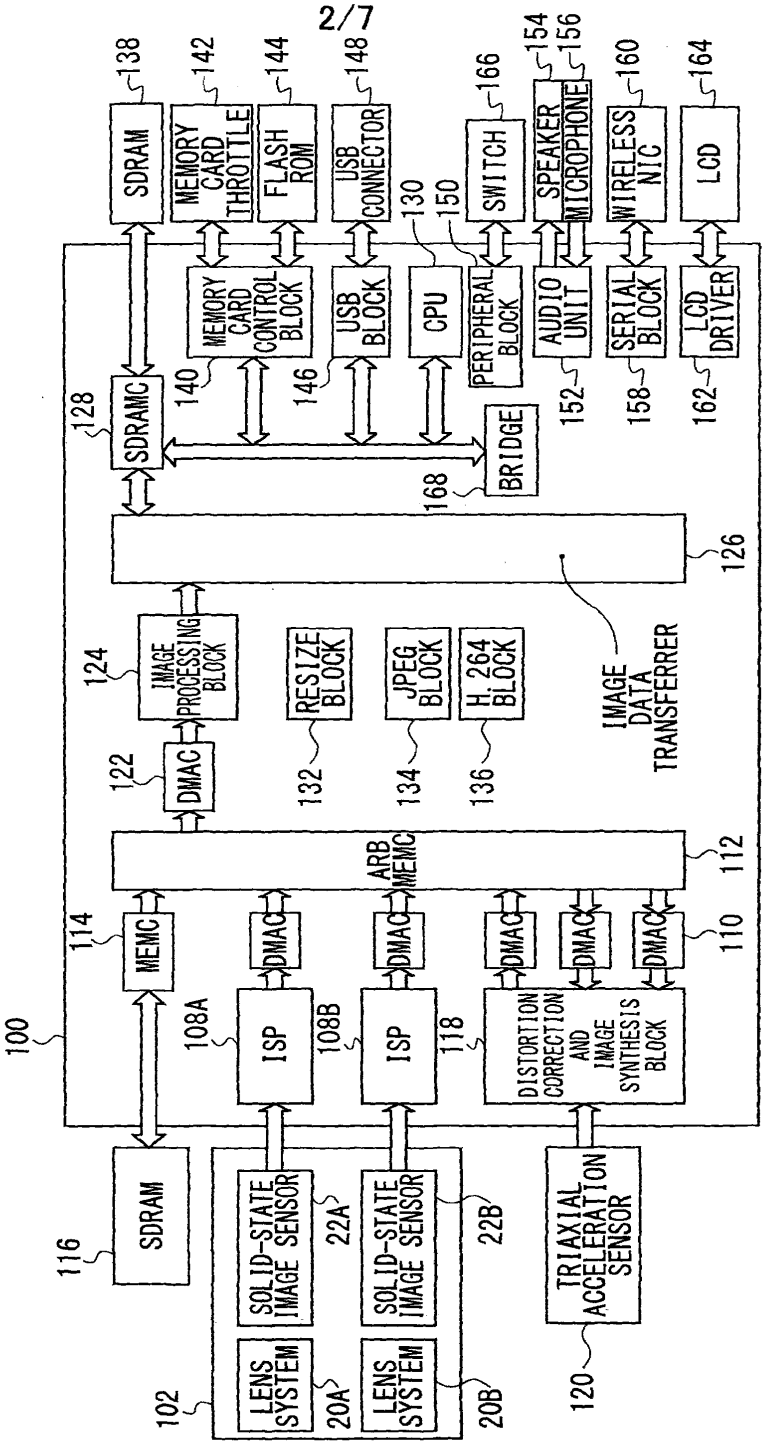

100
102
LENS SYSTEM
20A
SOLID-STATE IMAGE SENSOR
22A
LENS SYSTEM
20B
SOLID-STATE IMAGE SENSOR
22B
116
SDRAM
114
MEMC
108A
ISP
108B
ISP
118
DISTORTION CORRECTION AND IMAGE SYNTHESIS BLOCK
DMAC
ARB MEMC
112
110
122
DMAC
124
IMAGE PROCESSING BLOCK
RESIZE BLOCK
132
JPEG BLOCK
134
H.264 BLOCK
136
IMAGE DATA TRANSFERRER
126
128
SDRAMC
140
MEMORY CARD CONTROL BLOCK
146
USB BLOCK
CPU
130
150
PERIPHERAL BLOCK
168
BRIDGE
152
AUDIO UNIT
158
SERIAL BLOCK
162
LCD DRIVER
138
SDRAM
142
MEMORY CARD THROTTLE
144
FLASH ROM
148
USB CONNECTOR
166
SWITCH
154
SPEAKER
156
MICROPHONE
160
WIRELESS NIC
164
LCD
120
TRIAXIAL ACCELERATION SENSOR

FIG.3

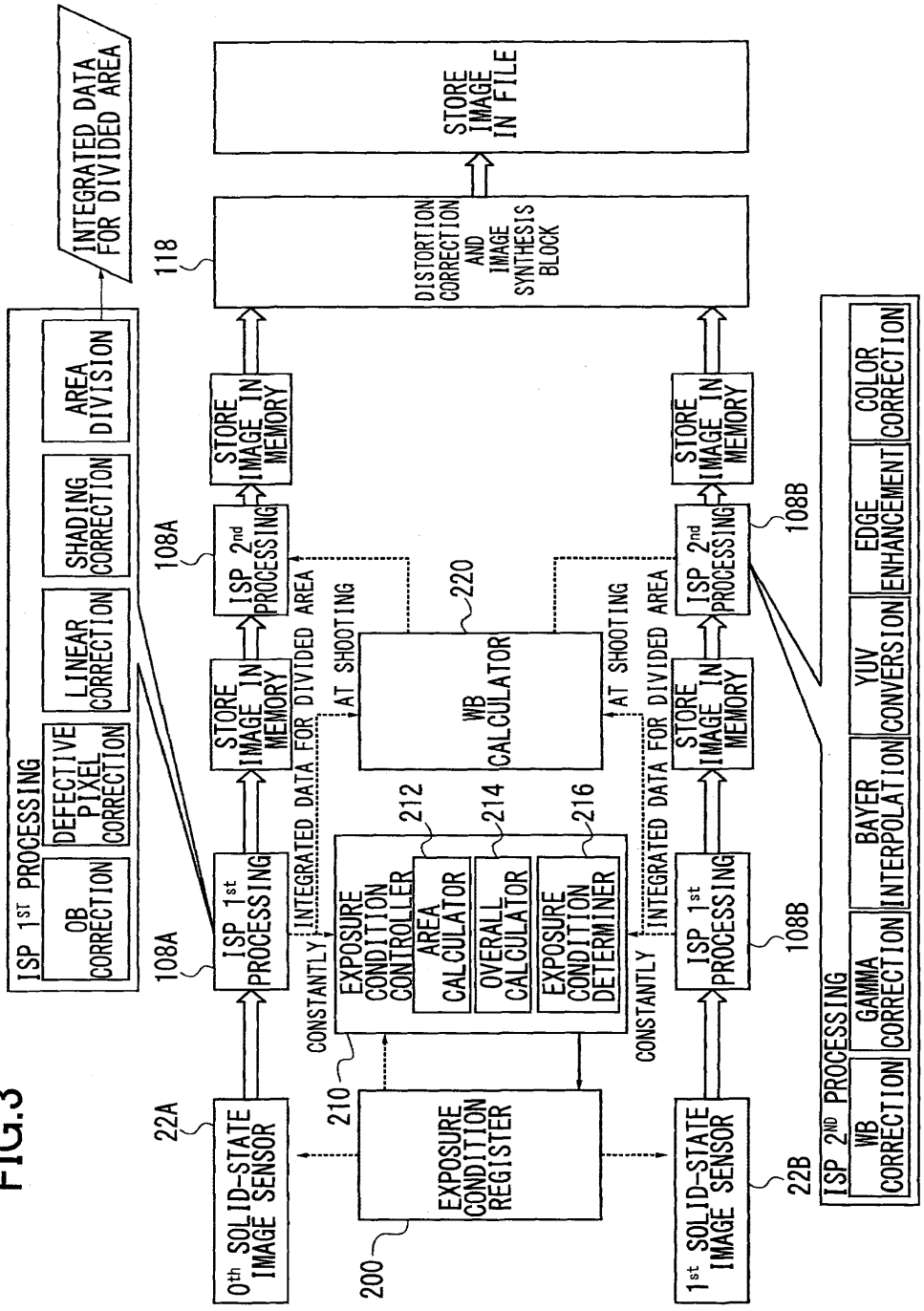

0th SOLID-STATE IMAGE SENSOR
1st SOLID-STATE IMAGE SENSOR
22A
22B
EXPOSURE CONDITION REGISTER
200
210
EXPOSURE CONDITION CONTROLLER
AREA CALCULATOR
OVERALL CALCULATOR
EXPOSURE CONDITION DETERMINER
212
214
216
CONSTANTLY
INTEGRATED DATA FOR DIVIDED AREA
AT SHOOTING
WB CALCULATOR
220
ISP 1st PROCESSING
108A
108B
OB CORRECTION
DEFECTIVE PIXEL CORRECTION
LINEAR CORRECTION
SHADING CORRECTION
AREA DIVISION
ISP 1ST PROCESSING
STORE IMAGE IN MEMORY
ISP 2nd PROCESSING
ISP 2ND PROCESSING
WB CORRECTION
GAMMA CORRECTION
BAYER INTERPOLATION
YUV CONVERSION
EDGE ENHANCEMENT
COLOR CORRECTION
INTEGRATED DATA FOR DIVIDED AREA
118
DISTORTION CORRECTION AND IMAGE SYNTHESIS BLOCK
STORE IMAGE IN FILE

FIG.4A

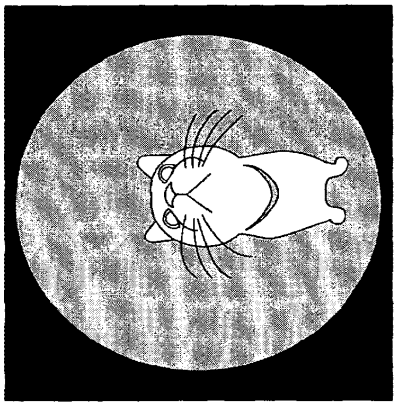


FIG.4B

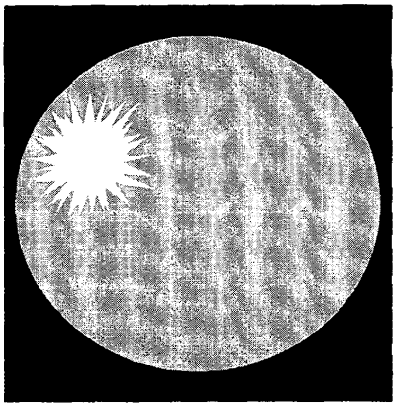


FIG.4C

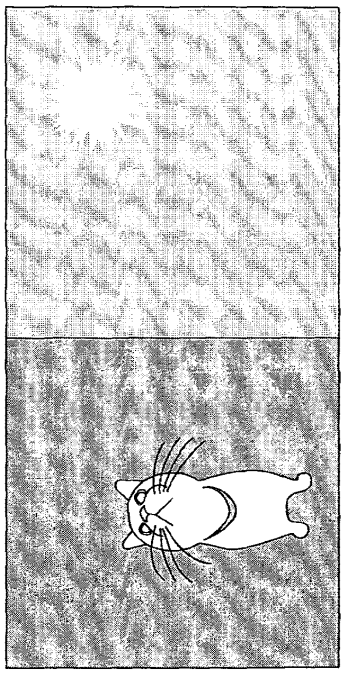


FIG.5A

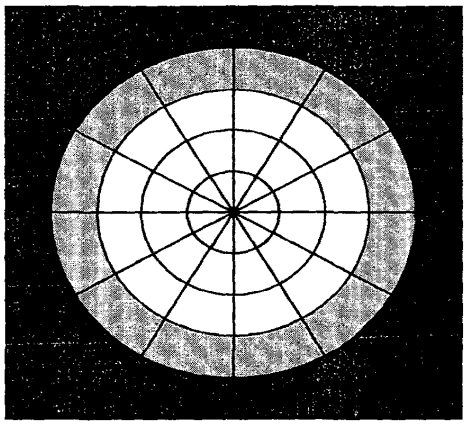


FIG.5B

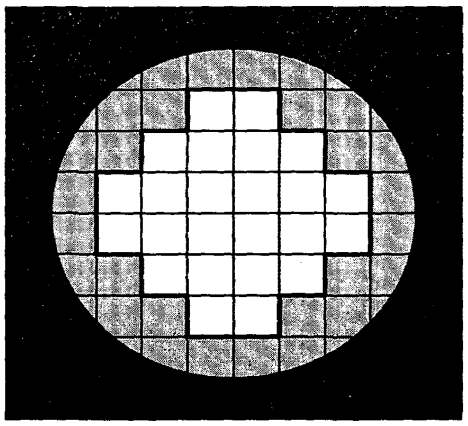


FIG.6

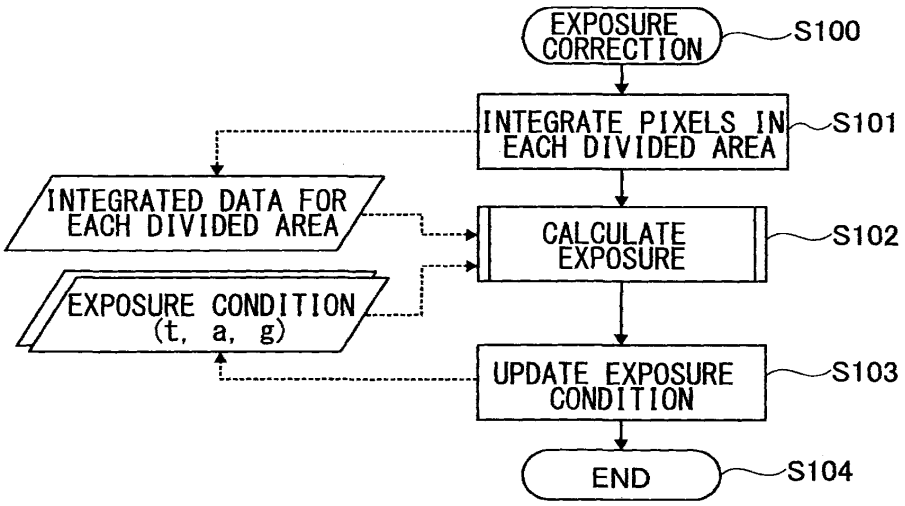
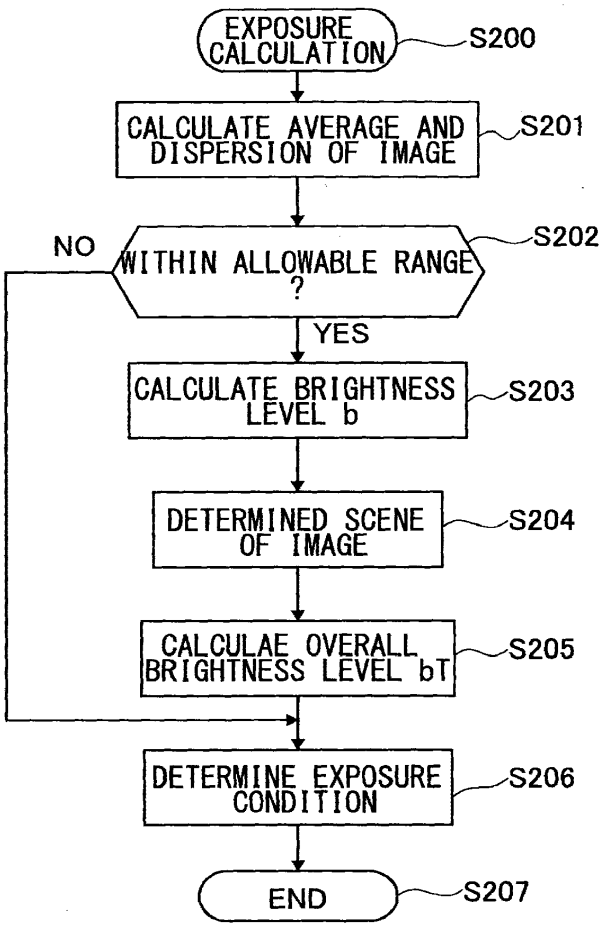

EXPOSURE CORRECTION
S100
INTEGRATE PIXELS IN EACH DIVIDED AREA
S101
INTEGRATED DATA FOR EACH DIVIDED AREA
CALCULATE EXPOSURE
S102
EXPOSURE CONDITION (t, a, g)
UPDATE EXPOSURE CONDITION
S103
END
S104

FIG.7


EXPOSURE CALCULATION
S200
CALCULATE AVERAGE AND DISPERSION OF IMAGE
S201
NO
WITHIN ALLOWABLE RANGE ?
S202
YES
CALCULATE BRIGHTNESS LEVEL b
S203
DETERMINED SCENE OF IMAGE
S204
CALCULAE OVERALL BRIGHTNESS LEVEL bT
S205
DETERMINE EXPOSURE CONDITION
S206
END
S207

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/074170

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. H04N5/232(2006.01)i, G03B7/28(2006.01)i, G03B15/00(2006.01)i, G03B19/07(2006.01)i, G03B37/04(2006.01)i, H04N5/238(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2013
Registered utility model specifications of Japan 1996-2013
Published registered utility model applications of Japan 1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2003-244511 A (FUJI PHOTO FILM CO.,LTD.) 2003.08.29, Paragraphs [0010],[0011] (No Family)	1,3-10 2
Y A	JP 2007-053617 A (FUJIFILM HOLDINGS CORP.) 2007.03.01, Paragraphs [0081]-[0090],Figs.4,28-31 (No Family)	1,3-10 2
Y A	JP 2002-281379 A (RICOH COMPANY,LTD.) 2002.09.27, Paragraphs [0107]-[0112], Figs.10,11 (No Family)	1,3-10 2

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25.09.2013	08.10.2013

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Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) Title: SPATIAL AUDIO APPARATUS

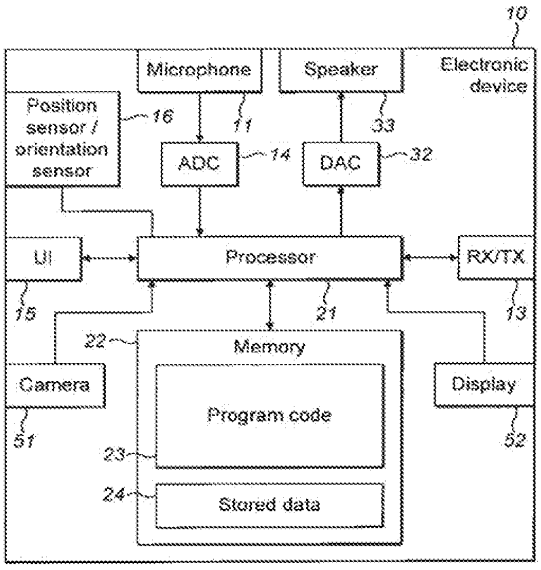


FIG. 1

(57) Abstract: An apparatus comprising: an input configured to receive from at least two microphones at least two audio signals; at least two processor instances configured to generate separate output audio signal tracks from the at least two audio signals from the at least two microphones; a file processor configured to link the at least two output audio signal tracks within a file structure.

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Published:

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

SPATIAL AUDIO APPARATUS

Field

The present application relates to apparatus for spatial audio signal processing. The invention further relates to, but is not limited to, apparatus for spatial audio signal processing within mobile devices.

Background

Spatial audio signals are being used in greater frequency to produce a more immersive audio experience. A stereo or multi-channel recording can be passed from the recording or capture apparatus to a listening apparatus and replayed using a suitable multi-channel output such as a multi-channel loudspeaker arrangement and with virtual surround processing a pair of stereo headphones or headset.

It would be understood that in the near future it will be possible for mobile apparatus such as mobile phone to have more than two microphones. This offers the possibility to record real multichannel audio. With advanced signal processing it is further possible to beamform or directionally amplify or process the audio signal from the microphones from a specific or desired direction.

Furthermore certain video file formats such as MP4 allow for the MP4 container to comprise multiple audio signal tracks and video encoded signals. Thus it is possible to record multiple surround sound tracks with different beams (or multiple stereo tracks) and with different settings or capture object-based audio signals.

Summary

Aspects of this application thus provide a spatial audio capture and processing whereby listening orientation or video and audio capture orientation differences can be compensated for.

According to a first aspect there is provided an apparatus comprising: an input configured to receive from at least two microphones at least two audio signals; at least two processor instances configured to generate separate output audio signal tracks from the at least two audio signals from the at least two microphones; a file processor configured to link the at least two output audio signal tracks within a file structure.

The at least one of the at least two processor instances may comprise: a surround sound processor instance configured to output a multichannel output audio signal track; a stereo sound processor instance configured to output a stereo output audio signal track; a mono sound processor instance configured to output a mono output audio signal track; and an audio object processor instance configured to output an audio object output audio track.

The apparatus may further comprise at least one mixer configured to receive at least two output audio signal tracks and generate at least one combined output audio signal track, wherein the file processor is configured to link the least one combined output audio signal track with at least one other track.

The apparatus may further comprise at least one encoder configured to receive at least one output audio signal track and generate at least one encoded output audio signal track, wherein the file processor is further configured to link the least one encoded output audio signal track with at least one other track.

The apparatus may further comprise a pre-processor configured to receive the at least two audio signals, and generate at least two audio signals to be passed to the at least one processor instance.

The pre-processor may comprise at least one of: an equaliser configured to equalise each of the at least two audio signals from the at least two microphones, so to compensate for any manufacturing differences in the at least two microphones; a wind noise reducer configured to reduce the wind noise of the at least two audio signals from the at least two microphones; a handling noise reducer configured to

reduce the handling noise of the at least two audio signals from the at least two microphones; dynamic range compressor configured to dynamically range compress the at least two audio signals from the at least two microphones; sample rate converter configured to convert the sampling rate of the at least two audio signals from the at least two microphones; a word length resolution modifier configured to change the word length resolution of the at least two audio signals from the at least two microphones; and a blockage processor configured to determine and compensate for a fault or blockage in at least one of the at least two microphones.

At least one of the at least two processor instances configured to generate separate output audio signal tracks from the at least two audio signals from the at least two microphones may comprise at least one of: a upmixer configured to generate an audio signal track with more channels than the number of input audio signals; a downmixer configured to generate an audio signal track with fewer channels than the number of input audio signals; a signal source analyser configured to determine the orientation of at least one signal source relative to the apparatus from the at least two audio signals from the at least two microphones; a signal source processor configured to modify the orientation of at least one signal source relative to the apparatus; a spatial processor configured to generate a spatial processing of the at least two audio signals from the at least two microphones; and a mapper configured to map the at least two audio signals from the at least two microphones to a output multichannel audio signal track.

The spatial processor may comprise at least one of: an audio focuser configured to generate a spatially focussed audio signal from the at least two audio signals from the at least two microphones; an audio zoomer configured to generate a spatially expanded audio signal from the at least two audio signals from the at least two microphones; a directional defined audio amplifier configured to amplify within a defined directional range the at least two audio signals from the at least two microphones; a directional defined audio attenuator configured to attenuate within a defined directional range the at least two audio signals from the at least two microphones; an audio de-emphasiser configured to apply a reverberation within a defined directional range the at least two audio signals from the at least two

microphones; an audio source displacer configured to modify a relative orientation of an audio source by a defined displacement angle; and a directionally defined audio filter configured to spatially filter within a defined directional range the at least two audio signals from the at least two microphones.

The apparatus may further comprising a camera configured to generate a video format signal, wherein the file processor configured to link the at least two output audio signal tracks within a file structure may be configured to generate a data structure linking the at least two output audio signal tracks with the video format signal.

The file processor may be configured to generate a mp4 format file structure comprising the at least two audio signal tracks as separate tracks linked in a mp4 format file structure description.

The apparatus may further comprise at least two microphones configured to generate the at least two audio signals.

The apparatus may further comprise a user interface input configured to configure at least one of the at least two processor instances.

The user interface input may comprise at least one of: a radio-button selection configured to select one processor instance template from a plurality of processor instance templates to be applied to at least one of the two processor instances; a selection-box selection configured to select one or more processor instance templates from a plurality of processor instance templates to be applied to the two processor instances; a track selection-box selection configured to select one or more processor instance templates from a plurality of processor instance templates for each of one or more processor instances; a channel selection configured to select the number of channels output by at least one of the two processor instances; an audio region selection configured to determine a spatial region within which at least one of the two processor instances applies spatial processing; a surround channel selection configured to select a surround sound instance template to be applied to at

least one of the two processor instances; a surround channel option selection configured to select one surround sound processor instance template from a plurality of surround sound processor instance templates to be applied to at least one of the two processor instances; an object track selection configured to select an object instance template to be applied to at least one of the two processor instances; and an object number selection configured to select an object instance template comprising a filter configured to select a number of objects to be applied to at least one of the two processor instances.

According to a second aspect there is provided an apparatus comprising at least one processor and at least one memory including computer code for one or more programs, the at least one memory and the computer code configured to with the at least one processor cause the apparatus to at least: receive from at least two microphones at least two audio signals; generate separate output audio signal tracks from the at least two audio signals from the at least two microphones; and link the at least two output audio signal tracks within a file structure.

Generating separate output audio signal tracks from the at least two audio signals from the at least two microphones may cause the apparatus to perform one of: output a multichannel output audio signal track; output a stereo output audio signal track; output a mono output audio signal track; and output an audio object output audio track.

The apparatus may be further caused to receive at least two output audio signal tracks and generate at least one combined output audio signal track.

The apparatus may be further caused to receive at least one output audio signal track and generate at least one encoded output audio signal track.

The apparatus may be further caused to receive the at least two audio signals, and process the at least two audio signals to be passed to the at least one processor instance.

The processing of the at least two audio signals may cause the apparatus to perform at least one of: equalise each of the at least two audio signals from the at least two microphones, so to compensate for any manufacturing differences in the at least two microphones; reduce the wind noise of the at least two audio signals from the at least two microphones; reduce the handling noise of the at least two audio signals from the at least two microphones; dynamically range compress the at least two audio signals from the at least two microphones; convert the sampling rate of the at least two audio signals from the at least two microphones; change the word length resolution of the at least two audio signals from the at least two microphones; and determine and compensate for a fault or blockage in at least one of the at least two microphones.

Generating separate output audio signal tracks from the at least two audio signals from the at least two microphones may cause the apparatus to perform at least one of: generate an audio signal track with more channels than the number of input audio signals; generate an audio signal track with fewer channels than the number of input audio signals; determine the orientation of at least one signal source relative to the apparatus from the at least two audio signals from the at least two microphones; modify the orientation of at least one signal source relative to the apparatus; generate a spatial processing of the at least two audio signals from the at least two microphones; and map the at least two audio signals from the at least two microphones to a output multichannel audio signal track.

Generating a spatial processing of the at least two audio signals from the at least two microphones may cause the apparatus to perform at least one of: generate a spatially focussed audio signal from the at least two audio signals from the at least two microphones; generate a spatially expanded audio signal from the at least two audio signals from the at least two microphones; amplify within a defined directional range the at least two audio signals from the at least two microphones; attenuate within a defined directional range the at least two audio signals from the at least two microphones; apply a reverberation within a defined directional range the at least two audio signals from the at least two microphones; modify a relative orientation of an audio source by a defined displacement angle; and spatially filter within a defined directional range the at least two audio signals from the at least two microphones.

The apparatus may be further caused to generate a video format signal, wherein linking the at least two output audio signal tracks within a file structure causes the apparatus to generate a data structure linking the at least two output audio signal tracks with the video format signal.

Linking the at least two output audio signal tracks within a file structure may cause the apparatus to generate a mp4 format file structure comprising the at least two audio signal tracks as separate tracks linked in a mp4 format file structure description.

The apparatus may comprise at least two microphones configured to generate the at least two audio signals.

The apparatus may further be caused to configure at least one of the at least two processor instances based on a user interface input.

Configuring at least one of the at least two processor instances based on a user interface input may cause the apparatus to perform at least one of: select one processor instance template from a plurality of processor instance templates to be applied to at least one of the two processor instances; select one or more processor instance templates from a plurality of processor instance templates to be applied to the two processor instances; select one or more processor instance templates from a plurality of processor instance templates for each of one or more processor instances; select the number of channels output by at least one of the two processor instances; determine a spatial region within which at least one of the two processor instances applies spatial processing; select a surround sound instance template to be applied to at least one of the two processor instances; select one surround sound processor instance template from a plurality of surround sound processor instance templates to be applied to at least one of the two processor instances; select an object instance template to be applied to at least one of the two processor instances; and select an object instance template comprising a filter configured to select a number of objects to be applied to at least one of the two processor instances.

According to a third aspect there is provided an apparatus comprising: means for receiving from at least two microphones at least two audio signals; means for generating separate output audio signal tracks from the at least two audio signals from the at least two microphones; and means for linking the at least two output audio signal tracks within a file structure.

The means for generating separate output audio signal tracks from the at least two audio signals from the at least two microphones may comprise at least one of: means for outputting a multichannel output audio signal track; means for outputting a stereo output audio signal track; means for outputting a mono output audio signal track; and means for outputting an audio object output audio track.

The apparatus may further comprise means for combining at least two output audio signal tracks to generate at least one combined output audio signal track.

The apparatus may further comprise means for encoding at least one output audio signal track to generate at least one encoded output audio signal track.

The apparatus may further comprise means for processing the at least two audio signals to be passed to the at least one processor instance.

The means for processing the at least two audio signals may comprise at least one of: means for equalising each of the at least two audio signals from the at least two microphones, so to compensate for any manufacturing differences in the at least two microphones; means for reducing the wind noise of the at least two audio signals from the at least two microphones; means for reducing the handling noise of the at least two audio signals from the at least two microphones; means for dynamically range compressing the at least two audio signals from the at least two microphones; means for converting the sampling rate of the at least two audio signals from the at least two microphones; means for changing the word length resolution of the at least two audio signals from the at least two microphones; and means for determining and compensating for a fault or blockage in at least one of the at least two microphones.

The means for generating separate output audio signal tracks from the at least two audio signals from the at least two microphones may comprise at least one of: means for generating an audio signal track with more channels than the number of input audio signals; means for generating an audio signal track with fewer channels than the number of input audio signals; means for determining the orientation of at least one signal source relative to the apparatus from the at least two audio signals from the at least two microphones; means for modifying the orientation of at least one signal source relative to the apparatus; means for generating a spatial processing of the at least two audio signals from the at least two microphones; and means for mapping the at least two audio signals from the at least two microphones to a output multichannel audio signal track.

The means for generating a spatial processing of the at least two audio signals from the at least two microphones may comprise at least one of: means for generating a spatially focussed audio signal from the at least two audio signals from the at least two microphones; means for generating a spatially expanded audio signal from the at least two audio signals from the at least two microphones; means for amplifying within a defined directional range the at least two audio signals from the at least two microphones; means for attenuating within a defined directional range the at least two audio signals from the at least two microphones; means for applying a reverberation within a defined directional range the at least two audio signals from the at least two microphones; and means for modifying a relative orientation of an audio source by a defined displacement angle; and spatially filter within a defined directional range the at least two audio signals from the at least two microphones.

The apparatus may further comprise means for generating a video format signal, wherein the means for linking the at least two output audio signal tracks within a file structure comprises means for generating a data structure linking the at least two output audio signal tracks with the video format signal.

The means for linking the at least two output audio signal tracks within a file structure may comprise means for generating a mp4 format file structure comprising the at

least two audio signal tracks as separate tracks linked in a mp4 format file structure description.

The apparatus may comprise at least two microphones configured to generate the at least two audio signals.

The apparatus may further comprise means for configuring at least one of the at least two processor instances based on a user interface input.

The means for configuring at least one of the at least two processor instances based on a user interface input may comprise at least one of: means for selecting one processor instance template from a plurality of processor instance templates to be applied to at least one of the two processor instances; means for selecting one or more processor instance templates from a plurality of processor instance templates to be applied to the two processor instances; means for selecting one or more processor instance templates from a plurality of processor instance templates for each of one or more processor instances; means for selecting the number of channels output by at least one of the two processor instances; means for determining a spatial region within which at least one of the two processor instances applies spatial processing; means for selecting a surround sound instance template to be applied to at least one of the two processor instances; means for selecting one surround sound processor instance template from a plurality of surround sound processor instance templates to be applied to at least one of the two processor instances; means for selecting an object instance template to be applied to at least one of the two processor instances; and means for selecting an object instance template comprising a filter configured to select a number of objects to be applied to at least one of the two processor instances.

According to a fourth aspect there is provided a method comprising: receiving from at least two microphones at least two audio signals; generating separate output audio signal tracks from the at least two audio signals from the at least two microphones; and linking the at least two output audio signal tracks within a file structure.

Generating separate output audio signal tracks from the at least two audio signals from the at least two microphones may comprise at least one of: outputting a multichannel output audio signal track; outputting a stereo output audio signal track; means for outputting a mono output audio signal track; and outputting an audio object output audio track.

The method may further comprise combining at least two output audio signal tracks to generate at least one combined output audio signal track.

The method may further comprise encoding at least one output audio signal track to generate at least one encoded output audio signal track.

The method may further comprise processing the at least two audio signals to be passed to the at least one processor instance.

Processing the at least two audio signals may comprise at least one of: equalising each of the at least two audio signals from the at least two microphones, so to compensate for any manufacturing differences in the at least two microphones; reducing the wind noise of the at least two audio signals from the at least two microphones; reducing the handling noise of the at least two audio signals from the at least two microphones; dynamically range compressing the at least two audio signals from the at least two microphones; converting the sampling rate of the at least two audio signals from the at least two microphones; changing the word length resolution of the at least two audio signals from the at least two microphones; and determining and compensating for a fault or blockage in at least one of the at least two microphones.

Generating separate output audio signal tracks from the at least two audio signals from the at least two microphones may comprise at least one of: generating an audio signal track with more channels than the number of input audio signals; generating an audio signal track with fewer channels than the number of input audio signals; determining the orientation of at least one signal source relative to the apparatus from the at least two audio signals from the at least two microphones; modifying the

orientation of at least one signal source relative to the apparatus; generating a spatial processing of the at least two audio signals from the at least two microphones; and mapping the at least two audio signals from the at least two microphones to a output multichannel audio signal track.

Generating a spatial processing of the at least two audio signals from the at least two microphones may comprise at least one of: generating a spatially focussed audio signal from the at least two audio signals from the at least two microphones; generating a spatially expanded audio signal from the at least two audio signals from the at least two microphones; amplifying within a defined directional range the at least two audio signals from the at least two microphones; attenuating within a defined directional range the at least two audio signals from the at least two microphones; applying a reverberation within a defined directional range the at least two audio signals from the at least two microphones; and modifying a relative orientation of an audio source by a defined displacement angle; and spatially filter within a defined directional range the at least two audio signals from the at least two microphones.

The method may further comprise generating a video format signal, wherein linking the at least two output audio signal tracks within a file structure comprises generating a data structure linking the at least two output audio signal tracks with the video format signal.

Linking the at least two output audio signal tracks within a file structure may comprise generating a mp4 format file structure comprising the at least two audio signal tracks as separate tracks linked in a mp4 format file structure description.

The method may further comprise configuring at least one of the at least two processor instances based on a user interface input.

Configuring at least one of the at least two processor instances based on a user interface input may comprise at least one of: selecting one processor instance template from a plurality of processor instance templates to be applied to at least one

of the two processor instances; selecting one or more processor instance templates from a plurality of processor instance templates to be applied to the two processor instances; selecting one or more processor instance templates from a plurality of processor instance templates for each of one or more processor instances; selecting the number of channels output by at least one of the two processor instance s; determining a spatial region within which at least one of the two processor instances applies spatial processing; selecting a surround sound instance template to be applied to at least one of the two processor instances; selecting one surround sound processor instance template from a plurality of surround sound processor instance templates to be applied to at least one of the two processor instances; selecting an object instance template to be applied to at least one of the two processor instances; and selecting an object instance template comprising a filter configured to select a number of objects to be applied to at least one of the two processor instances.

A computer program product stored on a medium may cause an apparatus to perform the method as described herein.

An electronic device may comprise apparatus as described herein.

A chipset may comprise apparatus as described herein.

Embodiments of the present application aim to address problems associated with the state of the art.

Summary of the Figures

For better understanding of the present application, reference will now be made by way of example to the accompanying drawings in which:

Figure 1 shows schematically an apparatus suitable for being employed in some embodiments;

Figure 2 shows schematically an example spatial audio signal processing apparatus according to some embodiments;

Figure 3 shows schematically a flow diagram of the operation of the spatial audio signal processing apparatus shown in Figure 2 according to some embodiments;

Figure 4 shows schematically an example surround/stereo/object processor instance apparatus according to some embodiments;

Figure 5 shows schematically a flow diagram of the operation of the surround/stereo/object processor instance apparatus shown in Figure 4 according to some embodiments;

Figure 6 shows schematically a first configuration of the example spatial audio signal processing apparatus according to some embodiments;

Figure 7 shows schematically a second configuration of the example spatial audio signal processing apparatus according to some embodiments;

Figure 8 shows schematically a third configuration of the example spatial audio signal processing apparatus according to some embodiments;

Figure 9 shows schematically a fourth configuration of the example spatial audio signal processing apparatus according to some embodiments;

Figure 10 shows schematically a fifth configuration of the example spatial audio signal processing apparatus according to some embodiments;

Figure 11 shows schematically a first user interface display configuration for controlling the example spatial audio signal processing apparatus according to some embodiments;

Figure 12 shows schematically a second user interface display configuration for controlling the example spatial audio signal processing apparatus according to some embodiments;

Figure 13 shows schematically a third user interface display configuration for controlling the example spatial audio signal processing apparatus according to some embodiments;

Figure 14 shows schematically a fourth user interface display configuration for controlling the example spatial audio signal processing apparatus according to some embodiments;

Figure 15 shows schematically a fifth user interface display configuration for controlling the example spatial audio signal processing apparatus according to some embodiments;

Figure 16 shows schematically a first example spatial audio signal processing beamform pattern according to some embodiments;

Figure 17 shows schematically a second example spatial audio signal processing beamform pattern according to some embodiments;

Figure 18 shows schematically a third example spatial audio signal processing beamform pattern according to some embodiments;

Figure 19 shows schematically a fourth example spatial audio signal processing beamform pattern according to some embodiments;

Figure 20 shows schematically a fifth example spatial audio signal processing beamform pattern according to some embodiments;

Figure 21 shows schematically a sixth example spatial audio signal processing beamform pattern according to some embodiments;

Figure 22 shows schematically a seventh example spatial audio signal processing beamform pattern according to some embodiments; and

Figure 23 shows schematically an eighth example spatial audio signal processing beamform pattern according to some embodiments.

Embodiments

The following describes in further detail suitable apparatus and possible mechanisms for the provision of effective orientation or directional processing of audio recording for example within audio-video capture apparatus. In the following examples audio signals and processing is described. However it would be appreciated that in some embodiments the audio signal/audio capture and processing is a part of an audio-video system.

As described herein mobile devices or apparatus are more commonly being equipped with multiple microphone configurations or microphone arrays suitable for recording or capturing the audio environment or audio scene surrounding the mobile device or apparatus. This microphone configuration thus enables the possible

recording of stereo or surround sound signals. Furthermore the known location and orientation of the microphones further enables the apparatus to process the captured or recorded audio signals from the microphones to perform spatial processing to emphasise or focus on the audio signals from a defined direction relative to other directions.

However in performing real time processing of the audio signal there are problems in the current implementations of audio processing. For example typically the audio signal recorded by the apparatus is defined with respect to a fixed forward beam or no beam at all.

Where there is no beam at all, everything around the apparatus is recorded and the user is unable to restrict what is being recorded. However this can result in the most dominant audio sources swamping other audio sources, and sometimes the most dominant audio source is not the most interesting for the user to record. For example a museum exhibit may be being shown next to a louder exhibit and the louder exhibit prevents the quieter exhibit being recorded.

Where the beam is fixed forward then only the audio sources approximately in line with the apparatus are recorded, which can be problematic where user wishes to redirect the audio at a later date (for example in any post processing operation). Furthermore fixed beam processing has limitations in that everything from that direction such as the front is recorded and then the user is unable to restrict or choose what is recorded. Also in some cases what happens directly in the front is not always the most interesting audio. For example the museum exhibit itself may not be the interesting audio source but rather a guide standing to one side of the exhibit or moving around the exhibit. A fixed or fixed forward processing would prevent the recording of the video of the exhibit and the recording of the audio of the guide explaining the exhibit.

The concept of embodiments is therefore to flexibly capture or record multiple audio tracks with different channel configurations. For example the channel configurations can be mono/stereo/surround sound/object processed audio signals and can have

various settings. For example one part of the concept covers forming multiple instances (or elements) of processed audio signals (for example beams) for surround sound in real time recording or embedding these within a video.

In the embodiments as described herein an apparatus or device comprising two or more microphones can generate these processing elements or instances and encode the output of the processing elements or instances separately.

Furthermore as described hereafter in some embodiments complex processing instances can in some embodiments be generated by combining the output of the processing elements or instances and encoding the combination output.

In some embodiments the elements or instances can be multichannel (or surround sound) processed outputs, or can be stereo processed outputs or mono processed outputs or audio object processed outputs.

In this regard reference is first made to Figure 1 which shows a schematic block diagram of an exemplary apparatus or electronic device 10, which may be used to record (or operate as a capture apparatus).

The electronic device 10 may for example be a mobile terminal or user equipment of a wireless communication system when functioning as the recording apparatus or listening apparatus. In some embodiments the apparatus can be an audio player or audio recorder, such as an MP3 player, a media recorder/player (also known as an MP4 player), or any suitable portable apparatus suitable for recording audio or audio/video camcorder/memory audio or video recorder.

The apparatus 10 can in some embodiments comprise an audio-video subsystem. The audio-video subsystem for example can comprise in some embodiments a microphone or array of microphones 11 for audio signal capture. In some embodiments the microphone or array of microphones can be a solid state microphone, in other words capable of capturing audio signals and outputting a suitable digital format signal. In some other embodiments the microphone or array of

microphones 11 can comprise any suitable microphone or audio capture means, for example a condenser microphone, capacitor microphone, electrostatic microphone, Electret condenser microphone, dynamic microphone, ribbon microphone, carbon microphone, piezoelectric microphone, or micro electrical-mechanical system (MEMS) microphone. In some embodiments the microphone 11 is a digital microphone array, in other words configured to generate a digital signal output (and thus not requiring an analogue-to-digital converter). The microphone 11 or array of microphones can in some embodiments output the audio captured signal to an analogue-to-digital converter (ADC) 14.

In some embodiments the apparatus can further comprise an analogue-to-digital converter (ADC) 14 configured to receive the analogue captured audio signal from the microphones and outputting the audio captured signal in a suitable digital form. The analogue-to-digital converter 14 can be any suitable analogue-to-digital conversion or processing means. In some embodiments the microphones are 'integrated' microphones containing both audio signal generating and analogue-to-digital conversion capability.

In some embodiments the apparatus 10 audio-video subsystem further comprises a digital-to-analogue converter 32 for converting digital audio signals from a processor 21 to a suitable analogue format. The digital-to-analogue converter (DAC) or signal processing means 32 can in some embodiments be any suitable DAC technology.

Furthermore the audio-video subsystem can comprise in some embodiments a speaker 33. The speaker 33 can in some embodiments receive the output from the digital-to-analogue converter 32 and present the analogue audio signal to the user. In some embodiments the speaker 33 can be representative of multi-speaker arrangement, a headset, for example a set of headphones, or cordless headphones.

In some embodiments the apparatus audio-video subsystem comprises a camera 51 or image capturing means configured to supply to the processor 21 image data. In some embodiments the camera can be configured to supply multiple images over time to provide a video stream.

In some embodiments the apparatus audio-video subsystem comprises a display 52. The display or image display means can be configured to output visual images which can be viewed by the user of the apparatus. In some embodiments the display can be a touch screen display suitable for supplying input data to the apparatus. the display can be any suitable display technology, for example the display can be implemented by a flat panel comprising cells of LCD, LED, OLED, or 'plasma' display implementations.

Although the apparatus 10 is shown having both audio/video capture and audio/video presentation components, it would be understood that in some embodiments the apparatus 10 can comprise one or the other of the audio capture and audio presentation parts of the audio subsystem such that in some embodiments of the apparatus the microphone (for audio capture) or the speaker (for audio presentation) are present. Similarly in some embodiments the apparatus 10 can comprise one or the other of the video capture and video presentation parts of the video subsystem such that in some embodiments the camera 51 (for video capture) or the display 52 (for video presentation) is present.

In some embodiments the apparatus 10 comprises a processor 21. The processor 21 is coupled to the audio-video subsystem and specifically in some examples the analogue-to-digital converter 14 for receiving digital signals representing audio signals from the microphone 11, the digital-to-analogue converter (DAC) 12 configured to output processed digital audio signals, the camera 51 for receiving digital signals representing video signals, and the display 52 configured to output processed digital video signals from the processor 21.

The processor 21 can be configured to execute various program codes. The implemented program codes can comprise for example audio-video recording and audio-video presentation routines. In some embodiments the program codes can be configured to perform audio signal modelling or spatial audio signal processing.

In some embodiments the apparatus further comprises a memory 22. In some embodiments the processor is coupled to memory 22. The memory can be any suitable storage means. In some embodiments the memory 22 comprises a program code section 23 for storing program codes implementable upon the processor 21. Furthermore in some embodiments the memory 22 can further comprise a stored data section 24 for storing data, for example data that has been encoded in accordance with the application or data to be encoded via the application embodiments as described later. The implemented program code stored within the program code section 23, and the data stored within the stored data section 24 can be retrieved by the processor 21 whenever needed via the memory-processor coupling.

In some further embodiments the apparatus 10 can comprise a user interface 15. The user interface 15 can be coupled in some embodiments to the processor 21. In some embodiments the processor can control the operation of the user interface and receive inputs from the user interface 15. In some embodiments the user interface 15 can enable a user to input commands to the electronic device or apparatus 10, for example via a keypad, and/or to obtain information from the apparatus 10, for example via a display which is part of the user interface 15. The user interface 15 can in some embodiments as described herein comprise a touch screen or touch interface capable of both enabling information to be entered to the apparatus 10 and further displaying information to the user of the apparatus 10.

In some embodiments the apparatus further comprises a transceiver 13, the transceiver in such embodiments can be coupled to the processor and configured to enable a communication with other apparatus or electronic devices, for example via a wireless communications network. The transceiver 13 or any suitable transceiver or transmitter and/or receiver means can in some embodiments be configured to communicate with other electronic devices or apparatus via a wire or wired coupling.

The transceiver 13 can communicate with further apparatus by any suitable known communications protocol, for example in some embodiments the transceiver 13 or transceiver means can use a suitable universal mobile telecommunications system

(UMTS) protocol, a wireless local area network (WLAN) protocol such as for example IEEE 802.X, a suitable short-range radio frequency communication protocol such as Bluetooth, or infrared data communication pathway (IRDA).

In some embodiments the apparatus comprises a position sensor 16 configured to estimate the position of the apparatus 10. The position sensor 16 can in some embodiments be a satellite positioning sensor such as a GPS (Global Positioning System), GLONASS or Galileo receiver.

In some embodiments the positioning sensor can be a cellular ID system or an assisted GPS system.

In some embodiments the apparatus 10 further comprises a direction or orientation sensor. The orientation/direction sensor can in some embodiments be an electronic compass, accelerometer, and a gyroscope or be determined by the motion of the apparatus using the positioning estimate.

It is to be understood again that the structure of the electronic device 10 could be supplemented and varied in many ways.

With respect to Figure 2, an example spatial audio signal processing apparatus according to some embodiments is shown. Furthermore with respect to Figure 3 a flow diagram of the operation of the spatial audio signal processing apparatus as shown in Figure 2 is shown.

In some embodiments the apparatus comprises the microphone or array of microphones 11 which are configured to capture or record the acoustic waves and generate an audio signal for each microphone which is passed to the spatial audio signal processing apparatus. As described herein in some embodiments the microphones 11 are configured to output an analogue signal which is converted into a digital format by the analogue to digital converter (ADC) 14. However in some embodiments the microphones are integrated microphones configured to output a digital format signal. Furthermore in some embodiments the microphone array is

physically separate from the apparatus, for example the microphone array can be located on a headset (where the headset also has an associated video camera capturing the video images which can also be passed to the apparatus and processed in a manner to generate an encoded video signal which can incorporate the processed audio signals as described herein) which wirelessly or otherwise passes the audio signals to the apparatus for processing.

The operation of receiving the audio signals from the microphone array is shown in Figure 3 by step 201.

In some embodiments the spatial audio signal processing apparatus comprises a pre-processor 101. The pre-processor is configured to receive the audio signals from the microphones and process these to generate audio signals to be used in the processing instances. For example in some embodiments the pre-processor can be configured to equalise the audio signals. However any suitable processing of the audio signals to enable them to be compared can be performed such as microphone damage or blockage processing. Examples of pre-processing that can in some embodiments be applied are: a wind noise reducer configured to reduce the wind noise of the audio signals from the microphones; a handling noise reducer configured to reduce the handling noise of the audio signals from the microphones; a dynamic range compressor configured to dynamically range compress the audio signals from the microphones; a sample rate converter configured to convert the sampling rate of the audio signals from the microphones; and a word length resolution modifier configured to change the word length resolution of the audio signals from the microphones.

The operation of pre-processing the microphone array audio signals (for example equalisation) is shown in Figure 3 by step 203.

In some embodiments the pre-processed audio signals from each of the microphones are then passed to an instance processor 103.

In some embodiments the spatial audio signal processing apparatus comprises an instance processor 103. The instance processor 103 comprises at least one processing instance, for example at least one instance of surround sound processing, stereo processing, mono processing or object processing.

The instance processor 103 is configured to utilise the multiple microphone input and from the audio signals from the multiple microphone input analyse the directions of separate audio or sound sources. Furthermore the instance processor 103 can then be configured to process these audio or sound sources, for example to map or synthesise the sounds according to their direction of arrival information into a target multichannel audio reproduction configuration.

For example in some embodiments the target multichannel audio reproduction configuration can be a surround sound 5.1 speaker system. In some embodiments the surround sound or multichannel audio reproduction configuration can be any suitable channel number or arrangement configuration.

Furthermore as described herein the instance processor 103 can be configured to output a mono, stereo, or object-based parameter processed output.

For example in some embodiments as described herein the mapping is performed by applying a suitable head related transfer function (HRTF) to the identified audio or sound source.

In some embodiments a minimum number of microphones are required to perform proper direction recognition. For example in some embodiments a minimum of three microphones in a triangle configuration towards the recording direction are required to get an accurate estimation of the direction.

In some embodiments audio sounds or signals which have no clear direction can be mapped to an ambience location, for example mapped to any set or combination of front, subwoofer and surround channels. In some embodiments the mapping is to the

surround channels but also a mapping to all channels can be implemented in some embodiments.

In some embodiments the instance processor 103 can be configured to further perform surround processing or general processing with respect to a desired direction or section or range of directions. In other words the instance processor 103 can be configured to receive a user input indicating a desired direction or range of directions and then process the audio signals from the microphones to provide a processed audio signal having an audio focus or zoom in the desired direction or range of directions. The audio focus or zoom processing in some embodiments can be amplification (for example of signals from the desired direction), attenuation (for example of signals from directions other than the desired direction), audio zooming, deemphasising, audio source moving, or filtering. For example in some embodiments the instance processor is configured to generate a focussed audio signal by amplifying audio signals from within a defined direction or region, and attenuating audio signals from outside the defined direction or region. This approach is also known as beamforming. The amplification and attenuation of the audio signals in some embodiments can be defined as a directionally defined audio filter (or spatial audio filter) configured to spatially filter within a defined directional range the audio signals. In some embodiments the spatial filter can be configured to be frequency as well as spatially specific, in other words be configured to filter in both spatial and frequency domains.

In some embodiments the instance processor can be configured to generate a direction or region defined audio signal amplification configured to amplify within a defined directional range the audio signals for example from the at least two microphones. In other words to amplify audio signals from a defined direction or region but not affect the other audio sources/signals outside of the defined direction or region.

In some embodiments the instance processor can be configured to generate a direction or region defined audio signal attenuation configured to attenuate within a defined directional range the audio signals, for example from the at least two

microphones. In other words to attenuate or nullify audio signals from a defined direction or region but not affect the other audio sources/signals outside of the defined direction or region.

In some embodiments the instance processor is configured to generate a focussed audio signal by generating a spatially expanded audio signal from the at least two audio signals from the at least two microphones, in other words audio sources from within a defined region can be artificially separated from each other and audio sources outside of the defined region are artificially moved closer together. This approach can produce the effect of producing noticeable audio separation between close audio sources within the defined region while 'merging' the audio sources outside of the defined region.

In some embodiments the instance processor can be configured to operate as an 'audio de-emphasiser' configured to apply a reverberation within a defined directional range to any audio source or signals within the region or direction. The reverberation can be experienced by the listener as the sound source or audio signals becoming 'background' or muffled.

In some embodiments the instance processor can be configured to displace or move any determined audio sources. For example in some embodiments the instance processor can be configured to modify a relative orientation of an audio source by a defined displacement angle.

In some embodiments the instance processor 103 may be configured to generate multiple instances, where each instance is configured to perform different processing.

Although in the following examples each instance is shown with a separate analysis, processing and mapping stage it would be understood that in some embodiments different instances can utilise common elements. For example in some embodiments a common analysis part can be utilised by several parallel synthesis parts that produce the different processing outputs. Thus where there are two processing instances being generated by the instance processor 103, a first instance producing a first directional amplified output and a second instance providing an wider

ambiance output, both of the instances could use the initial audio scene analysis which identifies or determines audio or sound sources rather than performing redundant analysis in each instance.

In some embodiments the actual audio source or sound source analysis can be a sub-bands analysis or determination.

The operation of generating instances of surround sound/stereo/mono/object instances is shown in Figure 3 by step 205.

In some embodiments the output of the instance processor 103 is passed to an instance mixer 105.

In some embodiments the apparatus comprises an instance mixer 105 configured to receive at least a pair of instance processor 103 instance outputs and mix the instance outputs to generate a complex processed output.

The operation of mixing instances to generate complex instances is shown in Figure 3 by step 206.

The instance mixer 105 can output the combined instance output to the encoder 107. Furthermore in some embodiments the instance processor 103 can be configured to output the processed instances to the encoder directly where no mixing is required.

In some embodiments the apparatus comprises an encoder 107. The encoder 107 can receive the output processed or mixed audio signals from the mixer 105, and the instance processor 103 and generate at least a single instance of encoder instance in order to encode the output audio signal. The encoder 107 can thus generate at least multiple encoding influences and perform the encoding in real time. The encoder 107 can be configured to output the encoding to a file multiplexer 109.

The operation of encoding the instance is shown in Figure 3 by step 207.

In some embodiments the apparatus comprises a file multiplexer 109. The file multiplexer 109 is configured to receive the encoded audio signal from the encoder and multiplex these tracks or instances into a single file. For example in some embodiments the file can be a mp4 file containing video that has been recorded on the apparatus at the same time.

The operation of storing the encoded instances is shown in Figure 3 by step 209.

With respect to Figure 4 an example instance on the instance processor 103_1 is described in further detail. Furthermore with respect Figure 5 the operation of the instance processor 103_1 shown in Figure 4 is shown.

In some embodiments the instance processor 103 comprises an instance analyser 301. The instance analyser 301 is configured to receive the pre-processed multiple microphone inputs.

The operation of receiving the pre-processed audio signal is shown in Figure 5 by step 401.

The instance processor 103 furthermore can in some embodiments be configured to analyse the direction of the separate sound or audio sources (or objects) within the audio scene being recorded. In some embodiments the instance analyser 301 is configured to output the detected sources or objects to an instance source/object processor 303.

An example spatial analysis, determination of sources and parameterisation of the audio signal is described as follows. However it would be understood that any suitable audio signal spatial or directional analysis in either the time or other representational domain (frequency domain etc.) can be used.

In some embodiments the instance analyser 301 comprises a framer. The framer or suitable framer means can be configured to receive the audio signals from the microphones and divide the digital format signals into frames or groups of audio

sample data. In some embodiments the framer can furthermore be configured to window the data using any suitable windowing function. The framer can be configured to generate frames of audio signal data for each microphone input wherein the length of each frame and a degree of overlap of each frame can be any suitable value. For example in some embodiments each audio frame is 20 milliseconds long and has an overlap of 10 milliseconds between frames. The framer can be configured to output the frame audio data to a Time-to-Frequency Domain Transformer.

In some embodiments the instance analyser 301 comprises a Time-to-Frequency Domain Transformer. The Time-to-Frequency Domain Transformer or suitable transformer means can be configured to perform any suitable time-to-frequency domain transformation on the frame audio data. In some embodiments the Time-to-Frequency Domain Transformer can be a Discrete Fourier Transformer (DFT). However the Transformer can be any suitable Transformer such as a Discrete Cosine Transformer (DCT), a Modified Discrete Cosine Transformer (MDCT), a Fast Fourier Transformer (FFT) or a quadrature mirror filter (QMF). The Time-to-Frequency Domain Transformer can be configured to output a frequency domain signal for each microphone input to a sub-band filter.

In some embodiments the instance analyser 301 comprises a sub-band filter. The sub-band filter or suitable means can be configured to receive the frequency domain signals from the Time-to-Frequency Domain Transformer for each microphone and divide each microphone audio signal frequency domain signal into a number of sub-bands.

The sub-band division can be any suitable sub-band division. For example in some embodiments the sub-band filter can be configured to operate using psychoacoustic filtering bands. The sub-band filter can then be configured to output each domain range sub-band to a direction analyser.

In some embodiments the instance analyser 301 can comprise a direction analyser. The direction analyser or suitable means can in some embodiments be configured to

select a sub-band and the associated frequency domain signals for each microphone of the sub-band.

The direction analyser can then be configured to perform directional analysis on the signals in the sub-band. The directional analyser can be configured in some embodiments to perform a cross correlation between the microphone/decoder sub-band frequency domain signals within a suitable processing means.

In the direction analyser the delay value of the cross correlation is found which maximises the cross correlation of the frequency domain sub-band signals. This delay can in some embodiments be used to estimate the angle or represent the angle from the dominant audio signal source for the sub-band. This angle can be defined as α. It would be understood that whilst a pair or two microphones can provide a first angle, an improved directional estimate can be produced by using more than two microphones and preferably in some embodiments more than two microphones on two or more axes.

The directional analyser can then be configured to determine whether or not all of the sub-bands have been selected. Where all of the sub-bands have been selected in some embodiments then the direction analyser can be configured to output the directional analysis results. Where not all of the sub-bands have been selected then the operation can be passed back to selecting a further sub-band processing step.

The above describes a direction analyser performing an analysis using frequency domain correlation values. However it would be understood that the direction analyser can perform directional analysis using any suitable method. For example in some embodiments the object detector and separator can be configured to output specific azimuth-elevation values rather than maximum correlation delay values. Furthermore in some embodiments the spatial analysis can be performed in the time domain.

In some embodiments this direction analysis can therefore be defined as receiving the audio sub-band data;

$$X_k^b(n) = X_k(n_b + n), \qquad n = 0, \ldots, n_{b+1} - n_b - 1, \qquad b = 0, \ldots, B - 1$$

where n_b is the first index of bth subband. In some embodiments for every subband the directional analysis as described herein as follows. First the direction is estimated with two channels. The direction analyser finds delay τ_b that maximizes the correlation between the two channels for subband b. DFT domain representation of e.g. $X_k^b(n)$ can be shifted τ_b time domain samples using

$$X_{k,\tau_b}^b(n) = X_k^b(n) e^{-j\frac{2\pi n \tau_b}{N}}.$$

The optimal delay in some embodiments can be obtained from

$$\max_{\tau_b} Re\left(\sum_{n=0}^{n_{b+1}-n_b-1} (X_{2,\tau_b}^b(n)^* X_1^b(n)) \right), \tau_b \in [-D_{max}, D_{max}]$$

where *Re* indicates the real part of the result and * denotes complex conjugate. X_{2,τ_b}^b and X_1^b are considered vectors with length of $n_{b+1} - n_b$ samples. The direction analyser can in some embodiments implement a resolution of one time domain sample for the search of the delay.

In some embodiments the direction analyser can be configured to generate a sum signal. The sum signal can be mathematically defined as.

$$X_{sum}^b = \begin{cases} (X_{2,\tau_b}^b + X_1^b)/2 & \tau_b \leq 0 \\ (X_1^b + X_{1,-\tau_b}^b)/2 & \tau_b > 0 \end{cases}$$

In other words the direction analyser is configured to generate a sum signal where the content of the channel in which an event occurs *first* is added with no

modification, whereas the channel in which the event occurs later is shifted to obtain best match to the first channel.

It would be understood that the delay or shift τ_b indicates how much closer the sound source is to one microphone (or channel) than another microphone (or channel). The direction analyser can be configured to determine actual difference in distance as

$$\Delta_{23} = \frac{v\tau_b}{F_s}$$

where *Fs* is the sampling rate of the signal and *v* is the speed of the signal in air (or in water if we are making underwater recordings).

The angle of the arriving sound is determined by the direction analyser as,

$$a_b = \pm \cos^{-1}\left(\frac{\Delta_{23}{}^2 + 2b\Delta_{23} - g^2}{2db}\right)$$

where *d* is the distance between the pair of microphones/channel separation and *b* is the estimated distance between sound sources and nearest microphone. In some embodiments the direction analyser can be configured to set the value of *b* to a fixed value. For example *b* = 2 meters has been found to provide stable results.

It would be understood that the determination described herein provides two alternatives for the direction of the arriving sound as the exact direction cannot be determined with only two microphones/channels.

In some embodiments the direction analyser can be configured to use audio signals from a third channel or the third microphone to define which of the signs in the determination is correct. The distances between the third channel or microphone and the two estimated sound sources are:

$$\delta_b^+ = \sqrt{(h + b\sin(\bar{a}_b))^2 + (d/2 + b\cos(\bar{a}_b))^2}$$

$$\delta_b^- = \sqrt{(h - b\sin(\bar{a}_b))^2 + (d/2 + b\cos(\bar{a}_b))^2}$$

where h is the height of an equilateral triangle (where the channels or microphones determine a triangle), i.e.

$$h = \frac{\sqrt{3}}{2}d.$$

The distances in the above determination can be considered to be equal to delays (in samples) of;

$$\tau_b^+ = \frac{\delta^+ - b}{v}F_s$$

$$\tau_b^- = \frac{\delta^- - b}{v}F_s$$

Out of these two delays the direction analyser in some embodiments is configured to select the one which provides better correlation with the sum signal. The correlations can for example be represented as

$$c_b^+ = Re\left(\sum_{n=0}^{n_{b+1}-n_b-1}(X_{sum,\tau_b^+}^b(n) * X_1^b(n))\right)$$

$$c_b^- = Re\left(\sum_{n=0}^{n_{b+1}-n_b-1}(X_{sum,\tau_b^-}^b(n) * X_1^b(n))\right)$$

The direction analyser can then in some embodiments then determine the direction of the dominant sound source for subband b as:

$$\alpha_b = \begin{cases} a_b & c_b^L \geq c_b^R \\ -\alpha_b & c_b^L < c_b^R \end{cases}$$

In some embodiments the instance analyser 301 comprises a mid/side signal generator. The main content in the mid signal is the dominant sound source found from the directional analysis. Similarly the side signal contains the other parts or ambient audio from the generated audio signals. In some embodiments the mid/side signal generator can determine the mid M and side S signals for the sub-band according to the following equations:

$$M^b = \begin{cases} (X_1^b{}_{,\tau_b} + X_2^b)/2 & \tau_b \leq 0 \\ (X_1^b + X_2^b{}_{,-\tau_b})/2 & \tau_b > 0 \end{cases}$$

$$S^b = \begin{cases} (X_1^b{}_{,\tau_b} - X_2^b)/2 & \tau_b \leq 0 \\ (X_1^b - X_2^b{}_{,-\tau_b})/2 & \tau_b > 0 \end{cases}$$

It is noted that the mid signal M is the same signal that was already determined previously and in some embodiments the mid signal can be obtained as part of the direction analysis. The mid and side signals can be constructed in a perceptually safe manner such that the signal in which an event occurs first is not shifted in the delay alignment. The mid and side signals can be determined in such a manner in some embodiments is suitable where the microphones are relatively close to each other. Where the distance between the microphones is significant in relation to the distance to the sound source then the mid/side signal generator can be configured to perform a modified mid and side signal determination where the channel is always modified to provide a best match with the main channel.

The mid (M), side (S) and direction (α) components of the captured audio signals can be output to an instance source/object processor 303.

The analysis of the audio signal to determine audio or sound source or objects is shown in Figure 5 by step 403.

The instance processor 103 in some embodiments comprises an instance source/object processor 303. The instance source/object processor 303 is configured to receive the determined sources or object values and process these according to any desired requirement, the processing operation based on or dependent on the instance. In some embodiments the instance can be generated based on a user input.

The instance source/object processor 303 can thus be configured to emphasise or deemphasise the source or direction. In some embodiments the emphasis can be based on a zooming or focusing and in some embodiments be based on an attenuating or removing of unwanted sounds or objects or in some embodiments a focusing/defocusing by applying a reverberation filter. The instance source/object processor 303 can be configured to output the processed sources to a channel mapper 305.

For example using the above parametrization of the determined sources/objects one instance can be to pass the mid signal associated with a source which is within a defined region and to remove the mid signal (M) associated with a source which is outside of the region. In other words

$M'=M*g$

where g is defined as

$g=1$ if $\theta_1<\alpha<\theta_2$

and

$g=0$ otherwise

where $\theta_1<\alpha<\theta_2$ defines the pass band region (the defined region).

The operation of processing the source/objects is shown in Figure 5 by step 405.

In some embodiments the instance processor 103 can comprise a channel mapper 305. The channel mapper 305 is configured to receive the processed source/object and generate a output multichannel, stereo or mono output.

In some embodiments the channel mapper 305 can for example be configured to apply a suitable mapping such as a head related transfer function (HRTF) to the identified sound sources locating them within a suitable stereo headset region.

In some embodiments the channel mapper 305 can output a single output (mono), two outputs (stereo), or any configuration multichannel output (surround sound).

The operation of mapping the processed object/sources for the instance is shown in Figure 5 by step 407.

Furthermore the channel mapper 305 can be configured to output the mapped audio signal to an encoder instance or to an instance mixer.

The output of the mapped audio signal is shown in Figure 5 by step 409.

With respect to Figure 6 a first configuration of the example spatial audio signal processing apparatus according to some embodiments is shown. The apparatus receives the audio signals from the microphones, which are shown as more than two microphones.

Furthermore the apparatus comprises the pre-processor 101 which carries out the pre-processing as described herein. For example providing generic microphone related processing such as microphone equalisation. It would be understood that in some embodiments although only one pre-processing block is shown for each instance or track that in some embodiments the pre-processor 101 is itself divided into instances of pre-processor or pre-processing instances which perform pre-processing for each of the instances or tracks.

In the example shown in Figure 6 the instance processor 103 comprises N surround sound instances, a first surround sound processor instance surround processor 1 501_1, a second surround sound processor instance surround processor 2 501_2 and a N'th surround sound processor instance surround processor N 501_N.

Each surround sound processing block performs surround sound processing so that it can up mix or down mix if needed. For example from a three microphone input to a 5.1 or 7.1 or stereo output. Furthermore each of the surround sound processor instances can perform a defined instance processing simulating a possible beamforming pattern or other processing as described herein.

Each of the surround sound processor instances 501_1 to 501_N outputs the multichannel output to the encoder and in particular an encoder instance matching the surround sound processor instance. Thus the first surround sound processor instance 501_1 outputs to a first encoder instance 503_1 and the N'th surround sound processor instance outputs to the N'th encoder instance 503_N.

In other words for each surround sound processor there is a separate multichannel encoder.

The encoder instances 503_1 to 503_N then output the encoded signal to the file multiplexer 109 to be multiplexed together. In some embodiments the file multiplexer 109 can be configured to further output the different tracks to separate files which are logically linked together, for example by means of file naming.

With respect to Figure 7 a second configuration of the example spatial audio signal processing apparatus according to some embodiments is shown. The apparatus receives the audio signals from the microphones, which, similar to the configuration shown in Figure 6, comprises more than two microphones.

Furthermore, similar to the example shown in Figure 6, the apparatus comprises the pre-processor 101 which carries out the pre-processing as described herein.

In the example shown in Figure 7 the instance processor 103 comprises X surround sound instances, a first surround sound processor instance surround processor 1 501_1, a second surround sound processor instance surround processor 2 501_2 and a X'th surround sound processor instance surround processor X 501_X.

Each surround sound processing block performs surround sound processing so that it can up mix or down mix if needed and can perform a defined instance processing for example simulating a possible beamforming pattern.

In the configuration shown in Figure 7, the apparatus comprises a mixer 105 configured to receive the output of the first and second instances or tracks. The mixer 105 is configured to mix the outputs of the first and second instances or tracks to produce a combined instance output. For example in some embodiments the first instance or track defines a first beamforming pattern and the second instance or track defines a second beamforming pattern then the combined instance or track defines the combination of the two beamforming patterns. It would be understood that in some embodiments the mixer can be configured to generate a combination other than an additive or simple additive combination, such as a difference between the tracks or instances or a weighted additive combination. Furthermore although two tracks are shown being mixed or combined it would be understood that the number of tracks or instances being mixed or combined can be more than two.

The combined or mixed instance or track can as shown in Figure 7 can then output to the encoder 107, where the instance or track is encoded by an encoding instance, for example encoder instance 503_1. Furthermore the encoder 107 comprises a X'th encoder instance 503_X configured to receive the X'th surround sound processor instance 501_X. In other words for each surround sound processor output or combined output there is a separate multichannel encoder.

The encoder instances 503_1 and 503_X then output the encoded signals to the file multiplexer 109 to be multiplexed together. In some embodiments the file multiplexer 109 can be configured to further multiplex the audio tracks or instances to a video track or instance.

With respect to Figure 8 a third configuration of the example spatial audio signal processing apparatus according to some embodiments is shown. The apparatus

receives the audio signals from the microphones, which, similar to the configuration shown in Figure 6, comprises more than two microphones.

Furthermore, similar to the example shown in Figure 6, the apparatus comprises the pre-processor 101 which carries out the pre-processing as described herein.

In the example shown in Figure 8 the instance processor 103 comprises N surround sound instances, a first surround sound processor instance surround processor 1 501_1, a second surround sound processor instance surround processor 2 501_2 and a N'th surround sound processor instance surround processor N 501_N.

Each surround sound processing block performs surround sound processing so that it can up mix or down mix if needed and can perform a defined instance processing for example simulating a possible beamforming pattern.

Furthermore the instance processor 103 comprises N stereo instances, a first stereo processor instance stereo processor 1 701_1, a second stereo processor instance stereo processor 2 701_2 and a N'th stereo processor instance stereo processor N 701_N.

The stereo processor instances in some embodiments differ from the surround processor instances in that no spatial processing is performed. However in such embodiments the processing performed on the audio signals can be processing such as sample rate conversion and range compression.

Each of the surround sound processor instances 501_1 to 501_N outputs the multichannel output to the encoder and in particular an encoder instance matching the surround sound processor instance. Thus the first surround sound processor instance 501_1 outputs to a first multichannel encoder instance 503_1 and the N'th surround sound processor instance outputs to the N'th multichannel encoder instance 503_N. Similarly each of the stereo processor instances 701_1 to 701_N outputs the stereo output to the encoder and in particular an encoder instance matching the stereo processor instance. Thus the first stereo processor instance 701_1 outputs to a

first stereo encoder instance 703_1 and the N'th stereo processor instance 701_N outputs to the N'th stereo encoder instance 703_N.

The encoder instances 503_1 to 503_N and 703_1 to 703_N can then be output the encoded signal to the file multiplexer 109 to be multiplexed together. In some embodiments the file multiplexer 109 can be configured to further multiplex the audio tracks or instances to a video track or instance.

With respect to Figure 9 a fourth configuration of the example spatial audio signal processing apparatus according to some embodiments is shown. The apparatus receives the audio signals from the microphones, which, similar to the configuration shown in Figure 6, comprises more than two microphones.

Furthermore, similar to the example shown in Figure 6, the apparatus comprises the pre-processor 101 which carries out the pre-processing as described herein.

In the example shown in Figure 9 the instance processor 103 comprises a surround sound instance, surround processor 501.

The surround sound processing block as described herein is configured to perform surround sound processing so that it can up mix or down mix if needed and can perform a defined instance processing for example simulating a possible beamforming pattern.

Furthermore the instance processor 103 comprises a stereo instance, stereo processor 701. The stereo processor instances configured to perform processing such as sample rate conversion and range compression.

The instance processor 103 furthermore comprises an object instance, object processor 801. The object processor 801 is configured to find or determine the audio objects or sources and output the object or source information. For example in some embodiments the object processor 801 is configured to determine an audio source or object and output this information or a processed version of this information. For

example using the example object determiner shown in Figure 3, the object processor is configured to output only the audio signal from a single object, in other words the mapper is configured to operate on a single mid signal and angle of arrival in generating the output rather than all of the mid signals and the side signal.

Each of the outputs from the surround sound instance – surround processor 501, stereo instance - stereo processor 701, and object instance - object processor 801 are output to the encoder and in particular an encoder instance matching the instance. Thus in the example shown in Figure 9, the surround processor 501 outputs to a multichannel encoder instance 503, the stereo processor 701 outputs to stereo encoder instance 703 and the object processor 801 outputs to an audio object encoder instance 803.

The encoder instances 503, 703 and 803 then output the encoded signal to the file multiplexer 109 to be multiplexed together. In some embodiments the file multiplexer 109 can be configured to further multiplex the audio tracks or instances to a video track or instance.

With respect to Figure 10 a fifth configuration of the example spatial audio signal processing apparatus according to some embodiments is shown. The apparatus receives the audio signals from the microphones, which comprises two microphones.

The apparatus further comprises the pre-processor 101 which carries out the pre-processing as described herein.

In the example shown in Figure 10 the instance processor 103 comprises N surround sound instances, a first surround sound processor instance surround processor 1 501_1, a second surround sound processor instance surround processor 2 501_2 and a N'th surround sound processor instance surround processor N 501_N.

Each surround sound processing block performs surround sound processing so that the processing block can up mix or down mix if needed however the lack of information from the limited number of microphones permits virtual surround

processing but does not enable the source location, spatial processing, and beamforming pattern simulation operations as no audio sources or objects can be determined sufficiently accurately. Furthermore similar to the stereo processor instances processing such as sample rate conversion, range compression or other processing, such as stereo widening, can be performed in the surround processors.

Furthermore the instance processor 103 comprises N stereo instances, a first stereo processor instance stereo processor 1 701_1, a second stereo processor instance stereo processor 2 701_2 and a N'th stereo processor instance stereo processor N 701_N.

The stereo processor instances furthermore do not perform spatial processing. However in such embodiments the processing performed on the audio signals can be processing such as sample rate conversion and range compression.

Each of the surround sound processor instances 501_1 to 501_N outputs the multichannel output to the encoder and in particular an encoder instance matching the surround sound processor instance. Thus the first surround sound processor instance 501_1 outputs to a first multichannel encoder instance 503_1 and the N'th surround sound processor instance outputs to the N'th multichannel encoder instance 503_N. Similarly each of the stereo processor instances 701_1 to 701_N outputs the stereo output to the encoder and in particular an encoder instance matching the stereo processor instance. Thus the first stereo processor instance 701_1 outputs to a first stereo encoder instance 703_1 and the N'th stereo processor instance 701_N outputs to the N'th stereo encoder instance 703_N.

The encoder instances 503_1 to 503_N and 703_1 to 703_N can then be output the encoded signal to the file multiplexer 109 to be multiplexed together. In some embodiments the file multiplexer 109 can be configured to further multiplex the audio tracks or instances to a video track or instance.

With respect to Figures 16 to 23 a series of example beamform patterns which can be generated by surround sound processor instances are shown. It would be

understood that the Figures shown herein are examples of possible beamform patterns only and the width of the teardrop patterns (in other words the directionality of the beams) implemented in embodiments can differ from those shown.

With respect to Figure 16 an example 'unbiased' or full pattern is shown. The apparatus 1501 is shown with a front direction 1500 and is configured to record or capture audio signals with a directional gain defined by the beamform pattern distance at an angle of arrival relative to the apparatus. In the unbiased pattern the recording is performed without any specific directional gain or directional focus. This is shown in Figure 16 by the circular beam pattern 1821 surrounding the apparatus 1501.

With respect to Figure 17 an example 'front zoom' beamform pattern is shown. The 'front zoom' beamform pattern can be one where the apparatus 1501 (with front direction arrow 1500) is shown with a first beamform pattern 2211 (a teardrop shape) directed centrally and to the front and thus indicating a gain or focus directly forward of the apparatus and a second beamform pattern 1513 (also a teardrop shape) directed directly behind and centrally. It would be understood that the second beamform pattern 1513 is an example of audio signal processing used to generate the first beamform pattern 2211. In other words the second beamform pattern 1513 can be considered to be a side-effect of the processing of the audio signal required to generated the first beamform 2211 pattern. The second beamform pattern 1513 is configured with a lower maximum gain than the first beamform pattern 2211. This type of beamform pattern configuration can for example be used to follow a video zoom and attempt to record or capture audio signals in front of the apparatus distant from the apparatus.

With respect to Figure 18 a third example, the 'narrator recording', beamform pattern is shown. The 'narrator recording' beamform pattern can be one where the apparatus 1501 (with front direction arrow 1500) is shown with a first beamform pattern 2001 (a teardrop shape) directed centrally and to the front and thus indicating a gain or focus directly forward of the apparatus and a second beamform pattern 2003 (also a teardrop shape) directed directly behind and centrally. The second

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beamform pattern 2003 is configured with a larger maximum gain than the first beamform pattern 2001. It would be understood that the first beamform pattern 2001 is an example of audio signal processing used to generate the second beamform pattern 2003. In other words the second beamform pattern 2001 is the desired beamform which also results in the side-effect of generating the first beamform pattern 2001. This type of beamform pattern configuration can for example be used to record audio sources directly in front of the apparatus but focusses on the user of the apparatus.

With respect to Figure 19 a fourth example, the 'dominant audio source recording', beamform pattern is shown. The 'dominant audio source recording' beamform pattern can be one where the apparatus 1501 (with front direction arrow 1500) is shown with a first beamform pattern 2111 (a teardrop shape) directed towards the audio source 1505 and to the front and thus indicating a maximum gain or focus directly towards the audio source and a second beamform pattern 1513 (a side effect teardrop shape similar to that shown in Figure 17) directed directly behind and centrally (similar to the rear beamform pattern shown in Figure 17). The second beamform pattern 1513 is configured with a lower maximum gain than the first beamform pattern 2111. This type of beamform pattern configuration can for example be used to record an audio source, for example the loudest audio source, which is off centre from the centre forward direction of the apparatus, in other words in some embodiments away from the centre of the image being recorded by the camera.

With respect to Figure 20 a fifth example, the 'secondary audio source recording', beamform pattern is shown. The 'secondary audio source recording' beamform pattern can for example be produced by an processing instance determining a dominant or primary audio source, a secondary or minor audio source and the directions of the audio sources and then generating a first beamform pattern 1511 (a teardrop shape) directed towards a minor or secondary audio source 1503, away from the dominant audio source 1505 and to the front and thus indicating a maximum gain or focus directly towards the secondary or minor audio source and a second beamform pattern 1513 (a side effect teardrop shape similar to that shown in Figures

17 and 19) directed directly behind and centrally. The second beamform pattern 1513 is configured with a lower maximum gain than the first beamform pattern 2111. This type of beamform pattern configuration can for example be used to record an audio source which is not the loudest audio source and which can be off centre from the centre-forward direction of the apparatus. This directed beamform pattern thus suppresses the loudest source with respect to the minor source.

With respect to Figure 21, a sixth example, the 'tracking audio source recording', beamform pattern is shown. The 'tracking audio source recording' can for example be produced by an processing instance determining an audio source and the direction of the audio source and then generating a beamform pattern having a first beamform pattern 1611 (a teardrop shape) directed towards the audio source 1601 and to the front and thus indicating a maximum gain or focus directly towards the audio source, and furthermore following the direction of the audio source. Furthermore the 'tracking audio source recording' can in some embodiments comprise a second beamform pattern 1513 (also a teardrop shape) directed directly behind and centrally (a side effect teardrop shape similar to that shown in Figures 17, 19 and 20). The second beamform pattern 1513 is configured with a lower maximum gain than the first beamform pattern 1611. This type of beamform pattern configuration can for example be used to record an audio source which moves in front of the apparatus without the need for the apparatus to move to track the source.

With respect to Figure 22 a fifth example, the 'avoid dominant audio source recording', beamform pattern is shown. The 'avoid dominant audio source recording' beamform pattern can for example be performed by an processing instance determining an audio source and the direction of the audio source and then generating a beamform pattern with a first beamform pattern 1711 (a teardrop shape) directed away from the audio source 1505 and to the front and thus indicating a maximum gain or focus away from the audio source and a second beamform pattern 1513 (also a teardrop shape) directed directly behind and centrally (a side effect teardrop shape similar to that shown in Figures 17, 19 to 21). The second beamform pattern 1513 is configured with a lower maximum gain than the first beamform pattern 1711. This type of beamform pattern configuration can for example be used

to record an audio environment but attempt to suppress an dominant source, for example the loudest audio source.

With respect to Figure 23 an example of a complex or combined beamform pattern is shown. The beamform pattern shown in Figure 23 is a combination of the beamform pattern shown in Figure 16, an 'unbiased' beamform and the beamform pattern shown in Figure 19, a 'dominant audio source recording' pattern. The combination which can be produced by a first processing instance generating the 'unbiased' beamform pattern and a second processing instance generating the 'dominant audio source recording' pattern can be passed to the mixer which is configured to subtract the 'dominant audio source recording' output from the 'unbiased' output to generate the pattern output shown in Figure 23, in other words an ambience recording or capture track.

With respect to Figures 11 to 15 a series of example user interface displays are shown which can be used to control the processing instances and mixing operations.

With respect to Figure 11 a first or 'basic' user interface is shown. The basic user interface 1001 is configured to enable a single output to be generated by selecting one simple or complex (combined) track or instance. For example as shown in Figure 11 a radio button list or selection list is shown from which one of the selections is used to enable a processing instance to be generated.

The example list as shown in Figure 11 comprises a first radio button 1011 labelled omnidirectional surround sound and configured if selected to generate an omnidirectional surround sound or unbiased pattern such as shown in Figure 16. The example list further comprises a second radio button 1013 labelled audio zoom front and configured if selected to generate a beamform pattern similar to that shown in Figure 17. The example list also comprises a third radio button 1015 labelled narrator speech configured if selected to generate a beamform pattern similar to that shown in Figure 18, and a fourth radio button 1017 labelled loud events configured if selected to generate a dominant audio source recording beamform pattern such as shown in Figure 19.

In this user interface example there are four options however there can be any number of options within the selection list.

With respect to Figure 12 a second or 'advanced' user interface 1100 is shown. The advanced user interface 1100 is configured to enable multiple tracks or instances to be generated and possibly multiplexed onto an output signal. For example as shown in Figure 12 a selection list of tick boxes are provided from which none, one or more tracks or instances can be selected.

The example list as shown in Figure 12 comprises a first tick box 1101 labelled zoom front and configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 17. The list also comprises a second tick box 1103 labelled narrator speech configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 18, a third tick box 1105 labelled loud events configured if selected to generate a processing and encoding instance which implements a dominant audio source recording beamform pattern such as shown in Figure 19, and a fourth tick box 1107 labelled ambience and configured if selected to generate a processing, mixing and encoding instance which implements a beamform pattern similar to that shown in Figure 23.

In this user interface example there are four option tick boxes however there can be any number of options within the selection list.

With respect to Figure 13 a third or 'professional' user interface 1200 is shown. The professional user interface 1200 is configured to enable multiple tracks or instances to be generated and possibly multiplexed onto an output signal. For example as shown in Figure 13 a two selection list of radio buttons are provided from which each of the more tracks or instances can be selected.

The first audio track, audio track 1, selection list as shown in Figure 13 comprises a first radio button 1201 labelled zoom front and configured if selected to generate a

processing and encoding instance which implements a beamform pattern similar to that shown in Figure 17, a second radio button 1203 labelled ambience and configured if selected to generate a processing, mixing and encoding instance which implements a beamform pattern similar to that shown in Figure 23, and a third radio button 1205 labelled narrator speech configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 18.

The user can thus generate or control the generation of the first audio track or instance by selecting one of the three options.

The second audio track, audio track 2, selection list as shown in Figure 13 comprises a fourth (for the user interface) radio button 1207 labelled zoom front and configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 17, a fifth radio button 1209 labelled ambience and configured if selected to generate a processing, mixing and encoding instance which implements a beamform pattern similar to that shown in Figure 23, and a sixth radio button 1211 labelled narrator speech configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 18.

The user can thus generate or control the generation of the second audio track or instance by selecting one of the three options.

In other words the user interface can be configured for a defined number of tracks to display a selection of possible instances for each track. In the example shown herein each track is provided with the same list of options, however it would be understood that in some embodiments the options provided for difference tracks may differ. For example a first selection in a first track may prevent the same option to be made for a second or further track. This can for example be shown in the user interface by the greying out of the radio button selection option which has already been selected in another track.

Furthermore in the example shown herein there are two tracks however it would be understood that there may be more than two tracks from which the selections can be chosen.

With respect to Figure 14 a fourth or 'super' user interface 1300 is shown. The super user interface 1300 is configured to enable complex tracks or instances to be generated and possibly multiplexed onto an output signal by selecting both additional (or additive) and subtracted (or difference) instances to be combined. For example as shown in Figure 14 two selection lists of tick boxes are provided from each none, one or more tracks or instances can be selected.

The first 'additive' list 1351 as shown in Figure 14 comprises a first tick box 1301 labelled zoom front and configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 17. The 'additive' list 1351 also comprises a second tick box 1303 labelled narrator speech configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 18 and a third tick box 1305 labelled ambience and configured if selected to generate a processing, mixing and encoding instance which implements a beamform pattern similar to that shown in Figure 23.

The second 'difference' list 1361 as shown in Figure 14 comprises a fourth (on the user interface) tick box 1307 labelled zoom front and configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 17. The 'difference' list 1361 also comprises a fifth tick box 1309 labelled narrator speech configured if selected to generate a processing and encoding instance which implements a beamform pattern similar to that shown in Figure 18 and a sixth tick box 1311 labelled ambience and configured if selected to generate a processing, mixing and encoding instance which implements a beamform pattern similar to that shown in Figure 23.

The settings can then be applied to the mixer such that the instances selected by the difference list selections are subtracted from the additive list selections. It would be

understood that in some embodiments the mixer thus comprises a first mixing instance to generate a complex beamform pattern, for example when the ambience option is selected and a further mixing instance configured to combine the output of the first mixing instance with another instance (either another mixing instance or a processing instance) for example where one instance or track is subtracted from a further track. In some embodiments the complex beamform pattern instance is generated as part of the general mixing, for example where an ambience option is selected as an additive track or instance option the mixer receives the 'unbiased' beamform instance as an additive track or instance and the 'dominant audio source recording' beamform pattern as a difference track or instance to be combined with the other selected tracks (in other words only a single mixing stage is required to mix both simple and complex beamform patterns).

In some embodiments these lists can be copied to enable further tracks to be generated from combined tracks. In other words more there can be embodiments where there is more than one output track from the selected additive and difference track options. Furthermore it would be understood that the selection lists can be any list arrangement and configuration. For example the additive and difference lists can comprise different lists of options.

With respect to Figure 15 a fifth or 'track' user interface 1400 is shown. The track user interface 1400 is configured to enable multiple types of tracks or instances to be generated and control the type of tracks that can be possibly multiplexed onto an output signal. For example as shown in Figure 15 a stereo instance and option, a surround sound track and options, and object audio track and options are enables to be selected from.

The user interface 1400 comprise a first tick box 1401 labelled stereo track which is configured if selected a stereo processing instance to be generated. Furthermore the settings comprise an audio zoom strength slider 1403 which controls the zoom or gain of the beam pattern applied. It would be understood that in some embodiments further sliders can be implemented to control the selectivity of the 'zoom' or other beam. In other words controlling the width of the beam. Similarly it would be

understood that in some embodiments sliders can be associated with other spatially processed beam or focussing operations controlling the effect of the beam or the focussing.

The user interface 1400 further comprises a second tick box 1405 labelled surround sound track which is configured if selected to enable a surround sound processing instance to be generated. Furthermore in some embodiments the user interface 1400 comprises a series of radio button selection options associated with the second tick box which select the type or option of surround sound track processing. For example in Figure 15 there comprises a first radio button 1407 labelled omnidirectional surround sound and configured if selected and the second tick box is also selected to generate an omnidirectional surround sound or unbiased pattern such as shown in Figure 16. The list further comprises a second radio button 1409 labelled front zoom and configured if selected and the second tick box is also selected to generate a beamform pattern similar to that shown in Figure 17.

The user interface 1400 further comprises a third tick box 1411 labelled object audio track which is configured if selected to enable an object processing instance to be generated. Furthermore in some embodiments the user interface 1400 comprises a data entry box or value selection 1413 associated with the third tick box which select the number of objects to be determined within the object audio track processing instance.

It would be understood that the number of instances, types of instance and selection of options for the instances are all possible user interface choices and the examples shown herein are example user interface implementations only.

It shall be appreciated that the term user equipment is intended to cover any suitable type of wireless user equipment, such as mobile telephones, portable data processing devices or portable web browsers, as well as wearable devices.

In general, the various embodiments of the invention may be implemented in hardware or special purpose circuits, software, logic or any combination thereof. For

example, some aspects may be implemented in hardware, while other aspects may be implemented in firmware or software which may be executed by a controller, microprocessor or other computing device, although the invention is not limited thereto. While various aspects of the invention may be illustrated and described as block diagrams, flow charts, or using some other pictorial representation, it is well understood that these blocks, apparatus, systems, techniques or methods described herein may be implemented in, as non-limiting examples, hardware, software, firmware, special purpose circuits or logic, general purpose hardware or controller or other computing devices, or some combination thereof.

The embodiments of this invention may be implemented by computer software executable by a data processor of the mobile device, such as in the processor entity, or by hardware, or by a combination of software and hardware. Further in this regard it should be noted that any blocks of the logic flow as in the Figures may represent program steps, or interconnected logic circuits, blocks and functions, or a combination of program steps and logic circuits, blocks and functions. The software may be stored on such physical media as memory chips, or memory blocks implemented within the processor, magnetic media such as hard disk or floppy disks, and optical media such as for example DVD and the data variants thereof, CD.

The memory may be of any type suitable to the local technical environment and may be implemented using any suitable data storage technology, such as semiconductor-based memory devices, magnetic memory devices and systems, optical memory devices and systems, fixed memory and removable memory. The data processors may be of any type suitable to the local technical environment, and may include one or more of general purpose computers, special purpose computers, microprocessors, digital signal processors (DSPs), application specific integrated circuits (ASIC), gate level circuits and processors based on multi-core processor architecture, as non-limiting examples.

Embodiments of the inventions may be practiced in various components such as integrated circuit modules. The design of integrated circuits is by and large a highly automated process. Complex and powerful software tools are available for converting

a logic level design into a semiconductor circuit design ready to be etched and formed on a semiconductor substrate.

Programs, such as those provided by Synopsys, Inc. of Mountain View, California and Cadence Design, of San Jose, California automatically route conductors and locate components on a semiconductor chip using well established rules of design as well as libraries of pre-stored design modules. Once the design for a semiconductor circuit has been completed, the resultant design, in a standardized electronic format (e.g., Opus, GDSII, or the like) may be transmitted to a semiconductor fabrication facility or "fab" for fabrication.

The foregoing description has provided by way of exemplary and non-limiting examples a full and informative description of the exemplary embodiment of this invention. However, various modifications and adaptations may become apparent to those skilled in the relevant arts in view of the foregoing description, when read in conjunction with the accompanying drawings and the appended claims. However, all such and similar modifications of the teachings of this invention will still fall within the scope of this invention as defined in the appended claims.

CLAIMS:

1. An apparatus comprising:

an input configured to receive from at least two microphones at least two audio signals;

at least two processor instances configured to generate separate output audio signal tracks from the at least two audio signals from the at least two microphones;

a file processor configured to link the at least two output audio signal tracks within a file structure.

2. The apparatus as claimed in claim 1, wherein at least one of the at least two processor instances comprises one of:

a surround sound processor instance configured to output a multichannel output audio signal track;

a stereo sound processor instance configured to output a stereo output audio signal track;

a mono sound processor instance configured to output a mono output audio signal track; and

an audio object processor instance configured to output an audio object output audio track.

3. The apparatus as claimed in claims 1 to 2, further comprising at least one mixer configured to receive at least two output audio signal tracks and generate at least one combined output audio signal track, wherein the file processor is configured to link the least one combined output audio signal track with at least one other track.

4. The apparatus as claimed in claims 1 to 3, further comprising at least one encoder configured to receive at least one output audio signal track and generate at least one encoded output audio signal track, wherein the file processor is further configured to link the least one encoded output audio signal track with at least one other track.

5. The apparatus as claimed in claims 1 to 4, further comprising a pre-processor configured to receive the at least two audio signals, and generate at least two audio signals to be passed to the at least one processor instance.

6. The apparatus as claimed in claim 5, wherein the pre-processor comprises at least one of:

an equaliser configured to equalise each of the at least two audio signals from the at least two microphones, so to compensate for any manufacturing differences in the at least two microphones;

a wind noise reducer configured to reduce the wind noise of the at least two audio signals from the at least two microphones;

a handling noise reducer configured to reduce the handling noise of the at least two audio signals from the at least two microphones;

dynamic range compressor configured to dynamically range compress the at least two audio signals from the at least two microphones;

sample rate converter configured to convert the sampling rate of the at least two audio signals from the at least two microphones;

a word length resolution modifier configured to change the word length resolution of the at least two audio signals from the at least two microphones; and

a blockage processor configured to determine and compensate for a fault or blockage in at least one of the at least two microphones.

7. The apparatus as claimed in claims 1 to 6, wherein at least two processor instances configured to generate separate output audio signal tracks from the at least two audio signals from the at least two microphones comprises at least one of:

a upmixer configured to generate an audio signal track with more channels than the number of input audio signals;

a downmixer configured to generate an audio signal track with fewer channels than the number of input audio signals;

a signal source analyser configured to determine the orientation of at least one signal source relative to the apparatus from the at least two audio signals from the at least two microphones;

a signal source processor configured to modify the orientation of at least one signal source relative to the apparatus;

a spatial processor configured to generate a spatial processing of the at least two audio signals from the at least two microphones; and

a mapper configured to map the at least two audio signals from the at least two microphones to a output multichannel audio signal track.

8. The apparatus as claimed in claim 7, wherein the spatial processor comprises at least one of:

an audio focuser configured to generate a spatially focussed audio signal from the at least two audio signals from the at least two microphones;

an audio zoomer configured to generate a spatially expanded audio signal from the at least two audio signals from the at least two microphones;

a directional defined audio amplifier configured to amplify within a defined directional range the at least two audio signals from the at least two microphones;

a directional defined audio attenuator configured to attenuate within a defined directional range the at least two audio signals from the at least two microphones;

an audio de-emphasiser configured to apply a reverberation within a defined directional range the at least two audio signals from the at least two microphones;

an audio source displacer configured to modify a relative orientation of an audio source by a defined displacement angle; and

a directionally defined audio filter configured to spatially filter within a defined directional range the at least two audio signals from the at least two microphones.

9. The apparatus as claimed in claims 1 to 8, further comprising a camera configured to generate a video format signal, wherein the file processor configured to link the at least two output audio signal tracks within a file structure is configured to generate a data structure linking the at least two output audio signal tracks with the video format signal.

10. The apparatus as claimed in claims 1 to 9, wherein the file processor is configured to generate a mp4 format file structure comprising the at least two audio signal tracks as separate tracks linked in a mp4 format file structure description.

11. The apparatus as claimed in claims 1 to 10, further comprising at least two microphones configured to generate the at least two audio signals.

12. The apparatus as claimed in claims 1 to 11, further comprising a user interface input configured to configure at least one of the at least two processor instances.

13. The apparatus as claimed in claim 12, wherein the user interface input comprises at least one of:

a radio-button selection configured to select one processor instance template from a plurality of processor instance templates to be applied to at least one of the two processor instances;

a selection-box selection configured to select one or more processor instance templates from a plurality of processor instance templates to be applied to the two processor instances;

a track selection-box selection configured to select one or more processor instance templates from a plurality of processor instances for each of one or more processor instance templates;

a channel selection configured to select the number of channels output by at least one of the two processor instances;

an audio region selection configured to determine a spatial region within which at least one of the two processor instances applies spatial processing;

a surround channel selection configured to select a surround sound instance template to be applied to at least one of the two processor instances;

a surround channel option selection configured to select one surround sound processor instance template from a plurality of surround sound processor instance templates to be applied to at least one of the two processor instances;

an object track selection configured to select an object instance template to be applied to at least one of the two processor instances; and

an object number selection configured to select an object instance template comprising a filter configured to select a number of objects to be applied to at least one of the two processor instances.

14. An apparatus comprising at least one processor and at least one memory including computer code for one or more programs, the at least one memory and the computer code configured to with the at least one processor cause the apparatus to at least:

receive from at least two microphones at least two audio signals;

generate separate output audio signal tracks from the at least two audio signals from the at least two microphones; and

link the at least two output audio signal tracks within a file structure.

15. The apparatus as claimed in claim 14, further caused to receive at least two output audio signal tracks and generate at least one combined output audio signal track.

16. The apparatus as claimed in claims 14 to 15, further caused to receive at least one output audio signal track and generate at least one encoded output audio signal track.

17. The apparatus as claimed in claims 14 to 16, further caused to generate a video format signal, wherein linking the at least two output audio signal tracks within a file structure causes the apparatus to generate a data structure linking the at least two output audio signal tracks with the video format signal.

18. An apparatus comprising:

means for receiving from at least two microphones at least two audio signals;

means for generating separate output audio signal tracks from the at least two audio signals from the at least two microphones; and

means for linking the at least two output audio signal tracks within a file structure.

19. The apparatus as claimed in claim 18, further comprising means for combining at least two output audio signal tracks to generate at least one combined output audio signal track.

20. The apparatus as claimed in claims 18 to 19, further comprising means for encoding at least one output audio signal track to generate at least one encoded output audio signal track.

21. The apparatus as claimed in claims 18 to 20, further comprising means for generating a video format signal, wherein the means for linking the at least two output audio signal tracks within a file structure comprises means for generating a data structure linking the at least two output audio signal tracks with the video format signal.

22. A method comprising:

receiving from at least two microphones at least two audio signals;

generating separate output audio signal tracks from the at least two audio signals from the at least two microphones; and

linking the at least two output audio signal tracks within a file structure.

23. The method as claimed in claim 22, further comprising combining at least two output audio signal tracks to generate at least one combined output audio signal track.

24. The method as claimed in claims 21 to 22, further comprising encoding at least one output audio signal track to generate at least one encoded output audio signal track.

25. The method as claimed in claims 22 to 24, further comprising generating a video format signal, wherein linking the at least two output audio signal tracks within a file structure comprises generating a data structure linking the at least two output audio signal tracks with the video format signal.

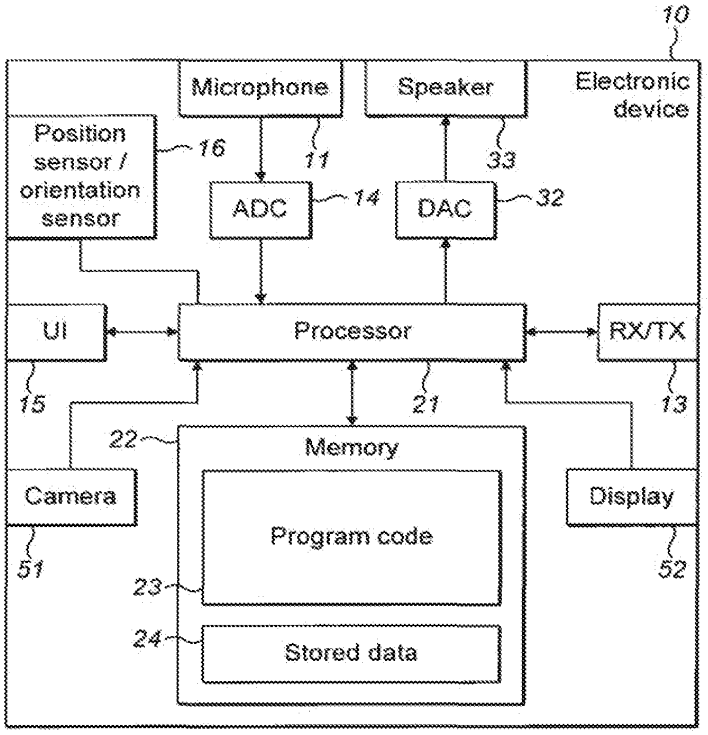


FIG. 1

Insta360
Exhibit 1003 Page 253

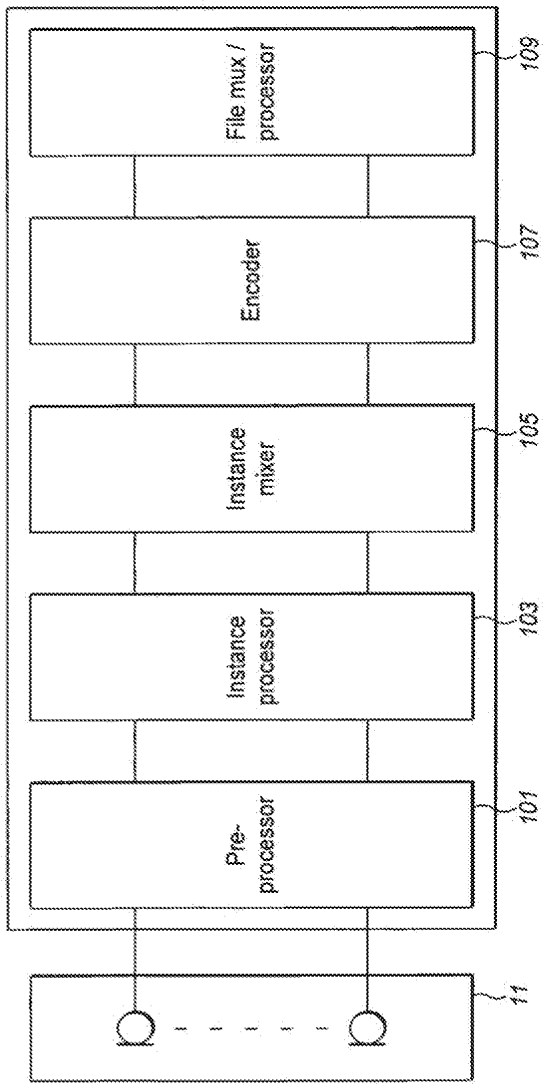


FIG. 2

Insta360
Exhibit 1003 Page 254

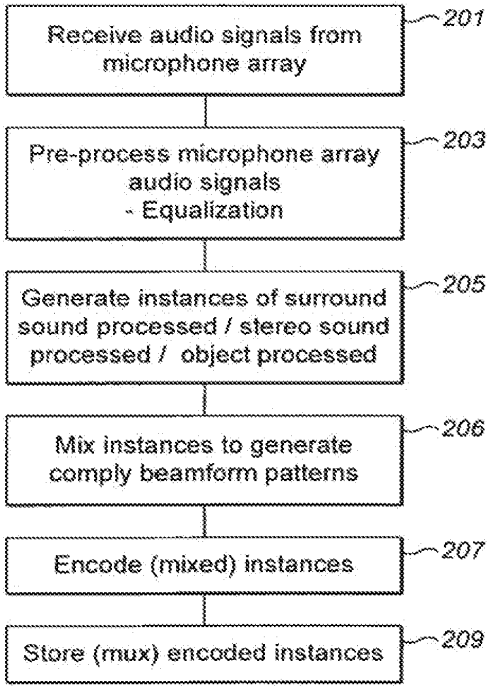


FIG. 3

Insta360
Exhibit 1003 Page 255

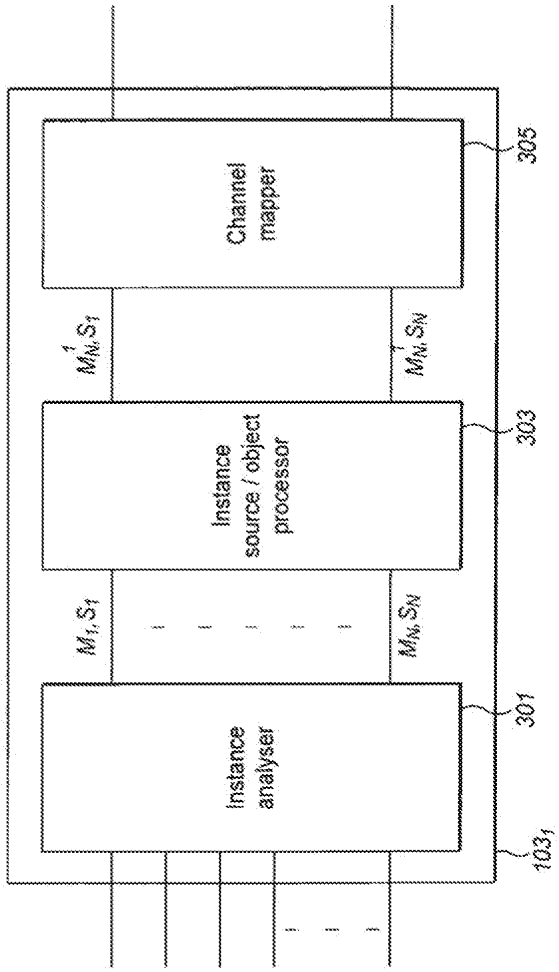


FIG. 4

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Exhibit 1003 Page 256

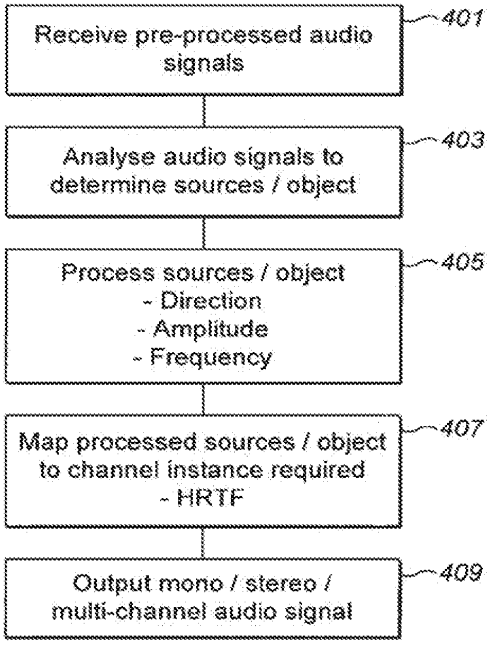


FIG. 5

Insta360
Exhibit 1003 Page 257

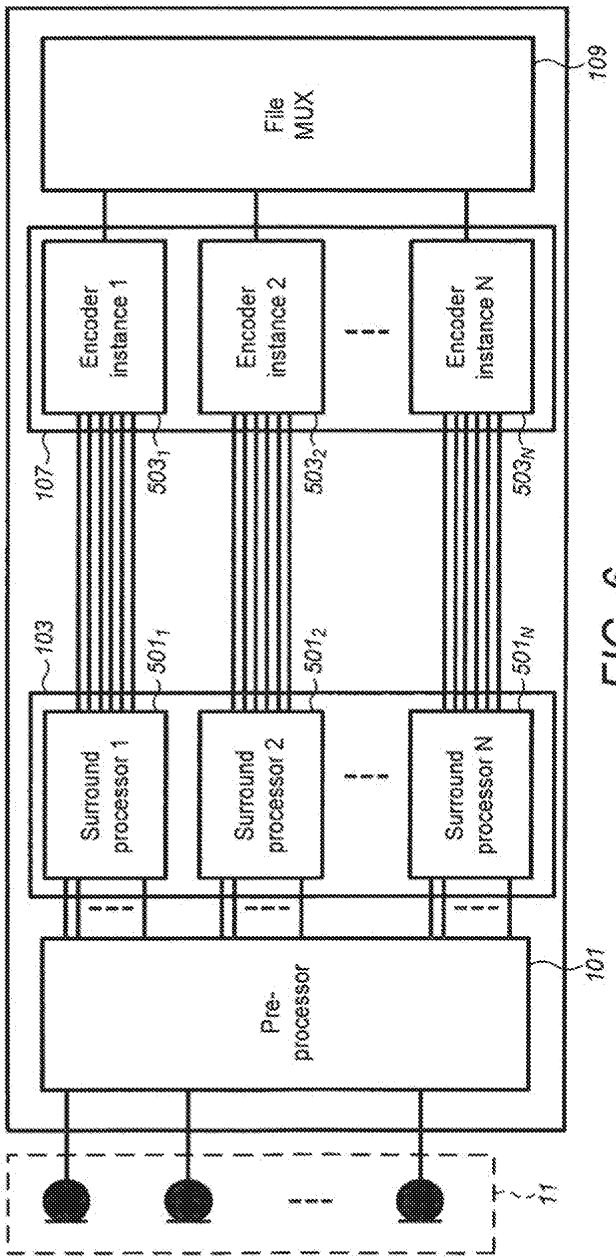


FIG. 6

Insta360
Exhibit 1003 Page 258

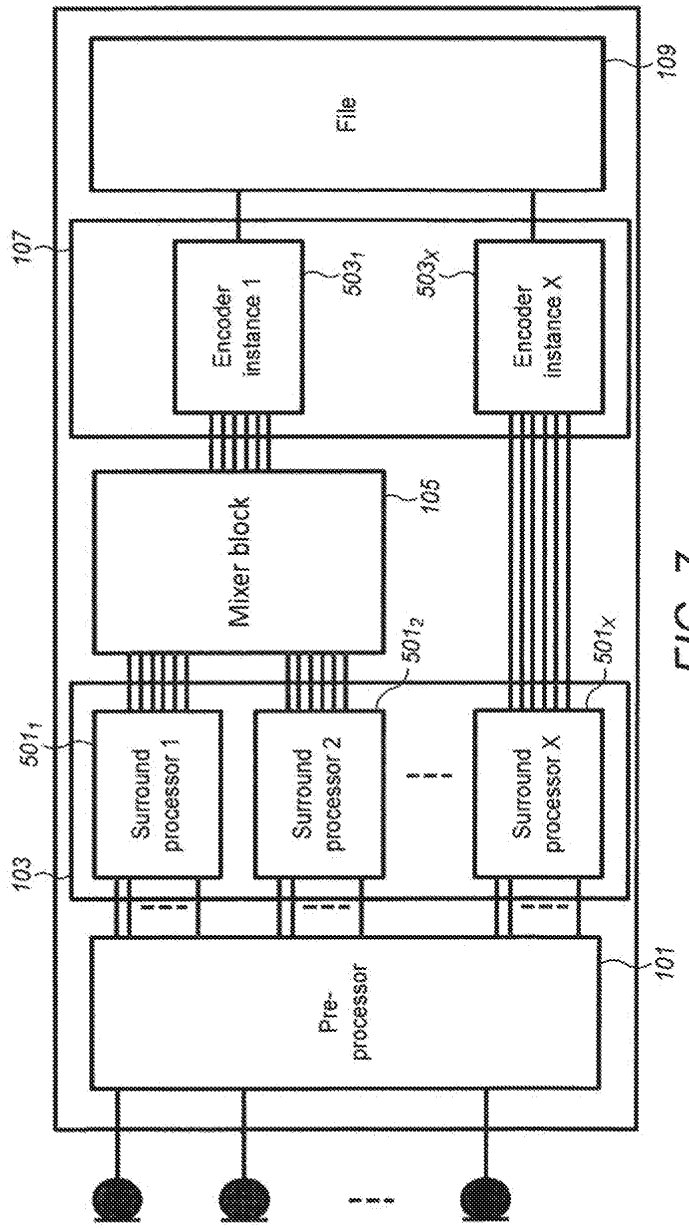


FIG. 7

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Exhibit 1003 Page 259

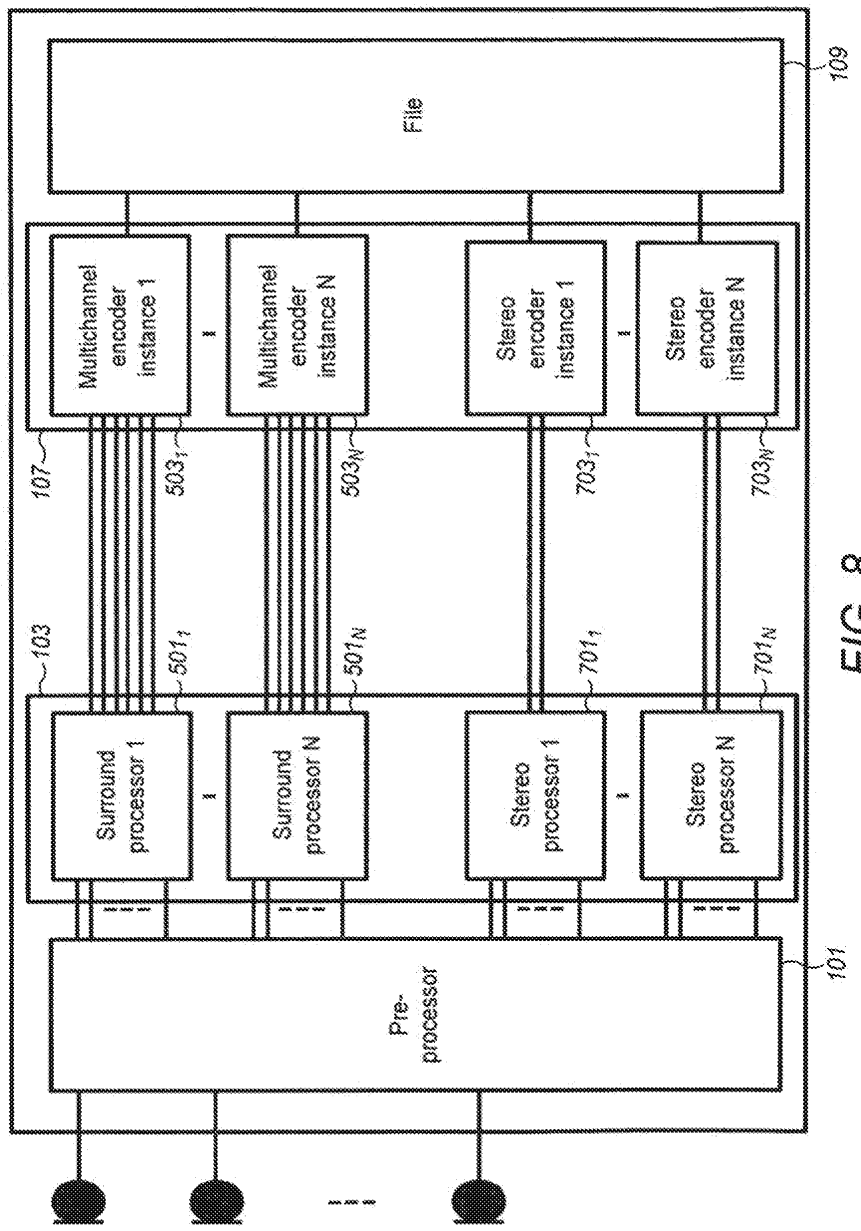


FIG. 8

Insta360
Exhibit 1003 Page 260

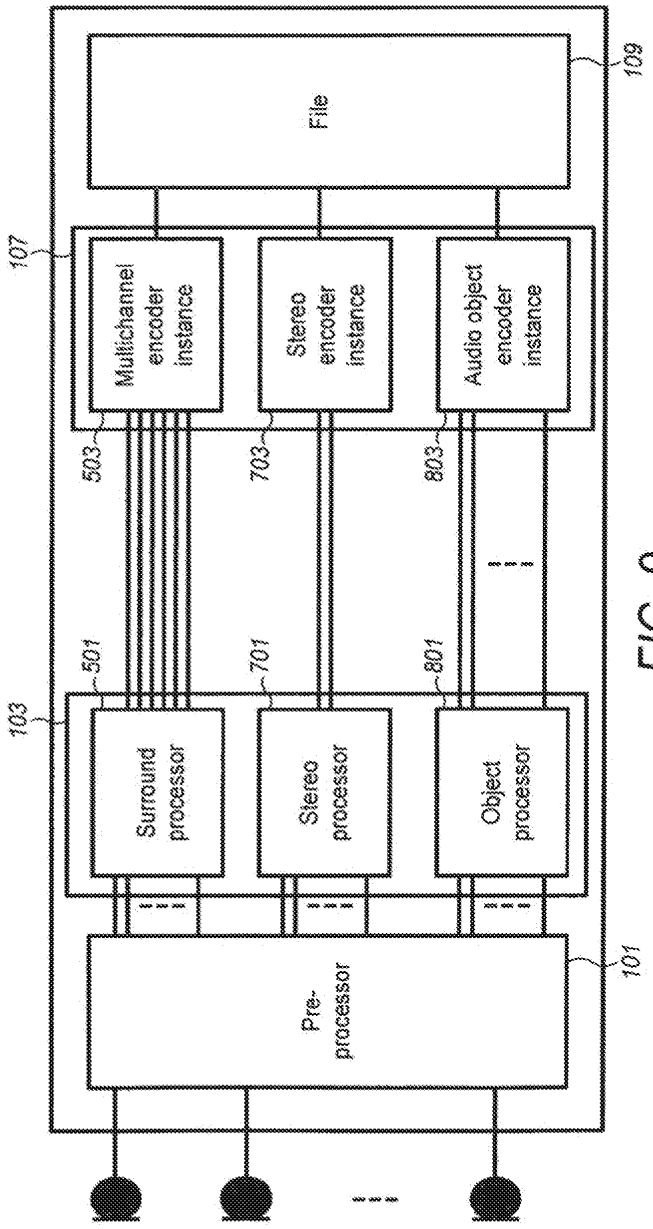


FIG. 9

Insta360
Exhibit 1003 Page 261

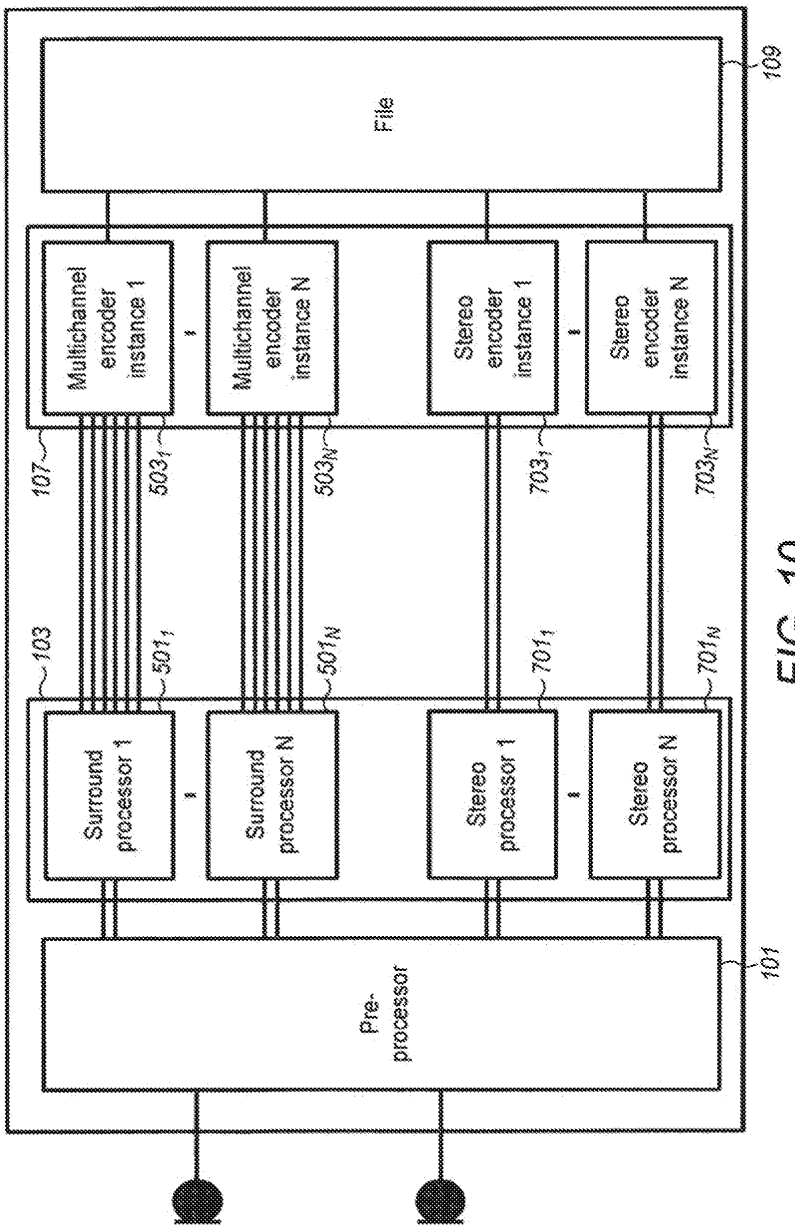


FIG. 10

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Exhibit 1003 Page 262

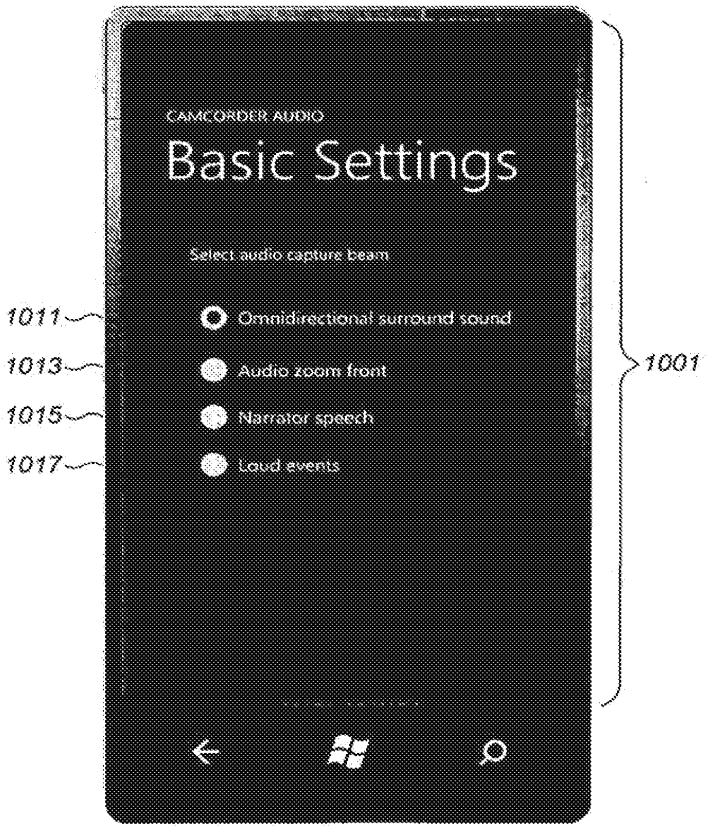


FIG. 11

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FIG. 12

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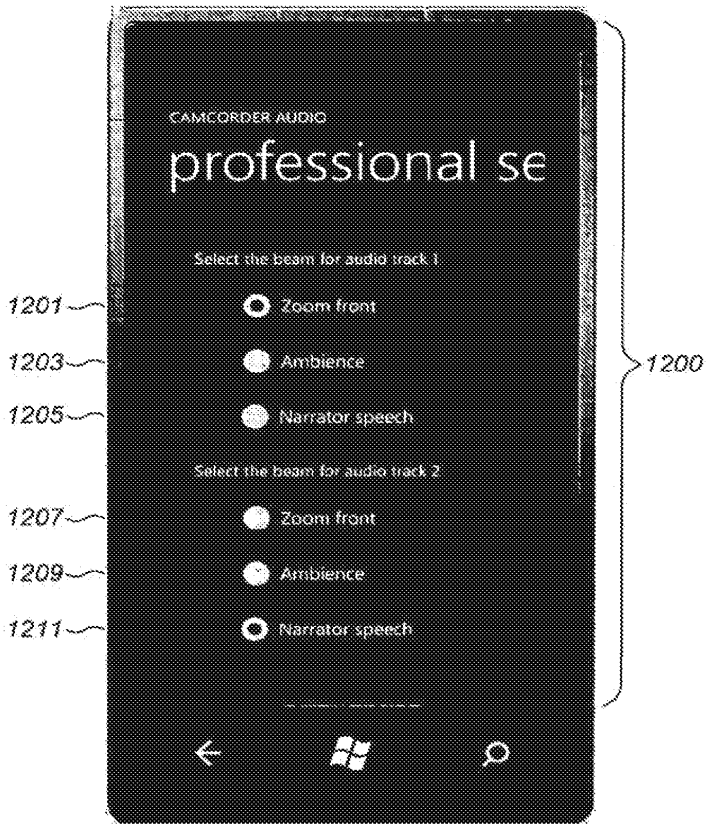

CAMCORDER AUDIO
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Select the beam for audio track 1
Zoom front
Ambience
Narrator speech
Select the beam for audio track 2
Zoom front
Ambience
Narrator speech
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1211
1200

FIG. 13

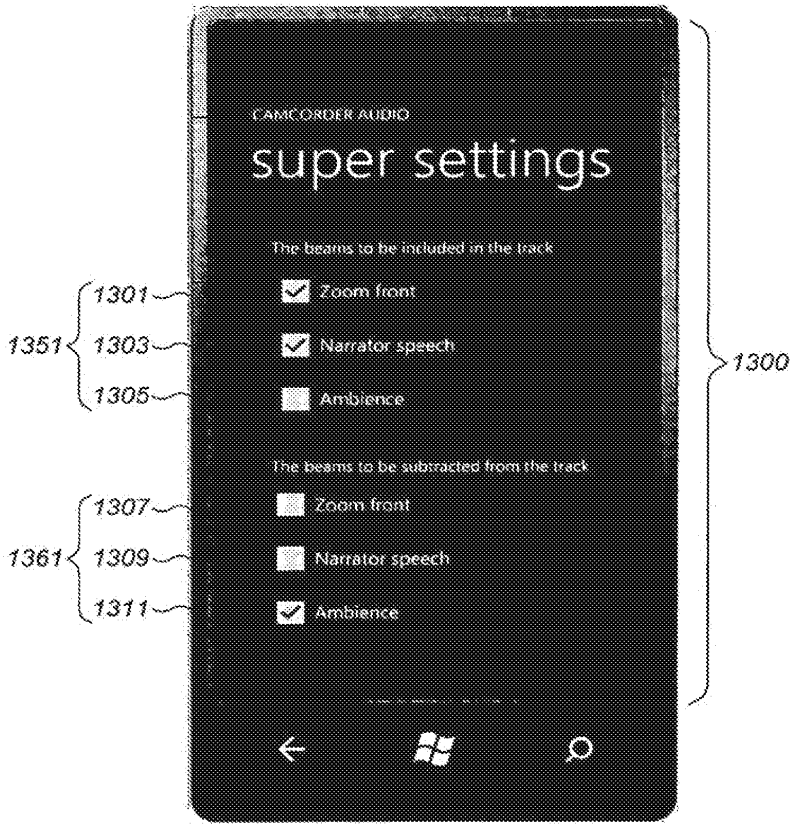


FIG. 14

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Exhibit 1003 Page 266

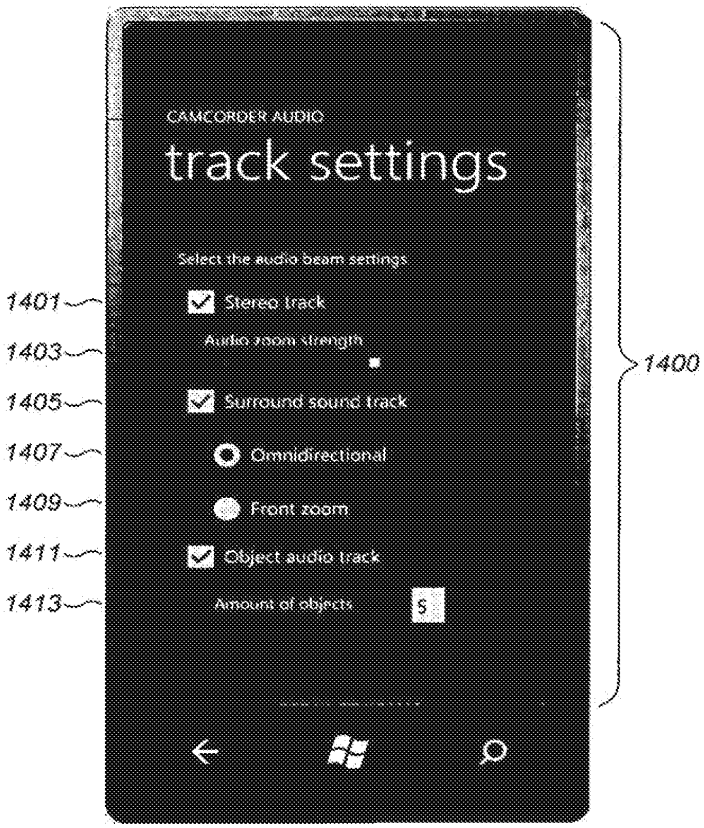


FIG. 15

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Exhibit 1003 Page 267

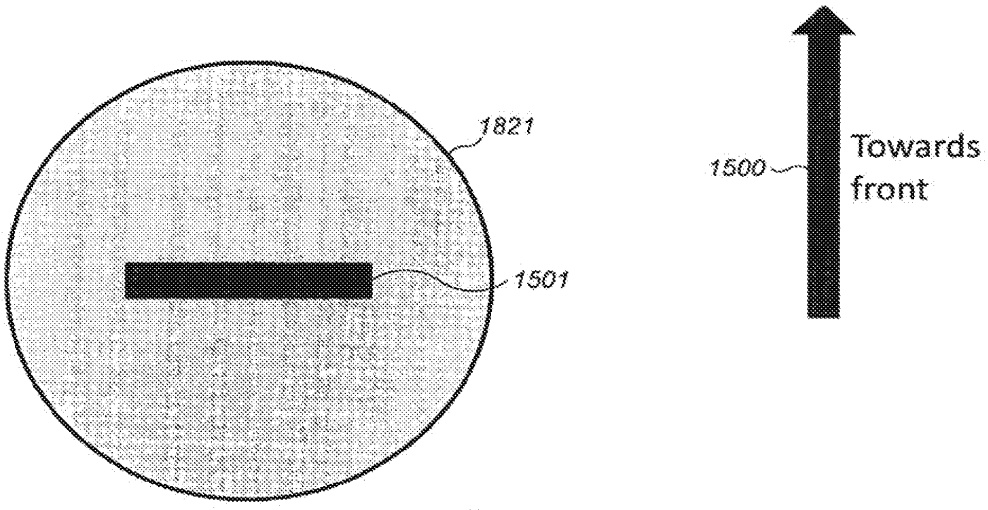


FIG. 16

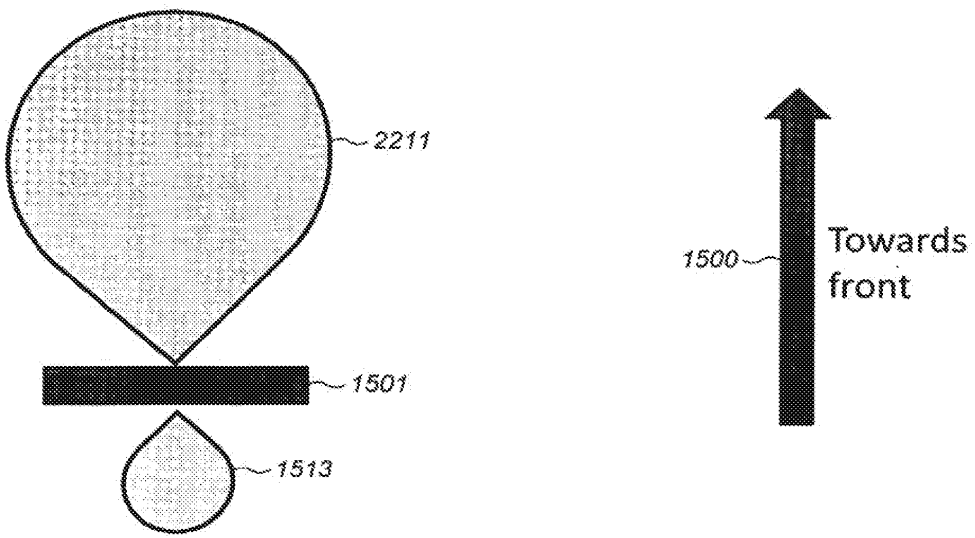


FIG. 17

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Exhibit 1003 Page 268

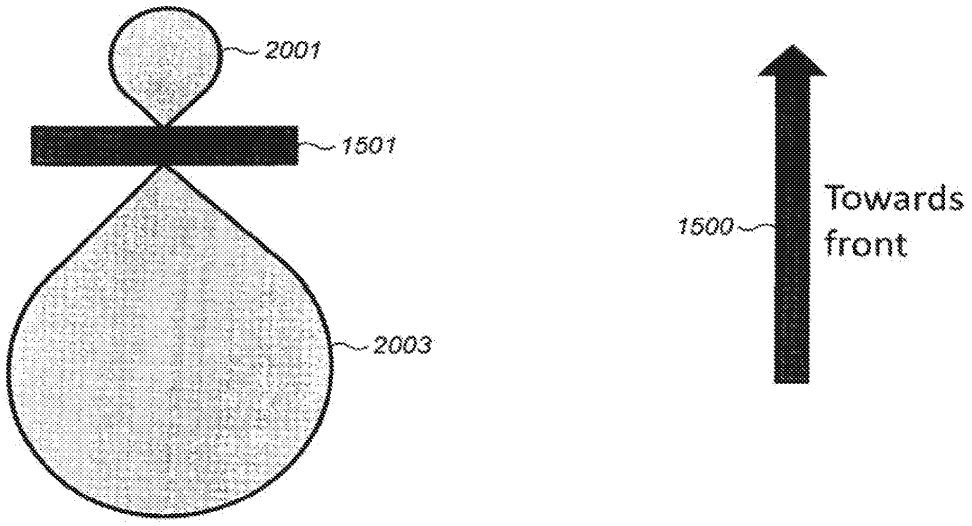


FIG. 18

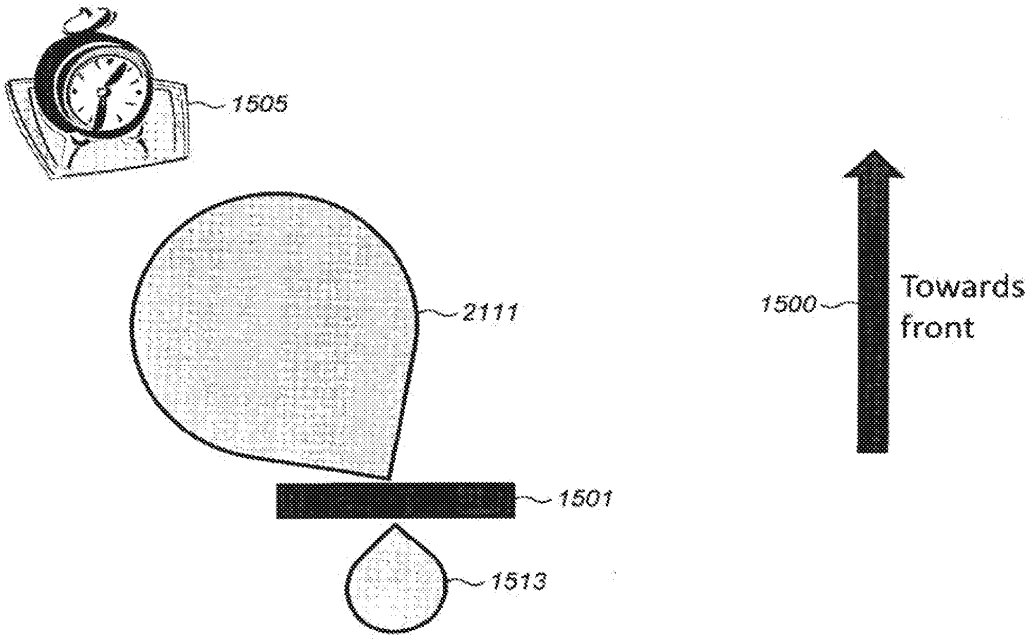


FIG. 19

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Exhibit 1003 Page 269

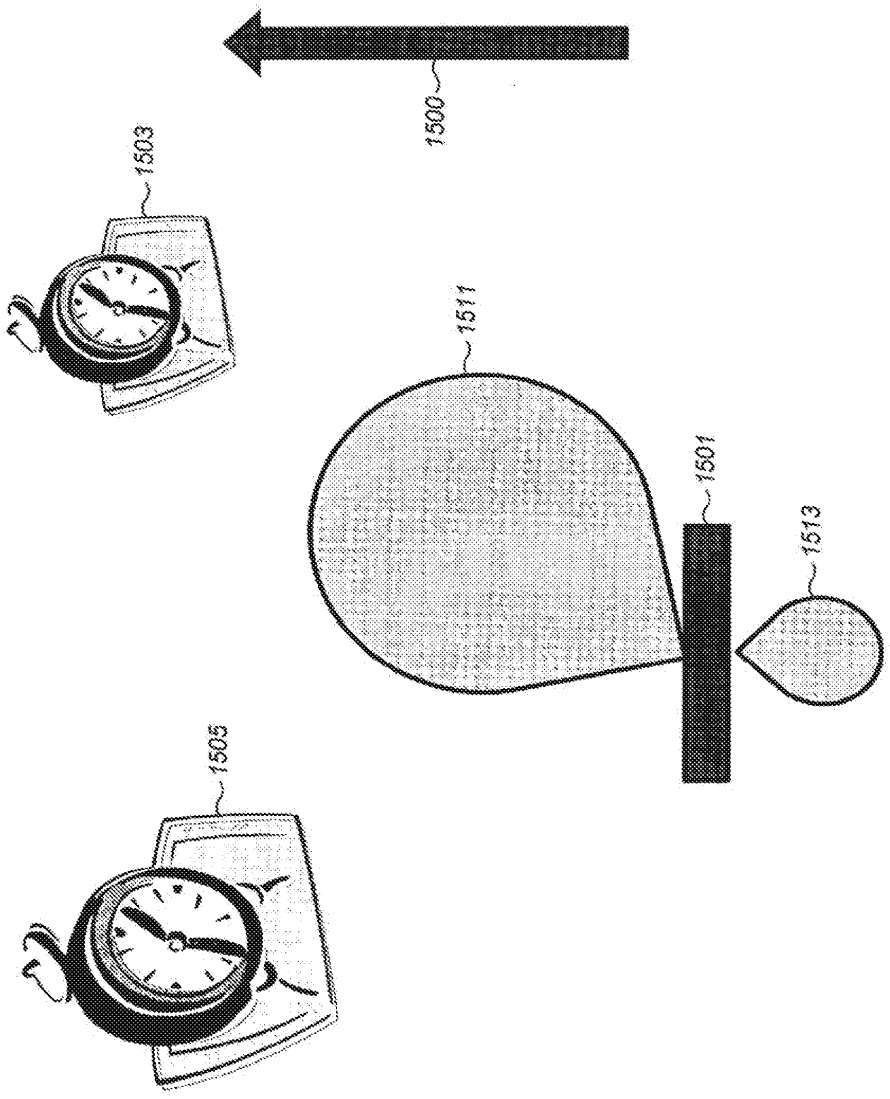


FIG. 20

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Exhibit 1003 Page 270

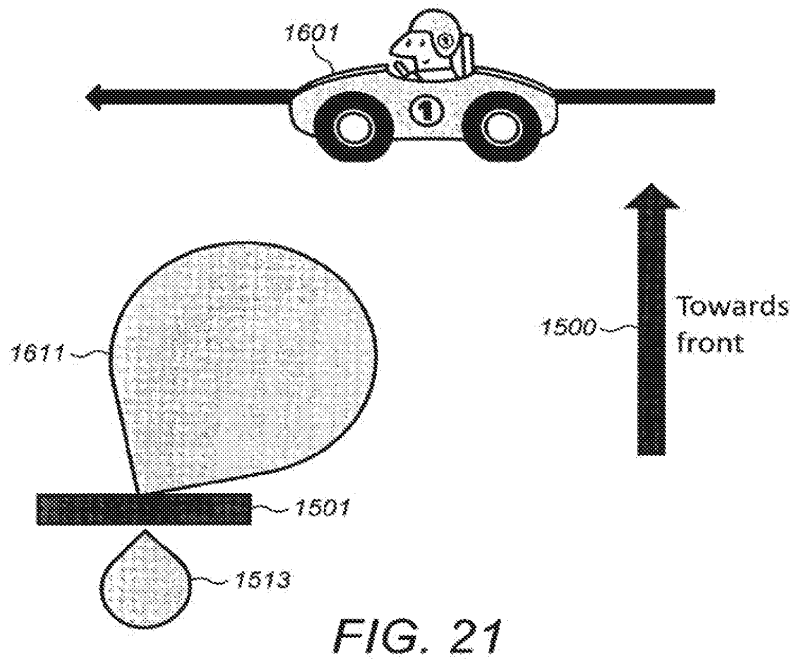


FIG. 21

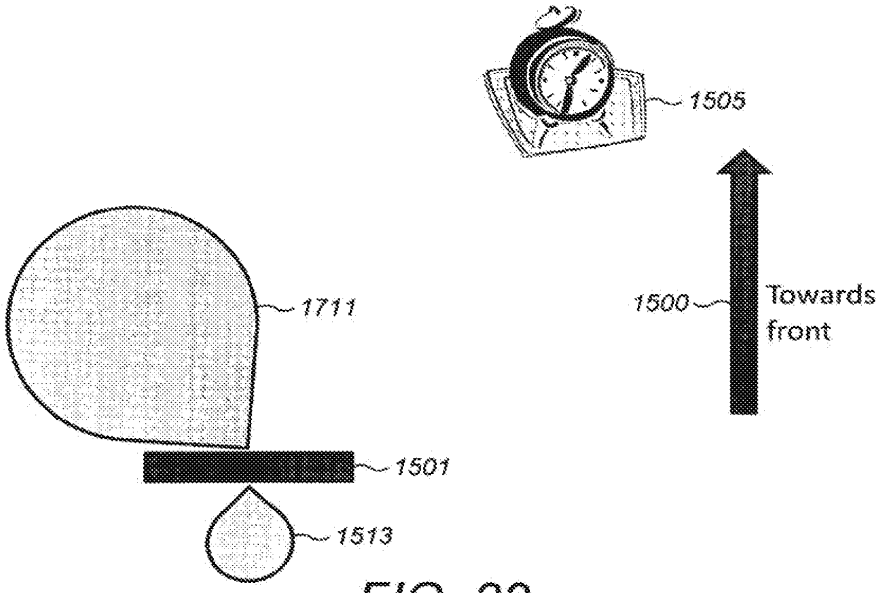


FIG. 22

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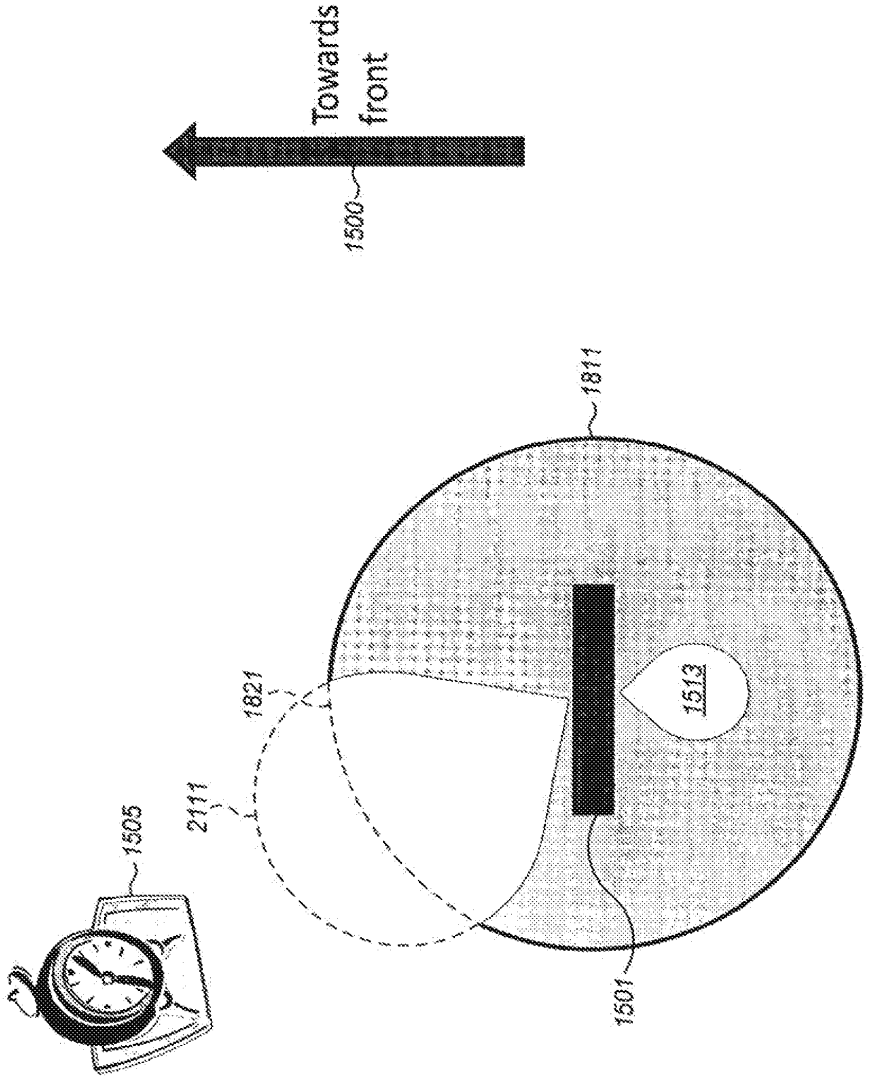


FIG. 23

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/074956

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04S3/00 H04S7/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04R H04S H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 594 800 A (GERZON MICHAEL A [GB]) 14 January 1997 (1997-01-14)	1-6, 9-11, 14-25
Y	figures 2,10 column 6, line 3 - line 15 column 13, line 48 - line 52	7,8,12, 13

X	US 2012/195433 A1 (EPPOLITO AARON M [US] ET AL) 2 August 2012 (2012-08-02)	1-6, 9-11, 14-25
Y	figures 3,4	7,8,12, 13

X	US 2008/051920 A1 (HORI TAIZO [JP]) 28 February 2008 (2008-02-28)	1-6, 9-11, 14-25
Y	figures 1,5,7,9	7,8,12, 13

-/--

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 May 2014	26/05/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Moscu, Viorel

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/074956

(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Apple Inc.: "Soudtrack Pro 3", , 7 October 2011 (2011-10-07), XP002718198, Retrieved from the Internet: URL:http://web.archive.org/web/20111215131414/http://documentation.apple.com/en/soundtrackpro/usermanual/Soundtrack%20Pro%203%20User%20Manual%20(en).pdf [retrieved on 2013-12-19]	1-6, 9-11, 14-25
Y	pages 17,21 pages 35,43 pages 305-334 pages 335-353 page 509	7,8,12, 13
Y	WO 2012/031605 A1 (FUNDACIO BARCELONA MEDIA UNI POMPEU FABRA [ES]; USHER JOHN [ES]; MATEO) 15 March 2012 (2012-03-15) figure 1A paragraphs [0042] - [0044]	7,8
Y	EP 2 146 522 A1 (FRAUNHOFER GES FORSCHUNG [DE]) 20 January 2010 (2010-01-20) figures 5A, 8 paragraph [0070]	7,8
Y	US 5 477 270 A (PARK WON-BOK [KR]) 19 December 1995 (1995-12-19) figures 1-3 column 2, line 27 - column 3, line 41	7,8
Y	US 2011/013075 A1 (KIM TAESU [KR] ET AL) 20 January 2011 (2011-01-20) figure 16C paragraph [0241] - paragraph [0244]	12,13

2

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

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Exhibit 1003 Page 274

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2012/074956

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5594800 A	14-01-1997	NONE	
US 2012195433 A1	02-08-2012	NONE	
US 2008051920 A1	28-02-2008	JP 4850628 B2	11-01-2012
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		US 5477270 A	19-12-1995
US 2011013075 A1	20-01-2011	NONE	

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2012/074956

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. [X] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

[X] No protest accompanied the payment of additional search fees.

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 9-11, 14-25

Device comprising multiple processor instances wherein each of the processor instances may be one of a: surround sound processor, stereo sound processor, mono sound processor, object sound processor. See Fig. 6-10.
Object: Allows the user to record various multichannel / single-channels formats and to further combine/mix them.

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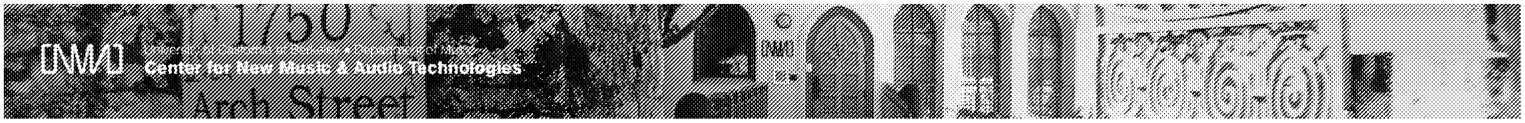
2. claims: 7, 8

Device performing spatial processing as: directional zooming, directional attenuation, de-emphasiser, source displacer, etc. See Claim 8, Fig.16-23.
Object: Allows the user to modify the sound image, in special to control the microphone directivity.

---

3. claims: 12, 13

Device comprising a User interface for making various audio processing settings. See Fig. 11-15.
Object: Allows the user to configure an audio device with processing settings.



Spatial Audio Lecture Series

CNMAT's Spatial Audio Lecture Series is a platform for presenting and discussing recent research and developments in the field of spatial audio and room acoustics. This series is complementary to the UC Berkeley's Earclub which focuses on auditory research.

The Spatial Audio Lecture Series is open to public. The current schedule is announced via this website and the mailing list. To be added to the mailing list, navigate to http://calmail.berkeley.edu/manage/list/listinfo/spatial-audio@lists.berkeley.edu.

If you would like to give a presentation or have any questions, please contact Nils Peters at spatial-audio@cnmat.berkeley.edu.

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Administrative Contact: Richard Andrews <richard (at) cnmat (dot) berkeley (dot) edu>

Center for New Music and Audio Technologies
1750 Arch Street
Berkeley, California
94720 U.S.A.
(510) 643-9990

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Page 278

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
Basile, Jr. Andrew R.
GoPro Inc.
C/o Young Basile
3001 W. Big Beaver, Suite 624
Troy MI 48084
ETATS-UNIS D'AMERIQUE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)*: 3 June 2019 (03-06-2019)
Applicant's or agent's file reference: GPRO2132APCT	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No.: PCT/US2019/020241	International filing date *(day/month/year)*: 1 March 2019 (01-03-2019)
Applicant: GOPRO, INC.	

1. [X] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the International Application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the International Search Report.

   How? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Fascimile No.: (41-22) 338.82.70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 - 9.011.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with any applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the International Searching Authority: European Patent Office, P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel. (+31-70) 340-2040 Fax: (+31-70) 340-3016	Authorized officer: STEIN, Patricia Tel: +49 (0)89 2399-1201

Form PCT/ISA/220 (July 2017)

REC'D JUN 0 4 2019

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
GPRO2132APCT		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2019/020241	1 March 2019 (01-03-2019)	21 May 2018 (21-05-2018)
Applicant		
GOPRO, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      [X] the international application in the language in which it was filed
      [ ] a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. [ ] This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. [ ] **Certain claims were found unsearchable** (See Box No. II)

3. [ ] **Unity of invention is lacking** (see Box No III)

4. With regard to the **title**,
   [X] the text is approved as submitted by the applicant
   [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   [X] the text is approved as submitted by the applicant
   [ ] the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority

6. With regard to the **drawings**,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 10
      [ ] as suggested by the applicant
      [ ] as selected by this Authority, because the applicant failed to suggest a figure
      [X] as selected by this Authority, because this figure better characterizes the invention
   b. [ ] none of the figures is to be published with the abstract

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/020241

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06T5/00 G06T5/50
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2013/329132 A1 (TICO MARIUS [US] ET AL) 12 December 2013 (2013-12-12) paragraphs [0024] - [0042]; claim 9; figure 7	1-7 8-15
A	US 2017/359534 A1 (LI XIAOXING [US] ET AL) 14 December 2017 (2017-12-14) the whole document	1-15
A	US 2015/146014 A1 (BLACK ROBERT A [US] ET AL) 28 May 2015 (2015-05-28) the whole document	1-15
A	WO 2014/042104 A1 (RICOH CO LTD [JP]; SHOHARA MAKOTO [JP] ET AL.) 20 March 2014 (2014-03-20) the whole document	1-15

-/--

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
21 May 2019	03/06/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Tillier, Christophe

1

Form PCT/ISA/210 (second sheet) (April 2005)

Insta360
Exhibit 1003 Page 281

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/020241

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/094169 A1 (YOSHIKAWA HIROMI [JP] ET AL) 30 March 2017 (2017-03-30) the whole document	1-15
A	US 2017/070689 A1 (SILVERSTEIN D AMNON [US] ET AL) 9 March 2017 (2017-03-09) the whole document	1-15
A	US 2011/242352 A1 (HIKOSAKA KENTARO [JP]) 6 October 2011 (2011-10-06) the whole document	1-15

1

Insta360
Exhibit 1003 Page 282

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2019/020241

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013329132 A1	12-12-2013	US 2013329132 A1	12-12-2013
		US 2016227137 A1	04-08-2016
		US 2017171466 A1	15-06-2017
US 2017359534 A1	14-12-2017	US 2017359534 A1	14-12-2017
		WO 2017214523 A1	14-12-2017
US 2015146014 A1	28-05-2015	NONE	
WO 2014042104 A1	20-03-2014	CN 104620569 A	13-05-2015
		EP 2896201 A1	22-07-2015
		JP 6065474 B2	25-01-2017
		JP 2014057156 A	27-03-2014
		US 2015222816 A1	06-08-2015
		WO 2014042104 A1	20-03-2014
US 2017094169 A1	30-03-2017	CA 2949473 A1	03-12-2015
		CN 106416226 A	15-02-2017
		EP 3149931 A1	05-04-2017
		JP 6467787 B2	13-02-2019
		JP 2015226144 A	14-12-2015
		KR 20160148635 A	26-12-2016
		PH 12016502339 A1	13-02-2017
		US 2017094169 A1	30-03-2017
		WO 2015182626 A1	03-12-2015
US 2017070689 A1	09-03-2017	US 2017070689 A1	09-03-2017
		WO 2017044292 A1	16-03-2017
US 2011242352 A1	06-10-2011	CN 102236896 A	09-11-2011
		US 2011242352 A1	06-10-2011

Information on Search Strategy - Pilot phase (see OJ 2015, A86)
The type of information contained in this sheet may change during the pilot for improving the usefulness of this new service.

Application Number
PCT/US2019/020241

TITLE: IMAGE SIGNAL PROCESSING FOR REDUCING LENS FLARE

APPLICANT: GOPRO, INC.

IPC CLASSIFICATION: G06T5/00, G06T5/50

EXAMINER: Tillier, Christophe

CONSULTED DATABASES: WPI, EPODOC, INET

CLASSIFICATION SYMBOLS DEFINING EXTENT OF THE SEARCH:

IPC:

CPC: G06T5/006, G06T5/50, G06T2207/10012, G06T2207/20221

FI/F-TERMS:

KEYWORDS OR OTHER ELEMENTS FEATURING THE INVENTION:
lens flare
multi-camera
overlap
flare model

EPO FORM P04A42

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:

see form PCT/ISA/220

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing
(day/month/year) see form PCT/ISA/210 (second sheet)

Applicant's or agent's file reference
see form PCT/ISA/220

FOR FURTHER ACTION
See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/020241	01.03.2019	21.05.2018

International Patent Classification (IPC) or both national classification and IPC
INV. G06T5/00 G06T5/50

Applicant
GOPRO, INC.

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☒ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will usually be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notifed the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA:	Date of completion of this opinion	Authorized Officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Fax: +49 89 2399 - 4465	see form PCT/ISA/210	Tillier, Christophe Telephone No. +49 89 2399-0

Form PCT/ISA/237 (Cover Sheet) (January 2015)

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1 (b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	8-15
	No:	Claims	1-7
Inventive step (IS)	Yes:	Claims	8-15
	No:	Claims	1-7
Industrial applicability (IA)	Yes:	Claims	1-15
	No:	Claims	

2. Citations and explanations

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1 US 2013/329132 A1 (TICO MARIUS [US] ET AL) 12 December 2013 (2013-12-12)

D2 US 2017/359534 A1 (LI XIAOXING [US] ET AL) 14 December 2017 (2017-12-14)

D3 US 2015/146014 A1 (BLACK ROBERT A [US] ET AL) 28 May 2015 (2015-05-28)

D4 WO 2014/042104 A1 (RICOH CO LTD [JP]; SHOHARA MAKOTO [JP] ET AL.) 20 March 2014 (2014-03-20)

D5 US 2017/094169 A1 (YOSHIKAWA HIROMI [JP] ET AL) 30 March 2017 (2017-03-30)

D6 US 2017/070689 A1 (SILVERSTEIN D AMNON [US] ET AL) 9 March 2017 (2017-03-09)

D7 US 2011/242352 A1 (HIKOSAKA KENTARO [JP]) 6 October 2011 (2011-10-06)

D1 (the whole document) discloses a non-transitory computer-readable storage medium (see claim 9), comprising executable instructions that, when executed by a processor, facilitate performance of operations, comprising:

obtaining a first input frame captured by a first image capture device of an image capture apparatus, the first image capture device having a first field-of-view, and the first input frame including lens flare corresponding to a primary light source (see par. [0025]);

obtaining a second input frame captured by a second image capture device of the image capture apparatus, the second image capture device having a second field-of-view partially overlapping the first field-of-view (see par. [0025] and [0030]);

obtaining primary light source information corresponding to the primary light source based on the first input frame and the second input frame (block 720 on fig. 7 and par. [0041]);

obtaining a processed frame by modifying the first input frame based on the primary light source information to minimize the lens flare (block 730 on fig. 7 and par. [0041]); and

outputting the processed frame (included in block 730 on fig. 7 and par. [0041]).

The present application does not meet the criteria of Article 33(2) PCT, because the subject-matter of claim 1 is not new.

Dependent claims 2-7 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, at least for the following reasons:

- claims 2-6, see D1 par. [0024]-[0042], but especially par. [0041], the predicted alignment of claim 6 corresponding to the term "corresponding pixels" in par. [0041]; and

- claim 7 : the model in D1 is that the image areas affected by flare tend to have a specific color, see D1 par. [0031].

As below-mentioned (Re Item VIII) the subject-matter of claims 8-15 is highly not clear, and therefore it is not possible to give a full opinion concerning novelty and inventive step of these claims. However, and as far as it can be understood from the application as a whole (and especially from fig. 10 and associated text, par. [0182]-[0204]), it seems that a clarified wording of these claims could lead to a novel and inventive set of claims. The applicants should as well take documents D1-D7 into account for further amendments.

Re Item VIII

Certain observations in the international application

The application does not meet the requirements of Article 6 PCT, because claims are not clear, at least for the following reasons:

- it is not clear to what refer the terms "minimize" and "omits" in claims 2, 4 and 3;

- in claims 8 and 11 it is not clear to what refer the first image circle and the second image circle based on respectively the first field-of-view and the second field-of-view;

- in claim 8 and 12 it is not clear to what refers the dark corner profile;

- the subject-matter of claim 8 seems to correspond to fig. 10 and associated text (par. [0182]-[0204]), but neither fig. 10 nor its associated text seems to disclose the step of obtaining primary light source information corresponding to the primary light source based on the first input frame and second input frame. The same remark holds for the step of obtaining an intensity difference between the primary light source information and the dark corner profile;

- in claims 8 and resp. 11, it is not clear how the step of obtaining a flare model is obtained. Especially, this step is not linked to the other steps of claim 8. Moreover, in claim 8 the flare model is obtained after having obtained primary light source information, contrary to claim 11 in which the flare model is used for obtaining the primary light source information. Again, both claims seem to fig. 10 and associated text (par. [0182]-[0204]) and therefore should claim basically the same subject-matter;

- in claim 11, the passage "to modify the first input frame, the image signal processor is configured to apply the flare model to the first input frame based on the primary light source information" seems useless since only the processed frame is output by the apparatus and the processed frame has already been obtained beforehand in the claim; and

- since claims 8 and 11 are not clear, their dependent claims (9, 10 and 12-15) are as well not clear.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
D. BENJAMIN ESPLIN
C/O ESPLIN & ASSOCIATES, PC
5411 AVENIDA ENCINAS
STE. 100
CARLSBAD, CALIFORNIA 92008
UNITED STATES OF AMERICA

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference **46DG-026028**	Date of mailing *(day/month/year)*
International application No. **PCT/US2019/031591**	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
Applicant **GOPRO, INC.**	International filing date *(day/month/year)* **09 May 2019 (09.05.2019)**

1. ☑ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

   Within **19 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45bis.1). The procedure for requesting supplementary international search is described in the PCT Applicant's Guide, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US **COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA**	Authorized officer **HARRY C. KIM**
Facsimile No. **(571)273-8300**	Telephone No. **571-272-4300**

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
D. BENJAMIN ESPLIN
C/O ESPLIN & ASSOCIATES, PC
5411 AVENIDA ENCINAS
STE. 100
CARLSBAD, CALIFORNIA 92008
UNITED STATES OF AMERICA

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)* 18 JUN 2019
Applicant's or agent's file reference **46DG-026028**	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. **PCT/US2019/031591**	International filing date *(day/month/year)* **09 May 2019 (09.05.2019)**
Applicant **GOPRO, INC.**	

1. [✓] The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. [ ] The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. [ ] **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   [ ] the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   [ ] no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

   Within **19 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45bis.1). The procedure for requesting supplementary international search is described in the PCT Applicant's Guide, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US **COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA**	Authorized officer **HARRY C. KIM**
Facsimile No. **(571)273-8300**	Telephone No. **571-272-4300**

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
46DG-026028		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2019/031591	**09 May 2019 (09.05.2019)**	**18 May 2018 (18.05.2018)**
Applicant	**GOPRO, INC.**	

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

   a. With regard to the **language**, the international search was carried out on the basis of:

   ☑ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

   ☑ the text is approved as submitted by the applicant.

   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

   ☑ the text is approved as submitted by the applicant.

   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

   a. the figure of the **drawings** to be published with the abstract is Figure No. 1

   ☑ as suggested by the applicant.

   ☐ as selected by this Authority, because the applicant failed to suggest a figure.

   ☐ as selected by this Authority, because this figure better characterizes the invention.

   b. ☐ none of the figures is to be published with the abstract.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/031591

A. CLASSIFICATION OF SUBJECT MATTER

IPC: H04N 5/232
CPC: H04N 5/23258

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

CPC: H04N 5/23258, 5/23267, 5/2252

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST: US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB; Search Terms: futur$4, ahead$4, look-ahead, captur$4, trajectory, path, observat$4, position, route, preced$4, ahead, subsequent, timing, time, moment, housing, enclosure, body, rotat$4, orientation, motion$4, movement, future, preceding, unintended, error, location, state, condition, imag$4, shoot$4, stabiliz$4, smooth$4, correct$, compensat$4, look$4

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018/0324358 A1 (YAMADA ET AL.) 08 November 2018 (08.11.2018), entire document.	1-20
A	US 2017/0289454 A1 (PATTERSSON) 05 October 2017 (05.10.2017), entire document.	1-20
A	US 2006/0291841 A1 (FUKUMOTO ET AL.) 28 December 2006 (28.12.2006), entire document.	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 June 2019 (13.06.2019)	18 JUN 2019
Name and mailing address of the ISA/US COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA Facsimile No. (571)273-8300	Authorized officer HARRY C. KIM Telephone No. 571-272-4300

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
D. BENJAMIN ESPLIN
C/O ESPLIN & ASSOCIATES, PC
5411 AVENIDA ENCINAS
STE. 100
CARLSBAD, CALIFORNIA 92008
UNITED STATES OF AMERICA

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	18 JUN 2019
Applicant's or agent's file reference: 46DG-026028	FOR FURTHER ACTION: See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/031591	09 May 2019 (09.05.2019)	18 May 2018 (18.05.2018)

International Patent Classification (IPC) or both national classification and IPC
IPC: H04N 5/232
CPC: H04N 5/23258

Applicant: GOPRO, INC.

1. This opinion contains indications relating to the following items:

- [x] Box No. I — Basis of the opinion
- [ ] Box No. II — Priority
- [ ] Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV — Lack of unity of invention
- [x] Box No. V — Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI — Certain documents cited
- [ ] Box No. VII — Certain defects in the international application
- [ ] Box No. VIII — Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA	13 June 2019 (13.06.2019)	HARRY C. KIM
Facsimile No. (571)273-8300		Telephone No. 571-272-4300

Form PCT/ISA/237 (Cover sheet) (January 2015)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/031591

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
   - [✓] the international application in the language in which it was filed.
   - [ ] a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. [ ] This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:
   - a. [ ] forming part of the international application as filed:
     - [ ] in the form of an Annex C/ST.25 text file.
     - [ ] on paper or in the form of an image file.
   - b. [ ] furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
   - c. [ ] furnished subsequent to the international filing date for the purposes of international search only:
     - [ ] in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).
     - [ ] on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. [ ] In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/031593

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	1-20	YES
	Claims	NONE	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations :

---------- EXPLANATION ----------

Claim(s) 1-20 meet the criteria set out in PCT Article 33(2)-(3) because the prior art does not teach or fairly suggest the claimed invention.

Claim(s) 1-20 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.

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Stabilizing Omnidirectional Videos Using 3D Structure and Spherical Image Warping

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Abstract

This paper addresses the problem of stabilizing spherical videos. Whereas various techniques have been proposed to stabilize conventional videos, this work is the first approach proposed for omnidirectional videos. We introduce a method for extracting the camera path and 3D information of the environment. A desired smooth stabilized path is obtained by modifying the original camera path. We propose a method for synthesizing a stabilized video with respect to the desired path. Each output frame is generated by warping a single frame from the input video. Experiments on real data show that the proposed approach removes shakes and jitters from omnidirectional videos successfully.

1 Introduction

A wide gap exists between the quality of amateur and professional videos. One of the most important reasons is the unwanted motions of camera which implies shakes and jitters in amateur videos, which implies shakes and jitters in amateur videos, while shooting amateur videos. Whereas, professional videos are shot under controlled conditions with a smooth camera motion. The aim of *video stabilization* is to remove shakes from videos.

Existing methods are developed for *conventional* videos, which are obtained by perspective (pinhole) cameras. These cameras have a limited view angle. Cameras able to capture the entire environment are becoming more popular and being applied to various tasks [10, 18]. Frames acquired by these cameras are called *omnidirectional* because they can observe in all the directions.. Since omnidirectional images capture data from the entire environment, they contain more information. Hence, it is preferable to use these videos instead of conventional ones in numerous applications like autonomous vehicle driving, localization, and digital mapping [2].

Omnidirectional cameras usually consist of a cluster of conventional cameras. Each camera takes a picture of a portion of the space, then all these pictures are stitched to form a single image. Displaying omnidirectional images is not as straightforward as conventional ones. One method is to expand them on a 2D plane which is called the *panoramic representation* (Fig. 1-left). Another method to represent omnidirectional images is the *spherical representation* where the image is mapped on a unit sphere (Fig. 1-right). Since epipolar geometry properties for spherical images are similar to those of conventional images, we consider spherical images in this work.

Since pinhole camera properties are not satisfied in panoramic representation of omnidirectional images,



Figure 1. Panoramic (left) and spherical (right) representation of omnidirectional images.

we cannot apply existing methods for conventional images on them. Therefore, new approaches should be developed for omnidirectional images. Our work is the first method which can perform video stabilization for omnidirectional videos; specifically, for spherical images. We also propose a structure from motion technique for spherical images in this paper. One of the advantages of using spherical images is that we can apply this method on all central omnidirectional videos (e.g. aligned camera cluster, central catadioptric sensors, fisheyes, etc) since all of them can be represented in the spherical representation [1, 15]. Furthermore, in conventional image stabilization, some empty regions appear in the margin of the output image because of the deformation. To remove these regions, most methods crop images so that the resolution of the output video becomes lower than the input video. In spherical images we can naturally overcome this problem. Also, our method synthesizes each output frame using a single input frame; therefore, it prevents ghosting regions in the presence of dynamic objects.

2 Related Work

Most video stabilization methods consist of three main steps: motion estimation, motion compensation, and image composition [16]. The task of motion estimation aims to compute the camera trajectory, given a motion model (e.g. homography, or essential matrix). The smoother these motions are, the less shakes the video has. Original motions are smoothed in the compensation step, and a stabilized video is synthesized in the third step. Stabilization methods can be divided into two main groups based on considering 2D or 3D motions.

2D approaches consider motions of interest points on the image plane. A common method is to study pixel motions between two successive frames by estimating a homography and smoothing all homographies in the whole sequence. In [6], authors use optical flow to detect a large planar region and fit a homography to that region. Although homography-based approaches perform well for planar scenes or when objects and

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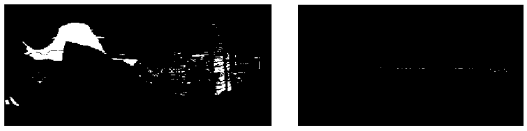


Figure 2. Trajectories extracted from the input video (left). SfM result: the camera path and 3D points corresponding to the trajectories (right).

buildings are far enough from the camera, they fail in highly non-planar scenes with different depths. To solve this problem, a 2.5D motion model is proposed in [7]. An approach for smoothing using Kalman filter is proposed in [11] and an image alignment method for motion estimation in [19]. Most of these methods damp shakes and jitters between two successive frames. In [9], authors propose a method to consider more than two frames. They track some interest points in the video and extract their trajectories. Then, these 2D trajectories are smoothed and the original frames are deformed with respect to them.

One of the drawbacks of considering 2D motions is that they do not contain all information of the motion because motions are happened in 3D. Hence, some people believe considering 3D motions instead of 2D motions leads to better results. 3D motion of a camera corresponds to its location and orientation while shooting the video. One may consider replacing the original camera path with a smoother one along which if the camera had moved, the video would have had less shakes. We propose a 3D approach for omnidirectional videos in this paper.

Different approaches have been proposed to smooth the original camera path and synthesize a new video for it. A method using motion inpainting for full-frame stabilization and deblurring is proposed in [14]. In [3], a method based on non-metric scene reconstruction for un-calibrated video sequences is proposed. It renders each output frame using multiple input frames. The drawback of this method is that dynamic objects are ghosting in output frames. To avoid this problem, authors in [12] propose a method which uses a single frame. They consider a grid on the input frame and find its corresponding grid in the output frame and use texture mapping to synthesize the output frame.

3 Obtaining a Desired Camera Path

In this section, we explain how the original camera path is estimated and a desired smooth path is obtained.

3.1 Extracting the Original Camera Path

We build a number of trajectories in the input video (Fig. 2-left) by detecting and tracking interest points in successive frames. Interest points can be detected and described using SIFT [13] on panoramic images or SIFTS [4] on spherical images.

These feature trajectories are used to obtain the camera path using *Structure from Motion* (SfM) for spherical images. The aim of SfM is to estimate a set of points cloud and camera poses. The points cloud $\{\mathbf{X}\}$ contains 3D points whose projections in the images are referred as trajectories. The camera poses consist of two components: location and orientation.

We propose an SfM method for spherical images in this paper. The camera poses of the first two frames of the sequence are estimated by decomposing the essential matrix using the method proposed in [17]. The points cloud is initialized by back projecting points observed from the first two frames and finding their intersections. The camera pose, location and orientation, for the third spherical frame is obtained by minimizing the reprojection error between projection of the points cloud and feature points obtained by SIFT. The points cloud is updated by adding new points which were not back projected previously. This process is performed for each frame in the sequence, frame by frame. After a certain number of frames, we refine the estimations of all camera poses and the points cloud obtained so far by minimizing the reprojection error.

Once camera poses of all frames in the sequences are estimated, all camera poses and the points cloud are refined by using a bundle adjustment method that we have developed for spherical images. Let $\mathbf{X}_p \in \{\mathbf{X}\}$ be corresponding to trajectory p. We project this point in a frame f where it is observed using equation

$$\mathbf{x}_{fp} = \mathbf{R}_f^\top (\mathbf{X}_p - \mathbf{T}_f) \tag{1}$$

where $\mathbf{R}_f$ and $\mathbf{T}_f$ are the rotation and translation, respectively, for frame f, and $\mathbf{x}_{fp}$ is on the unit sphere. Let $\mathbf{x'}_{fp}$ be the corresponding point to $\mathbf{X}_p$ extracted by SIFT in frame f. We minimize the angle $\Delta\theta_{fp}$ between all corresponding points $\mathbf{x}_{fp}$ and $\mathbf{x'}_{fp}$ as follows

$$\min_{\{\mathbf{X}_p, \mathbf{R}_f, \mathbf{T}_f\}} \sum_p \sum_f w_{fp} (\Delta\theta_{fp})^2 \tag{2}$$

where w_{fp} is 1 if $\mathbf{X}_p$ is observed at frame f and is zero otherwise. A result of SfM is shown in (Fig. 2-right).

3.2 Estimating a Desired Smooth Path

A desired path is one along which if the camera had moved, we would have had a less shaky movie. To obtain a desired path, we modify the pose of each camera so that the whole path becomes smoother. Camera locations can be represented as 3D translation vectors and camera orientations as rotation matrices. We smooth translation component by Gaussian smoothing applied element-wisely. Since the space of rotation matrices is not linear, theoretically rotation matrices cannot be smoothed element-wisely using Gaussian filtering. In [8], a method is proposed for smoothing a sequence of rotation matrices by transferring them into a linear space. However, experimental results show that if we consider quaternion representation of rotation and smooth them using Gaussian filter, we can obtain good results. Also, in specific scenarios we can fit a certain model to our data. For example, if we know that the camera moved on a straight line without rotation, we can assign a constant rotation to all frames. This can be performed by considering the average value of quaternions.

4 Synthesizing a New Video

After obtaining a desired path, we generate a stabilized video which would have been shot if the camera

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had moved along this path. For each frame I from the original video, we synthesize a corresponding stabilized frame I'. 3D points from the point cloud obtained by SfM which are observed from I are likely observed from I' too. We project these points into both frames to obtain some corresponding points. These corresponding points guide us to warp I to obtain I'. However, these points are distributed sparsely on the image, and some regions may not contain any points. This causes an inaccurate warping. To generate an appropriate output frame, we consider a structure for I and preserve this structure in I'. Our approach is inspired from [12]. Their method is developed for conventional images but we propose a triangular grid on the surface of a unit sphere as the structure for omnidirectional images (Fig. 3-left). Corresponding points are utilized to find a similar corresponding triangular grid in I'.

Assume we have a triangular grid on spherical image I and we want to find its corresponding grid on I'. Let $\mathbf{P}_j$ and $\mathbf{P}'_j$ be the projections of a point from the point cloud in images I and I', respectively. Let $\mathbf{P}_j$ be inside triangle $\mathbf{V}_i$ whose vertices are $\mathbf{V}_i^1$, $\mathbf{V}_i^2$ and $\mathbf{V}_i^3$, and also assume $\mathbf{P}'_j$ is inside triangle $\mathbf{V}'_i$ whose vertices are $\mathbf{V'}_i^1$, $\mathbf{V'}_i^2$ and $\mathbf{V'}_i^3$. Vertices of triangles $\mathbf{V}_i$ and $\mathbf{V}'_i$ should represent corresponding points. We expect the relative position of $\mathbf{P}'_j$ to its surrounding triangle in I' to be similar to the relative position of $\mathbf{P}_j$ to its surrounding triangle in I because the structure of the grid is preserved. This relative position for $\mathbf{P}_j$ can be represented by linear combination

$$\mathbf{P}_j = \sum_{k=1}^{3} w_k \mathbf{V}_i^k. \tag{3}$$

Since the relative position of $\mathbf{P}_j$ and $\mathbf{P}'_j$ to their surrounding triangles are similar, the following equation should be satisfied for $\mathbf{P}'_j$

$$\mathbf{P'}_j = \sum_{k=1}^{3} w_k \mathbf{V'}_i^k \tag{4}$$

where w_k are computed in Eq. (3), and $\mathbf{V'}_i^k (k = 1, 2, 3)$ are unknown. We can estimate these unknown variables by solving the minimization problem

$$E_{data} = \sum_j \|\mathbf{P'}_j - \sum_{i=1}^{3} w_k \mathbf{V'}_i^k\|^2 \tag{5}$$

for all points $\mathbf{P}'_j$ projected from the points cloud.

Since we have just a few corresponding points between I and I', many triangles may not contain any points; hence, their vertices do not appear in Eq. (5). To solve this problem, we added a term which considers all vertices of the grid, similar to [12]. Since the new camera pose and the original one are close to each other, the relative positions of vertices in two corresponding triangles should be similar. A relative position proposed in [5] is utilized in this work.

Consider a triangle cell in the original frame, which lies on the surface of the unit sphere. Each vertex of this cell can be represented with respect to a local coordinate system whose axes are the direction of the line connecting two other vertices and its 90 degrees rotation (Fig. 3-right). This can be written as follows

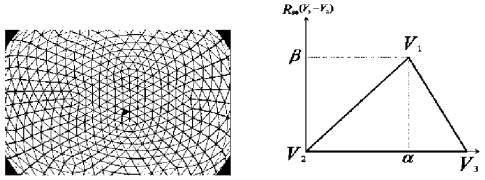


Figure 3. A uniform triangular grid on the unit sphere (left) which is used to preserve the structure of the input image, and a cell of this grid (right) to explain the relative location of one of its vertices with respect to other two vertices.

$$\mathbf{V}_1 = \mathbf{V}_2 + \alpha(\mathbf{V}_3 - \mathbf{V}_2) + \beta \mathbf{R}_{90}(\mathbf{V}_3 - \mathbf{V}_2) \tag{6}$$

where $\mathbf{R}_{90}$ is a 90 degrees rotation matrix in the plane on which the triangle lies, and α and β are the coordinates of $\mathbf{V}_1$ with respect to $\mathbf{V}_2$ and $\mathbf{V}_3$. Since we preserve the structure of the grid, the same relation should be satisfied for the corresponding cell in the new frame. We consider this for all vertices of all triangles. We will have the minimization term

$$E_{struct} = \sum \|\mathbf{V'}_2 + \alpha(\mathbf{V'}_3 - \mathbf{V'}_2) + \beta \mathbf{R}_{90}(\mathbf{V'}_3 - \mathbf{V'}_2) - \mathbf{V'}_1\|^2 \tag{7}$$

for all triangles in the grid.

To obtain the vertices of the grid in the output frame, we solve a constrained minimization problem whose objective function is

$$E = E_{data} + \lambda E_{struct} \tag{8}$$

and constraints are forcing each vertex to have unit length because they should lie on the unit sphere. We applied a simple Levenberg-Marquardt minimization, which provided satisfying results.

After obtaining the grid in the output image, we perform texture mapping to fill inside each triangle on the surface of the unit sphere to synthesize the final output.

5 Experimental Results

We applied our method on various videos shot by an omnidirectional camera, LadyBug2[1]. This system consists of 6 cameras and is able to capture data from more than 70 percent of the full sphere around it. Videos are very shaky because the system was mounted on a helmet and carried by a pedestrian. Results show that our approach removes shakes successfully.

First, we extract some trajectories from the input video. We use SIFT for detecting and describing interest points in the panoramic representation. Then, interest points are transferred on the equivalent unit sphere and next steps are performed considering the unit sphere. Trajectories on the sky are removed because they are not useful in SfM. Our proposed SfM method for spherical images is used to estimate the

[1] http://www.ptgrey.com/products/ladybug2/

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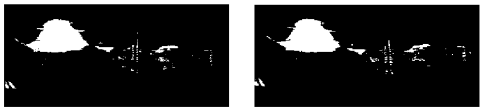


Figure 4. Feature trajectories before stabilization on the original frame (left) and after on the synthesized frame (right).

camera path and 3D structure. The original camera path is smoothed to obtain a desired path. We apply the Gaussian filter element wisely to the location component and quaternion representation of the orientation component. If the camera had moved along this desired path, the video would have not had shakes. We synthesize a new video with respect to the desired path.

To synthesize an output frame, we consider a uniform triangular grid on its corresponding spherical input frame. This grid has 642 vertices and partitions the surface of the unit sphere to 1280 triangles. The corresponding grid for the output frame is estimated using the method explained in section 4. Then, the content of the input frame is transferred to the output frame by mapping texture of each triangle from the input frame to its corresponding triangle in the output frame.

A comparison between point trajectories of the original video and stabilized video can show how our method works. If a video is shaky, its feature trajectories will have many jitters but if it is smooth, these trajectories will be smooth too. Trajectories in (Fig. 4-left) are extracted from the original video, and in (Fig. 4-right) from the stabilized video obtained by the proposed approach. It is easy to see that the trajectories in the output video are smooth while trajectories in the input video have many jitters. This indicates that our method succeeds to remove shakes.

6 Conclusion

This paper addresses the stabilization of omnidirectional videos. One of the contributions of this paper is proposing an SfM method for spherical images. The original camera motion is estimated using this SfM method and a desired trajectory is obtained by smoothing the original motion. Then, a new video is synthesized with respect to this desired path. This work is the first method for stabilizing omnidirectional videos. One of the advantages of using spherical images is that all representations of central omnidirectional systems can be converted to the spherical representation. Furthermore, in conventional videos the resolution of the output video is lower than the input video because frames are cropped to remove blank margins. In spherical images we can naturally overcome this problem. Also, our method can work in presence of dynamic objects because it uses a single image from the input video to synthesize its corresponding output frame. Experimental results on challenging real data show that our method works successfully.

Acknowledgments

This research is sponsored, in part, by Ministry of Education, Culture, Sports, Science and Technology under Digital Museum Project. It is also supported, in part, by Global Research Network Program (No. D00096(I00363)) of National Research Foundation of Korea.

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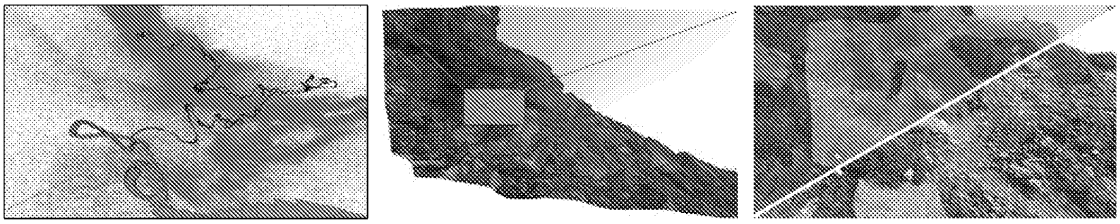
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First-person Hyper-lapse Videos

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(a) Scene reconstruction (b) Proxy geometry (c) Stitched & blended

Figure 1: *Our system converts first-person videos into hyper-lapse summaries using a set of processing stages. (a) 3D camera and point cloud recovery, followed by smooth path planning; (b) 3D per-camera proxy estimation; (c) source frame selection, seam selection using a MRF, and Poisson blending.*

Abstract

We present a method for converting first-person videos, for example, captured with a helmet camera during activities such as rock climbing or bicycling, into *hyper-lapse* videos, i.e., time-lapse videos with a smoothly moving camera. At high speed-up rates, simple frame sub-sampling coupled with existing video stabilization methods does not work, because the erratic camera shake present in first-person videos is amplified by the speed-up. Our algorithm first reconstructs the 3D input camera path as well as dense, per-frame proxy geometries. We then optimize a novel camera path for the output video that passes near the input cameras while ensuring that the virtual camera looks in directions that can be rendered well from the input. Finally, we generate the novel smoothed, time-lapse video by rendering, stitching, and blending appropriately selected source frames for each output frame. We present a number of results for challenging videos that cannot be processed using traditional techniques.

CR Categories: I.3.8 [Computer Graphics]: Applications;

Keywords: hyper-lapse, time-lapse, image-based rendering

Links: DL PDF WEB VIDEO DATA CODE

1 Introduction

Yesterday's cameras were expensive, heavy, and difficult to operate devices, but those days are past. Today, digital cameras are cheap, small, easy to use, and have become practically ubiquitous. Cameras are now commonly attached to our cars, computers, phones and wearable cameras are becoming popular. Well known examples of wearable cameras include the GoPro, the Sony Action Cam, and Google Glass. We call these *first-person cameras*, since the action is seen as if through the eye of the camera operator.

First-person cameras are typically operated hands-free, allowing filming in previously impossible situations, for example during extreme sport activities such as surfing, skiing, climbing, or even sky diving. In many cases, first-person video is captured implicitly, rather than through explicit start-stop commands. Processing and consuming the resulting videos poses significant challenges for casual users. Such videos suffer from erratic camera shake and changing illumination conditions. More importantly, however, the videos are usually long and monotonous, which makes them boring to watch and difficult to navigate.

There has been a substantial amount of work on extracting important scenes from video [Chen et al. 2007; Detyniecki and Marsala 2008; Money and Agius 2008]. However, these techniques require high level scene understanding and have not reached a level of robustness that would make them practical for real-world tasks. A simpler and more robust technique that does not require scene understanding is time-lapse, i.e., increasing the speed of the video by selecting every n-th frame. Most first-person videos depict moving cameras (e.g., walking, hiking, climbing, running, skiing, train rides, etc.). Time-lapse versions of such videos are sometimes called *hyper-lapse* to emphasize that the camera is moving through space as well as accelerated through time.

Carefully controlled moving camera videos, such as those mounted on the front of a train, or extracted directional subsets of street-view panoramas, can be easily processed into hyper-lapse videos such as those at `http://hyperlapse.tllabs.io/` and `http://labs.teehanlax.com/project/hyperlapse`. Unfortunately, more casually captured videos such as from walking, running, climbing, or helmet mounted cameras during bicycling have significant shake and/or twists and turns. Increasing the frame rate of such videos amplifies the camera shake to the point of making these videos un-watchable.

Video stabilization algorithms could conceivably help create smoother hyper-lapse videos. Although there has been significant recent progress in video stabilization techniques (see Section 2), they do not perform well on casually captured hyper-lapse videos.

The dramatically increased camera shake makes it difficult to track the motion between successive frames. Also, since all methods operate on a single-frame-in-single-frame-out basis, they would require dramatic amounts of cropping. Applying the video stabilization *before* decimating frames also does not work because the methods use relatively short time windows, so the amount of smoothing is insufficient to achieve smooth hyper-lapse results.

In this paper, we present a method to create smooth hyper-lapse videos that can handle the significant motion noise in casually captured moving first-person videos. Similar to some previous stabilization techniques, we use structure-from-motion to build a 3D model of the world. We extend these techniques to a larger scale than previous work. We also compute per-frame 3D proxies for later use in our image-based rendering stage (Figure 1a–b).

The reconstructed camera positions plus geometric model allows us to optimize a new smoothed camera path in 6D pose space. Most previous methods employ relatively simple path smoothing algorithms, for example low-pass temporal filtering. With the substantial amount of smoothing required for time-lapse videos, simple algorithms do not give good results. In Section 5, we describe a novel optimization-based approach that balances several objectives.

Finally we render our output hyper-lapse video. Unlike previous stabilization work, we combine several input frames to form each output frame to avoid the need for over-cropping (see Figures 1c and 7). We leverage the recovered camera parameters and local world structure using image-based rendering techniques to reconstruct each output frame. We show resulting hyper-lapse videos from a number of input videos and discuss limitations and ideas for future work.

2 Previous Work

Our work is related to previous work in 3D video stabilization, 3D scene reconstruction, and image-based rendering.

Traditional video stabilization techniques use parameteric global transforms such as translations and rotations (optionally followed by local refinements), since these can be estimated quickly and robustly [Matsushita et al. 2006]. More recent techniques perform a full or partial (e.g., projective) reconstruction of the scene and camera motion. Liu et al. [2009] compute 3D camera trajectories and sparse 3D point clouds, which are then used to compute local "content-preserving" warps of the original video frames. In subsequent work, they extend their technique to work in cases where accurate 3D motion and geometry may not be available using subspace constraints on motion trajectories [Liu et al. 2011].

Grundmann et al. [2011] optimize the camera path based on L_1 norms of pose and its derivatives, which better simulate the actions of studio cameras. They also investigate the use of seam carving (video retargeting) techniques. Goldstein and Fattal [2012] use non-metric projective reconstruction and epipolar transfer to stabilize videos, again for cases where full 3D reconstructions cannot be reliably obtained, such as scenes with moving objects. Finally, Liu et al. [2013] use bundles of local camera paths to handle non-rigid effects such as rolling shutter while also minimizing geometric distortions. In our work, we also use 3D camera path reconstruction, but we synthesize our final frames from multiple source frames using image-based rendering.

In order to compute our 3D camera motions and scene proxies, we build upon techniques from structure-from-motion, which has seen dramatic progress in recent years [Snavely et al. 2006; Crandall et al. 2013; Wu 2013]. Similar to many of these papers, we use an incremental approach that adds well estimated cameras to the current 3D reconstruction. To handle our large datasets, we first remove redundant frames and then partition the frames into overlapping blocks. In order to estimate continuous 3D proxies for each frame, we interpolate a densified version of the 3D point cloud. Details on these components are presented in Section 4.

3 Overview

We captured first-person videos of several sport activities, such as cycling, hiking, or climbing, with GoPro Hero2 and Hero3 cameras (Table 1). The videos range from 3 to 13 minutes. Our goal is to speed these up by a factor of about $10\times$. As we show in Section 7, the amplification of camera shake resulting from the speed-up greatly exceeds the smoothing capabilities of existing video stabilization technologies.

The key to achieving better results with our system is in reconstructing an accurate representation of the scene, which allows us to optimize a new camera path in 6D pose space that is smooth while not deviating too far from the original cameras. It also supports using image-based rendering techniques and fusing multiple input frames to produce one output frame.

Our method consists of three stages:

1. **Scene reconstruction:** using structure-from-motion algorithms followed by dense depth map interpolation (Section 4);
2. **Path planning:** optimizing a 6D camera path that is smooth in location and orientation, passes near all of the input cameras, and is oriented towards directions which we can render well (Section 5);
3. **Image-based rendering:** projecting, stitching, and blending carefully selected input frames with per-frame proxy geometry (Section 6).

4 Scene Reconstruction

In the first stage of our system, we reconstruct both scene geometry and camera positions for each frame of the input.

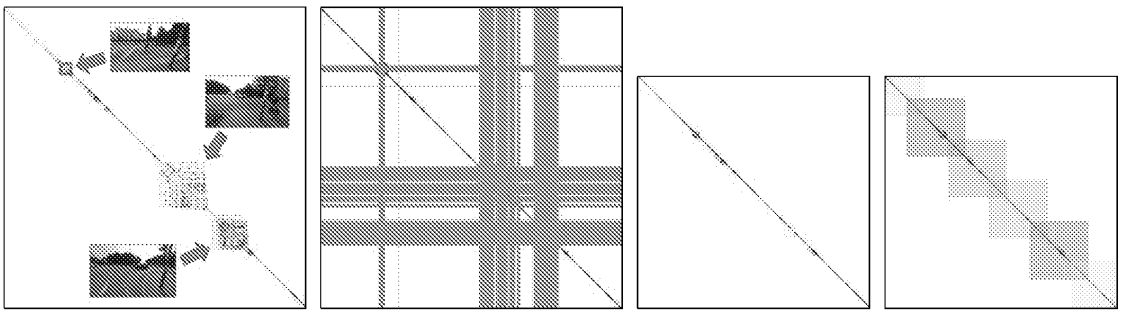
4.1 Preprocessing

The GoPro cameras we use capture video in a fish-eye projection with about 170° *diagonal* field of view. We use the OCamCalib toolbox [Scaramuzza et al. 2006] to calibrate the lens distortion and convert the videos to (cropped) linear perspective projection. While this change of projection is not strictly necessary, it simplifies the implementation of the remaining steps while removing only the most distorted corners of the fisheye images. The converted perspective input videos have a field of view of about $112^\circ \times 86^\circ$ in the horizontal and vertical directions, respectively.

4.2 Structure-from-Motion

Once these images have been reprojected, our next step is to estimate the extrinsic camera parameters of the input video frames as well as depth maps for the input images. This problem can be solved using structure-from-motion algorithms. We use an incremental algorithm similar to the ones described by Snavely et al. [2006] and Wu [2013]. The algorithm estimates the location and orientation of the input cameras. In addition, it computes a sparse 3D point cloud, where each point has an associated list of frames where it is visible.

The algorithm starts by finding feature points in every image and matching them among all pairs. For a small percentage of frames



(a) Original match graph (b) Redundant frames (c) Reduced match graph (d) Partition into batches

Figure 2: *Removing rendundant frames and batch processing. Places where the camera has stopped moving, e.g., at a red light, show up as blocks on the diagonal of the match graph. We detect and remove these, and partition the resulting reduced match graph into overlapping blocks for independent processing.*

that are strongly affected by motion blur or are completely textureless the algorithm might not find enough feature points that can be reliably matched. We drop these frames from the reconstruction and ignore them in the subsequent stages. Next, we remove redundant frames by searching for rows and columns in the match table that have large off-diagonal components and removing these from the original set of video frames (Figures 2a–c). We then run the remainder of the incremental structure-from-motion pipeline.

A difficulty with this approach is that incremental structure-from-motion algorithms do not scale well to problems as large as ours. In fact, we terminated an initial attempt to reconstruct a long video after a week of runtime. To alleviate this problem, we divide our datasets into overlapping batches of 1400 frames each with 400 frames overlap and reconstruct each batch separately in parallel (Figure 2d), which takes less than an hour for each batch.

To combine the batches into a single global coordinate system we first compute the best rigid alignment between all pairs using Horn's method [1987]. The cameras within the overlaps between batches now have 2 coordinates. We resolve the ambiguity by linearly combining them, where the blending weight moves from 0 to 1 in the overlap zone. Finally, we run one more round of bundle adjustment on the global system. After having obtained the full reconstruction, we scale it so that the average distance between two consecutive input cameras is 1. Figure 1a shows an example of the estimated camera path and sparse 3D point cloud produced by this pipeline.

4.3 Proxy Geometry

The reconstruction described in the previous subsection is sparse, since the depth is only known at a few isolated points in each frame. Accurately rendering the frame's geometry from a novel viewpoint requires dense depth maps or surface models. In this section, we describe how we use interpolation techniques to obtain smooth proxy geometries. To get the best quality, however, we need to first increase the density of points within each frame.

For this, we turn to *guided matching* [Beardsley et al. 1996]. Since we now have a good estimate of the camera poses, we can run feature point matching again but in a less conservative manner. Since a feature point in one image has to lie along the epipolar line in the neighboring images, we only match with other feature points nearby this line (we use a rather large search radius of 10 pixels to account for rolling shutter distortion). This dramatically increases the likelihood of finding matches.

As in other SfM algorithms, to robustly compute 3D points from feature matches, we form tracks of features across multiple frames. The original algorithm [Snavely et al. 2006] computes tracks by connecting all pairwise matching feature points with common endpoints. It then drops any tracks that loop back on themselves, i.e., that contain more than one feature point in the same image. We found this strategy too strict, since it forms and then rejects many large tracks. Instead we use a simple greedy algorithm that builds tracks by successively merging feature matches, but only if the merge would not result in a track that contains two features in the same image. Finally, we triangulate a 3D point for every track by minimizing the reprojection error. This is a non-linear least squares problem, which we solve using the Levenberg-Marquardt algorithm [Nocedal and Wright 2000].

Having increased the number of points, we are now ready to compute a dense mesh for every frame. We divide the field of view into a regular grid mesh of $w \times h$ vertices (we set $w = 41$ and h proportional to the inverse aspect ratio of the input video in our implementation). Our goal now is to compute the depth of every vertex in the mesh. However, since the reprojection error is related to disparity (inverse depth), we solve for disparity, $d(x)$, for every vertex x, instead. This is also practical because it avoids numerical problems with distant parts of the scene (i.e., points at infinity). Our objectives are to approximate the sparse points where the depth is known and to be smooth elsewhere. We achieve this by solving the following optimization problem:

$$\min_{\{d(x)\}} \sum_{x \in V} E_{depth}(x) \; + \sum_{x \in V,\, y \in N(x)} E_{smooth}(x,y), \tag{1}$$

where V is the set of vertices, and $N(x)$ is the 4-neighborhood of x.

The unary term

$$E_{depth}(x) = \sum_i B(x - p_i)\left(d(x) - z_i^{-1}\right)^2 \tag{2}$$

measures the approximation error. p_i and z_i are the image space projection and depth of the sparse reconstructed points, and B is a bilinear kernel whose width is one grid cell. The pairwise term

$$E_{smooth}(x,y) = \lambda\,(d(x) - d(y))^2 \tag{3}$$

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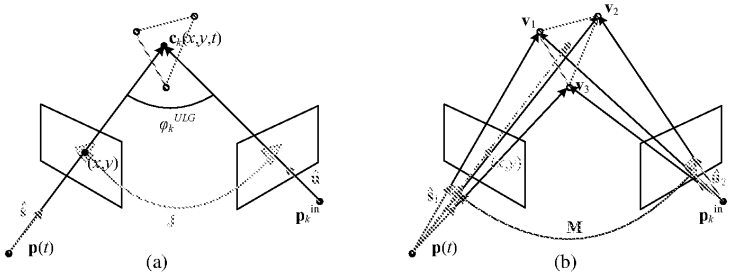


Figure 3: *Rendering quality term computations. (a) The Unstructured Lumigraph angular error φ_k^{ULG} measures the angle between the direction vectors $\hat{\mathbf{s}}$ and $\hat{\mathbf{u}}$ from the new $\mathbf{p}(t)$ and original $\mathbf{p}_k^{\text{in}}$ camera centers and the proxy surface point $\mathbf{c}_k(x,y,t)$. The affine transform $\mathbf{J}$ can be used to compute the texture stretch φ_k^{TS} at the reference pixel (x,y) but depends on the orientation of the new (rendering) camera. (b) The view invariant texture stretch φ_k^{TS3} can be computed using the condition number of the 3×3 mapping $\mathbf{M}$ between the unit vectors $\hat{\mathbf{s}}_i$ and $\hat{\mathbf{u}}_i$ pointing from the camera centers to the vertices $\mathbf{v}_i$ of the proxy triangle.*

encourages a smooth solution. $\lambda = 1$ balances between both objectives. The solution to Eq. 1 is a set of sparse linear equations, which we solve using a standard linear least-squares solver.

At this point, we have recovered the camera positions and orientations for each frame. In addition, we have a depth map in the form of a dense rectangular grid of points for each frame (Figure 1b).

5 Path Planning

Having a reconstruction of the scene, we now compute a smooth path for the output video. Our goal is to satisfy several conflicting objectives: we seek a path that is smooth everywhere and approximates the input camera path, i.e., it should not venture too far away from the input camera poses. Further it should be oriented toward directions that we can render well using image-based rendering.

Most previous methods employ path smoothing algorithms [Snavely et al. 2008; Liu et al. 2009; Liu et al. 2011; Goldstein and Fattal 2012; Liu et al. 2013]. However, we found that these simple algorithms cannot produce good results with our rather shaky input camera paths. We compare against these approaches in Section 7 and Figure 10.

Instead, we formulate path planning as an optimization problem that tries to simultaneously satisfy the following four objectives:

1. **Length:** The path should be no longer than necessary;
2. **Smoothness:** The path should be smooth both in position and orientation;
3. **Approximation:** The path should be near the input cameras;
4. **Rendering quality:** The path should have well estimated proxy geometry in view for image-based rendering.

We first formalize these objectives in Section 5.1, and then describe how to optimize them in Sections 5.2–5.5.

5.1 The Objectives

Let $\{\mathbf{p}_k^{\text{in}}, \mathbf{R}_k^{\text{in}}\}$ be the set of input camera positions and rotation matrices, and let $\mathbf{p}(t)$ and $\mathbf{f}(t)$ be the desired output camera continuous position and orientation curves, respectively. $\mathbf{f}(t)$ is represented as a unit front vector, i.e., it has two degrees of freedom. We define the remaining right and up vectors by taking cross products with a global world up vector. We assume the field of view of the output camera is a fixed user-supplied parameter and set it to 80% of the input camera's field of view in all our results.

The length and smoothness objectives are stated mathematically as penalty terms:

$$E_{length} = \int \left\|\mathbf{p}'(t)\right\|^2 \mathrm{d}t \tag{4}$$

$$E_{smooth\text{-}\mathbf{p}} = \int \left\|\mathbf{p}''(t)\right\|^2 \mathrm{d}t \tag{5}$$

$$E_{smooth\text{-}\mathbf{f}} = \int \left\|\mathbf{f}''(t)\right\|^2 \mathrm{d}t \tag{6}$$

For the approximation requirement, we seek to minimize the distance of every input camera to the closest point on the path:

$$E_{approx} = \sum_k \min_t \left\|\mathbf{p}_k^{\text{in}} - \mathbf{p}(t)\right\|^2 \tag{7}$$

The rendering quality is less straight forward, as it depends on the scene geometry as well the input camera positions. We seek to estimate the quality we can achieve using image-based rendering given a particular output camera position and orientation. Let $\varphi_k(x,y,t)$, defined below, be a penalty when using the geometry proxy of input camera k to render the pixel (x,y) at time t. The following expression then measures the expected quality for a particular output frame at time t by integrating over the image space:

$$\Phi(t) = \iint \min_k \varphi_k(x,y,t)\ \mathrm{d}x\mathrm{d}y. \tag{8}$$

We now integrate this penalty over the length of the curve to get our rendering quality penalty term:

$$E_{quality} = \int \Phi(t)\ \mathrm{d}t. \tag{9}$$

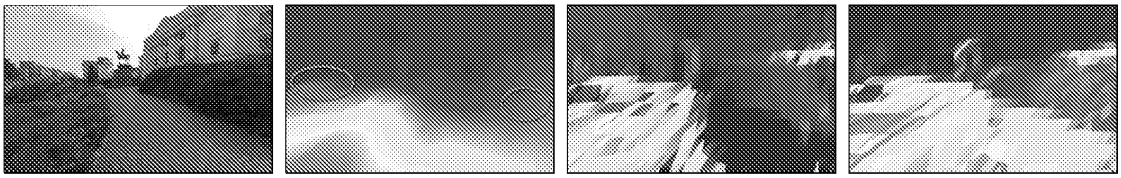
How should φ_k be defined? Many possible choices have been discussed in the literature. In the Unstructured Lumigraph, Buehler et al. [2001] provide an overview, and propose using the angular error, i.e.:

$$\varphi_k^{ULG} = \cos^{-1}(\hat{\mathbf{s}}\cdot\hat{\mathbf{u}}), \tag{10}$$

where

$$\hat{\mathbf{s}} = \frac{\mathbf{c}_k(x,y,t) - \mathbf{p}_k^{\text{in}}}{\left\|\mathbf{c}_k(x,y,t) - \mathbf{p}_k^{\text{in}}\right\|}, \quad \hat{\mathbf{u}} = \frac{\mathbf{c}_k(x,y,t) - \mathbf{p}(t)}{\left\|\mathbf{c}_k(x,y,t) - \mathbf{p}(t)\right\|} \tag{11}$$

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(a) Reprojected frame (b) Unstructured Lumigraph error (c) Texture stretch (d) Rotation invariant texture stretch

Figure 4: *Rendering quality term comparison. (b) The Unstructured Lumigraph error does does not always correlate well with visual artifacts; it has comparable values in the two encircled areas. However, in the reprojected frame, the left area shows strong texture stretching while the right one does not. (c-d) Directly measuring texture stretch correlates better with visual artifacts. Our new measure is invariant to view rotations.*

denote unit direction vectors between the camera centers and $\mathbf{c}_k(x,y,t)$, which denotes the intersection of the ray for pixel (x,y,t) with the geometry of the proxy for input camera k (Figure 3a). Unfortunately, this error does not take the obliqueness of the projection onto the proxy into account, and can associate very distorted views with low penalties (Figure 4b).

A better measure is to directly penalize the amount of texture stretch of the projection (Figure 4c):

$$\varphi_k^{TS} = 1 - \frac{\min_i \sigma_i^{\mathbf{J}}}{\max_i \sigma_i^{\mathbf{J}}}, \tag{12}$$

where $\sigma_i^{\mathbf{J}}$ are the singular values of the Jacobian of the texture coordinates:

$$\mathbf{J} = \begin{bmatrix} \frac{\partial u}{\partial x} & \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} & \frac{\partial v}{\partial y} \end{bmatrix}. \tag{13}$$

The Jacobian can be easily evaluated in a pixel shader using the `dFdx/dFdy` instructions, and the singular values for the 2x2 matrix computed using a closed form expression.

A disadvantage of this measure is that it is not invariant to the view orientation, since in a perspective projection, the periphery of the image is always more stretched than the center. It is preferable to have a measure that does not change as we rotate the viewpoint, since this allows for much more efficient optimization of the objective, as will become evident in Section 5.5.

We achieve this considering the stretch of *directions* (i.e., 3D unit vectors) rather then perspective projected 2D texture coordinates (Figure 4d). Let $\mathbf{v}_1, \mathbf{v}_2, \mathbf{v}_3$ be the vertices of a proxy triangle (Figure 3b). We now define the directions w.r.t. the input and output camera positions as:

$$\hat{\mathbf{s}}_i = \frac{\mathbf{v}_i - \mathbf{p}_k^{\text{in}}}{\left\|\mathbf{v}_i - \mathbf{p}_k^{\text{in}}\right\|}, \quad \hat{\mathbf{u}}_i = \frac{\mathbf{v}_i - \mathbf{p}(t)}{\|\mathbf{v}_i - \mathbf{p}(t)\|}. \tag{14}$$

This defines a linear mapping $\mathbf{M} = \mathbf{S}\mathbf{U}^{-1}$, where $\mathbf{S} = (\hat{\mathbf{s}}_1, \hat{\mathbf{s}}_2, \hat{\mathbf{s}}_3)$, $\mathbf{U} = (\hat{\mathbf{u}}_1, \hat{\mathbf{u}}_2, \hat{\mathbf{u}}_3)$. Our final IBR penalty function is thus:

$$\varphi_k^{TS3} = 1 - \frac{\min_i \sigma_i^{\mathbf{M}}}{\max_i \sigma_i^{\mathbf{M}}}, \tag{15}$$

where σ_i^M are the singular values of $\mathbf{M}$. We compute Eq. 15 in closed form in a shader (the source code is provided in the supplementary material).

The weighted sum of all these objectives gives our combined objective:

$$\begin{aligned} E = \lambda_1\, E_{length} + \lambda_2\, E_{smooth\text{-}\mathbf{p}} + \\ \lambda_3\, E_{smooth\text{-}\mathbf{f}} + \lambda_4\, E_{approx} + \lambda_5\, E_{quality}, \end{aligned} \tag{16}$$

where $\lambda_1 = 100$, $\lambda_2 = 100$, $\lambda_3 = 1000$, $\lambda_4 = 0.1$, $\lambda_5 = 0.01$ are balancing coefficients (recall that the scale of the reconstructed scene is normalized).

5.2 Optimization Strategy

Optimizing Eq. 16 directly is prohibitively expensive, since the $E_{quality}$ term is expensive to evaluate. It turns out, however, that we can greatly increase the tractability of the optimization by factoring it into two stages.

First, we optimize the location $\mathbf{p}(t)$ of the path while ignoring the energy terms that depend on the orientation $\mathbf{f}(t)$. While this reduced objective is still nonlinear, it can be efficiently optimized by iteratively solving sparse linear subproblems, as described in Section 5.3.

Next, we optimize the orientation $\mathbf{f}(t)$ of the output cameras while keeping the previously computed position curve $\mathbf{p}(t)$ fixed. This strategy dramatically improves efficiency because we designed our proxy penalty function φ_k^{TS3} to be rotation invariant. This enables us to precompute the min expression in Equation 8 once for all directions. We describe this part of the optimization in Section 5.5.

5.3 Optimizing the Path Location

In the first stage, our goal is to optimize the path location curve $\mathbf{p}(t)$ by minimizing the objectives E_{length}, $E_{smooth\text{-}\mathbf{p}}$, and E_{approx}, that do not depend on the orientation. We represent $\mathbf{p}(t)$ as a cubic B-spline curve, with the number of control vertices set to 5% of the number of input frames. The reduced objective now becomes:

$$\begin{aligned} E_{location} = \lambda_4 \sum_k \left\|\mathbf{p}_k^{\text{in}} - \mathbf{p}(t_k)\right\|^2 + \\ \lambda_1 \int \left\|\mathbf{p}'(t)\right\|^2 \mathrm{d}t \;+\; \lambda_2 \int \left\|\mathbf{p}''(t)\right\|^2 \mathrm{d}t, \end{aligned} \tag{17}$$

where $t_k = \arg\min_t \left\|\mathbf{p}_k^{\text{in}} - \mathbf{p}(t)\right\|$, is the parameter of the closest curve point to camera k. This is a standard spline fitting problem, which is frequently encountered in the literature.

While this is a non-linear objective, it can be efficiently solved using an iterative strategy. Note that the two integral terms in Eq. 17 have simple quadratic closed-form expressions for cubic B-splines. Now, the solution idea is to fix t_k during one iteration, which turns Eq. 17 into a quadratic problem that can be optimized by solving a sparse linear set of equations. The overall strategy is then to alternately optimize Eq. 17 and to update the t_k. Figure 5 shows a sample mapping of input frames to their corresponding t_k values while Figure 1a shows an example of a smoothed 3D camera path.

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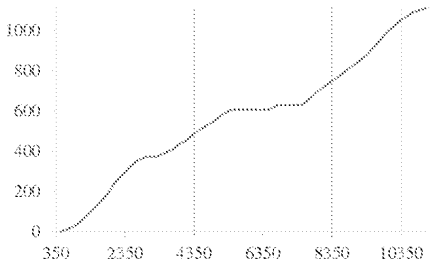


Figure 5: *Sample mapping from input frame numbers (horizontal axis) to their t_k values (vertical axis).*

For a detailed analysis of this algorithm and more implementation details, please see Wang et al.'s paper [2006].

5.4 Selecting Output Camera Positions Along Path

Having determined a continuous curve, $\mathbf{p}(t)$, that best meets our objectives aside from orientation, we now select camera positions along the curve. We now drop the parameter t and introduce the subscript i to refer to output frames. The curve samples are also our output video's frame positions.

A constant velocity along the curve in the hyper-lapse video is achieved by simply sampling of the curve into the desired number of output frames at evenly spaced locations along the curve in arc-length. Alternatively, if we wish to preserve some (or all) of the original camera velocities, we can use the mapping of input frames to their corresponding t_k values (Eq. 17) to compute a dynamic time warp. Sampling the curve in Figure 5 at regular (horizontal) intervals results in a set of non-uniformly spaced t samples that are denser in time when the original camera was slower or stopped.

In practice, we can blend between a constant and adaptive velocity. We show constant velocity results and an example of a variable velocity video in Section 7 and our supplementary materials.

5.5 Optimizing the Path Orientation

We now optimize the orientation curve $\mathbf{f}(t)$ by minimizing the $E_{smooth\text{-}\mathbf{f}}$ and $E_{quality}$ terms. The new objective becomes:

$$E_{orientation} = \lambda_5 \sum_i \Phi_i(\mathbf{f}_i) \; + \; \lambda_3 \sum_i \|2\mathbf{f}_i - \mathbf{f}_{i-1} - \mathbf{f}_{i+1}\|^2. \quad (18)$$

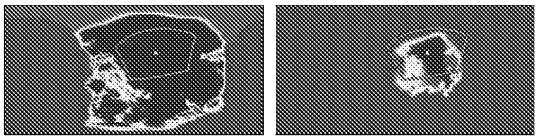
The key to making this optimization efficient lies in precomputing a $\Phi_i(\mathbf{f})$ lookup table for each output camera i, which we store in a cube map. First, at every output camera location $\mathbf{p}_i$, we render all proxy geometries using an appropriate shader (see supplementary material) and set the blending mode to compute the minimum in the frame buffer. Repeating this process in each of the six cardinal directions produces a cube map that stores:

$$\hat{\varphi}_i(\mathbf{f}) = \min_k \varphi_k(\mathbf{f}, i). \quad (19)$$

Next, we compute the image integrals for the $\Phi_i(\mathbf{f})$ IBR fitness terms using these precomputed quantities:

$$\Phi_i(\mathbf{f}) = \iint_{I(\mathbf{f})} \hat{\varphi}_i(\mathbf{f}')\, d\mathbf{f}', \quad (20)$$

where $I(\mathbf{f})$ indicates the set of rays $\mathbf{f}'$ that are in image I, and again store the results in cube maps (Figure 6). Since the functions in Equations 19 and 20 are relatively smooth, we use a cube face resolution of 64^2 and 16^2 pixels, respectively. This operation reduces evaluating the first term in Eq. 18 to a simple cube map texture fetch, and thus makes minimizing that equation extremely efficient. We use non-linear conjugate gradient with golden section line search to optimize it [Shewchuk 1994], and compute the partial derivatives of the cube map fetches analytically in a custom cube map sampler.



Per-pixel orientation penalty $\hat{\varphi}_i(\mathbf{f})$ Integrated orientation penalty $\Phi_i(\mathbf{f})$

Figure 6: *Look up tables for computing orientation penalties. The green dot shows the optimized forward vector $\mathbf{f}$ for one of the output frames, and the purple shape is the corresponding field of view. The orientation optimization algorithm tries to keep the orientation inside the feasible (dark blue) area of the second map.*

6 Rendering

Our final stage is to render images for the novel camera positions and orientations we discussed in the previous section. We use a greedy algorithm to select a subset of source images from which to assemble each output frame (Section 6.1). Then, we render each of the selected source images and stitch the results together using a Markov random field (MRF) and reconstruct the final images in the gradient domain (Section 6.2).

6.1 Source Frame Selection

For every output frame, our task is to determine a handful of input frames, which, when reprojected using their proxy geometry, cover the output frame's field-of-view with acceptable quality. We do this both for efficiency and to reduce popping, which might occur if each pixel were to be chosen from a different frame. For each output camera, we can trivially determine the nearest source camera. Unfortunately, that frame might point in a different direction than the output frame. For this reason we have to consider a relatively large range of input frames. In our implementation, we search over ± 500 frames around the nearest source camera. We start by rendering weight maps for each of these candidate frames, where:

$$w_{k,i}(x,y) = \text{clamp}\left(\frac{\varphi_{k,i}(x,y) - \tau_{min}}{\tau_{max} - \tau_{min}},\, 0,\, 1\right) \quad (21)$$

denotes a weight for using proxy k for output frame i. $\tau_{max} = 0.7$ is an upper threshold above which we consider the quality "good enough", and $\tau_{min} = 0.3$ is a lower threshold below which we deem the quality of the proxy too low to be used for rendering. For pixels that are not covered by the proxy, we set $w_{k,i} = 0$.

We now select the source frame that gives the highest overall quality:

$$s_0 = \arg\max_k \sum_{x,y} w_k(x,y). \quad (22)$$

We keep selecting the images that give us the most *improvement* over the previously selected subset:

$$s_n = \arg\max_k \sum_{x,y} \max\left(0,\, w_k(x,y) - a_n(x,y)\right), \quad (23)$$

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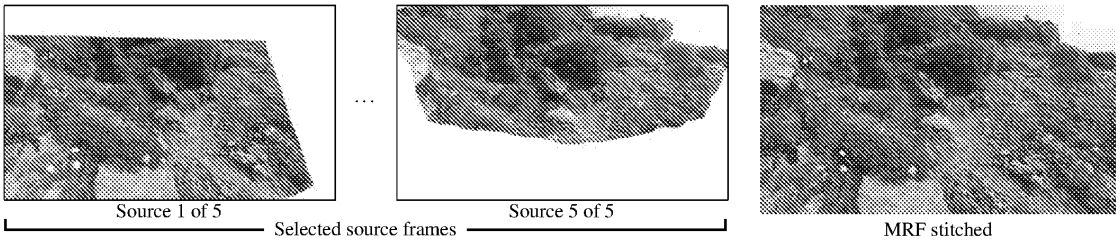


Figure 7: *Source frame selection and stitching. Left: source frame selection to ensure that all pixels are adequately covered with high-quality inputs; Right: Markov random field source pixel selection. (In practice, a spatio-temporal MRF is used—see Figure 1c.)*

where a_n is an accumulation buffer that contains the previously selected best value for every pixel:

$$a_n(x,y) = \max_{m<n} w_{s_m}(x,y). \tag{24}$$

We keep selecting source frames in this manner until the average improvement per pixel in Eq. 23 falls below a threshold of 0.1.

There are two more issues we need to address. First, some video frames are poor because of camera shake-induced motion blur. Let $b_k(x,y)$ be a per-pixel blur measure, which we obtain by low-pass filtering the gradient magnitude of the texture of image k. We now replace the weights used above by the following ones:

$$\tilde{w}_k = \frac{w_k b_k}{\max_l b_l}. \tag{25}$$

We also need to take the relative depths of pixels into account, to avoid selecting occluded parts of the scene. We render depth maps along with the weight maps, and for every pixel consider all the depth samples that fall onto it. We now want to discard all pixels that are occluded; however, we cannot use a strict z-buffer because we have to account for inaccuracies in the reconstructed depths.

Instead, we apply a Gaussian mixture model [Hastie et al. 2005] to these samples, where we determine the best number of Gaussians using the Bayesian information criterion [Schwarz 1978]. This essentially gives us a classification of the depths into one or several layers. We can now safely set the weights of every pixel not on the front layer to zero.

The above process selects on average 3 to 5 source frames for every output frame. While this is done independently for every output frame, we observe in practice that similar source frames are selected for nearby output frames. This is important for achieving more temporally coherent results when rendering. We encourage this even further by allowing every selected source to be not only used for the frame it was selected in, but also the surrounding ± 8 frames. However, in these extra frames we multiply the weight maps with a global attenuation coefficient that linearly drops to zero at the edges of the ± 8 frame window (indicated by the gray values in Figure 8). The attenuation tends to reduce popping artifacts in the stitching.

6.2 Fusion

Our last remaining task is to stitch and blend the previously selected source frames together to obtain the final output frames. We first optimize a discrete pixel labeling, where every (space-time) pixel p in the output video chooses the label α_p from one of the rendered source proxies that have been selected for that particular frame [Agarwala et al. 2004]. We define the objective:

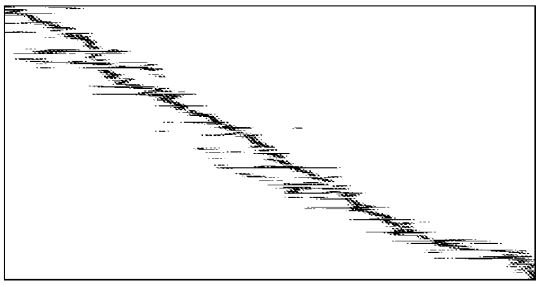


Figure 8: *Frame selection for the* CLIMBING *video. This image schematically shows (in black) which of the 331 source frames (rows) are used in each of the 636 output frames.*

$$\min_{\{\alpha_p\}} \sum_p E_d(p,\alpha_p) + \lambda_{s\text{-}s} \sum_{p,q\in N(p)} E_s(p,q,\alpha_p,\alpha_q) + \lambda_{s\text{-}t} \sum_{p,q\in T(p)} E_s(p,q,\alpha_p,\alpha_q), \tag{26}$$

where the "data" term $E_d(p,\alpha_p) = 1 - w_{\alpha_p}(p)$ encourages selecting high quality pixels, the "smoothness" terms E_s, defined below, encourage invisible stitch seams, $\lambda_{s\text{-}s} = 10$, and $\lambda_{s\text{-}t} = 0.1$. $N(p)$ denotes the set of 4-neighbors within the same output frame, and $T(p)$ denotes the two temporal neighbors in the previous and next frames, which generally will not lie at the same pixel coordinates, and which we obtain by computing the medoid of the motion vectors of all candidate proxies at the given pixel).

Our smoothness terms are defined following previous work [Agarwala et al. 2004]:

$$E_s(p,q,\alpha_p,\alpha_q) = \left\| t_{\alpha_p}(p) - t_{\alpha_q}(p) \right\| + \left\| t_{\alpha_p}(q) - t_{\alpha_q}(q) \right\|, \tag{27}$$

where $t_{\alpha_p}(p)$ denotes the RGB value of the rendered proxy at pixel p. We solve Eq. 26 in a greedy fashion by successivly optimizing single frames while keeping the previously optimized frames fixed. Each frame's labels are optimized using the alpha expansion algorithm [Kolmogorov and Zabih 2004] in a coarse-to-fine manner [Lombaert et al. 2005].

The optimized labeling hides visible seams as much as possible. However, there might still be significant color differences because of exposure and white balancing changes in the source frames. We

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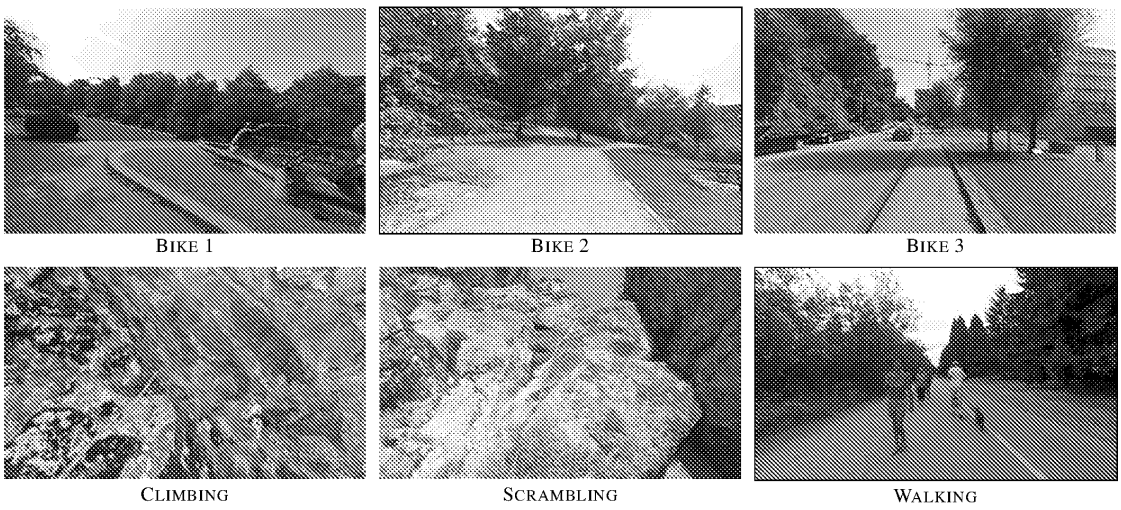


Figure 9: *Sample rendered output frames from our six test videos*

Name	Duration mm:ss	Input Frames	Output Frames
BIKE 1	6:00	10,787	1111
BIKE 2	3:55	7,050	733
BIKE 3	13:11	23,700	2189
SCRAMBLING	9:07	16,400	1508
CLIMBING	3:37	6,495	636
WALKING	9:36	17,250	1744

Table 1: *Processed video statistics: activity and clip number, input duration (minutes and seconds), input frame count, output frame count.*

Stage	Computation time
Match graph (kd-tree)	10-20 minutes
Initial SfM reconstruction	1 hour (for a single batch)
Densification	1 hour (whole dataset)
Path optimization	a few seconds
IBR term precomputation	1-2 minutes
Orientation optimization	a few seconds
Source selection	1 min/frame (95% spent in GMM)
MRF stitching	1 hour
Poisson blending	15 minutes

Table 2: *Approximate computation times for various stages of the algorithm, for one of the longer sequences,* BIKE 3

balance out these differences by solving a spatio-temporal Poisson reconstruction problem to obtain our final pixels r:

$$\min_r \sum_p \lambda_{b\text{-}d}\big(r(p)-t_{\alpha_p}(p)\big)^2 + \lambda_{b\text{-}s}\Big(\big(\Delta_x r(p)-\Delta_x t_{\alpha_p}(p)\big)^2+\big(\Delta_y r(p)-\Delta_y t_{\alpha_p}(p)\big)^2\Big)+ \lambda_{b\text{-}t}\big(\Delta_i r(p)-\Delta_i t_{\alpha_p}(p)\big)^2, \tag{28}$$

where Δ_x, Δ_y, and Δ_i denote the horizontal, vertical, and temporal finite forward difference operator, respectively. $\lambda_{b\text{-}d} = 0.001$, $\lambda_{b\text{-}s} = 1$, and $\lambda_{b\text{-}t} = 0.01$ are balancing coefficients. We solve Eq. 28 in a reduced domain using multi-splines with a spacing of 32 pixels [Szeliski et al. 2011] using a standard conjugate gradients solver [Shewchuk 1994].

7 Results and Evaluation

We present our experimental results on six video sequences acquired with GoPro Hero2 and Hero3 cameras. All of the videos were taken in a single shot and captured at 29.97 frames per second with a resolution of 1280×960 pixels. Table 1 lists the sequences, which are described by their activities and clip numbers, their input duration and frame number, and the number of output frames. The videos are between 3 and 13 minutes in length, and the output videos have a decimation (speed-up) factor of roughly $10\times$, a value that provides significant speed-up while still providing enough context to follow the motion.

Figure 9 shows a sample rendered output frame from each of the six videos. Our supplementary materials show the complete rendered videos (downsampled to 720 pixel width). We also show comparisons to more naïve methods to produce the same output length as our method. We include one rendered video where instead of using a constant camera velocity, we adapt the velocity to mimic that of the original camera motion, as described in Section 5.4.

As can be seen from these videos, our technique does an excellent job of providing fluid camera motion while minimizing rendering artifacts. The remaining artifacts are caused by errors in the proxy geometry due to nearby objects, independently moving objects, and wide changes in exposure, which the Poisson blend could not disguise. Some additional artifacts are due to sudden camera movements, errors in the reconstruction due to rolling shutter artifacts, and motion blur, despite our efforts to not use such frames for the rendering.

Computation Times. Several components of the hyper-lapse construction are computationally expensive, such as SfM reconstruction and spatio-temporal MRF stitching and Poisson blend-

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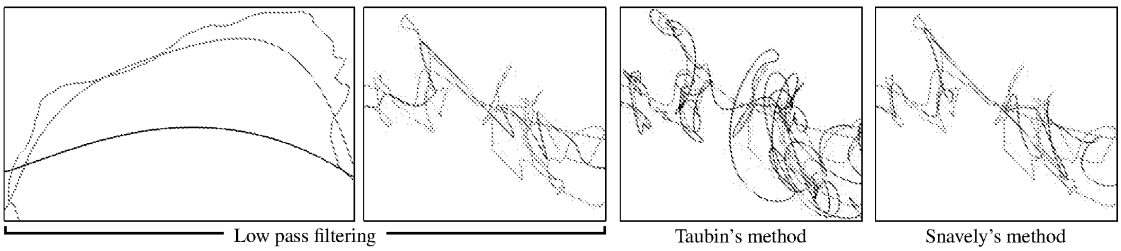


Figure 10: *Simple smoothing algorithms cannot produce satisfactory camera paths. The original camera path is shown in blue, our path in red, and the alternative path in black. Left: Low pass filtering the input camera positions produces a path that is over-smoothing in some part while it still contains sudden turns in other parts. Middle: Taubin's method [Taubin et al. 1996] runs into numerical problems. Right: The pull-back term in Snavely et al's algorithm [2008] prevents reaching a smooth configuration.*

ing. In this work, we were more interested in building a proof-of-concept system rather than optimizing for performance. As a result, our current implementation is slow. It is difficult to measure the exact timings, as we distributed parts of the SfM reconstruction and source selection to multiple machines on a cluster. Table 2 lists an informal summary of our computation times. We expect that substantial speedups are possible by replacing the incremental SfM reconstruction with a real-time SLAM system [Klein and Murray 2009], and finding a faster heuristic for preventing selecting of occluded scene parts in the source selection. We leave these speed-ups to future work.

7.1 Evaluating Alternatives

We experimented with a number of alternatives at each stage of the pipeline. Here, we outline some of those results.

Global 3D Model Reconstruction. We experimented with applying CMVS/PMVS [Furukawa and Ponce 2010], a state-of-the-art 3D reconstruction algorithm, to our input video and then rendering this model along our newly computed camera path. As can be seen in the `bike1_dense_recon.mp4` video, difficulties in reconstructing textureless and moving areas cause the algorithm to produce only a partial model, which cannot achieve the degree of realism we are aiming for with our hyper-lapse videos.

Path Planning. Some alternatives to our path planning results can be seen in Figure 10. As described in Section 5, we first experimented with low-pass smoothing the original camera poses. However, we found that there is no setting that reaches a good solution everywhere. In some regions, the path remains too noisy while in others, it oversmooths sharp turns with the same settings. Taubin's method [1996] is designed to smooth without the "shrinkage" problems. However, it runs into numerical problems before achieving sufficient smoothing. Snavely et al. [2008] use a variant of low-pass filtering that employs a pull-back term, which prevents the curve from moving too far away from the input curve. However, if this term is weighted too high, it prevents smoothing, while if it is weighted lower, it suffers from the same problems as regular low-pass filtering.

Video Stabilization. As mentioned in our introduction, we also experimented with traditional video stabilization techniques, applying the stabilization both before and after the naïve time-lapse frame decimation step. We tried several available algorithms, including the Warp Stabilizer in Adobe After Effects, Deshaker[1], and the Bundled Camera Paths method [Liu et al. 2013]. We found that they all produced very similar looking results and that neither variant (stabilizing before or after decimation) worked well, as demonstrated in our supplementary material. We also tried a more sophisticated temporal coarse-to-fine stabilization technique that stabilized the original video, then subsampled the frames in time by a small amount, and then repeated this process until the desired video length was reached. While this approach worked better than the previous two approaches (see the video), it still did not produce as smooth a path as the new technique developed in this paper, and significant distortion and wobble artifacts accumulated due to the repeated application of stabilization.

8 Conclusions

In this paper, we have shown how to create smooth hyper-lapse videos from casually captured first-person video. We leverage structure-from-motion methods to operate on very long sequences by clustering the input, solving a series of sub-problems, and merging results. We also densify the resulting point clouds in a second pass and then interpolate depth maps per input frame. This provides the input to a new path planning algorithm for the output hyper-lapse camera.

We have developed a new view-independent quality metric that accounts for foreshortening induced by texture-mapping source images onto final views. This novel metric is integrated into the path planning objective and results in a path that is both smooth and optimally placed and oriented to be renderable from the available input frames. Finally, each output frame is rendered from carefully selected source frames that are most capable of covering the frame as defined by the path planning. The source frames are stitched and blended to create the final frames. Our pipeline produces smooth hyper-lapse videos while limiting the need for severe cropping. The resulting videos could not be achieved by any existing method.

That said, there are many avenues to continue improving the results. We have generally relied on L_2 metrics for smoothness and stability. As Grundmann et al. [2011] showed, the use of L_1 measures often results in more natural stabilization results. Exploring such metrics throughout our process may result in even more natural feeling hyper-lapses. Also, the rolling shutter used in almost all modern video cameras causes a variety of *wobble* artifacts. Some recently reported work, such as Liu et al. [2013], should be applied to the input sequence before further processing. As stereo and structure-from-motion codes continue to improve, we hope to eliminate some

[1] `http://www.guthspot.se/video/deshaker.htm`

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of the remaining artifacts caused by nearby surfaces, thin structures, and moving objects.

As the prevalence of first-person video grows, we expect to see a greater demand for creating informative summaries from the typically long video captures. Our hyper-lapse work is just one step forward. As better semantic understanding of the scene becomes available, either through improved recognition algorithms or through user input, we hope to incorporate such information, both to adjust the speed along the smoothed path, the camera orientation, or perhaps to simply jump over uninformative sections of the input. Finally, we look forward to being surprised by the many new and exciting videos of adventures recorded with first-person video systems.

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Audio-Visual Panoramas and Spherical Audio Analysis using the Audio Camera

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Abstract

Capturing a scene for later or contemporaneous display needs to capture the complex interactions between the source(s) in the scene and the environment. High order spherical Ambisonics and plane-wave analysis are powerful mathematical tools for such scene analysis. The spherical microphone array (and its embodiment in the Audio Camera) is a useful tool for capture and analysis of scenes. Further information about the environment is available from the visual scene.

We present the audio-visual panoramic camera as a tool that greatly simplifies the task of processing audio visual information by providing one common framework for both modalities. Via the Audio Camera [1], we show that microphone arrays can be viewed as a central projection camera that can effectively image the audible acoustic frequency spectrum. We demonstrate a new device, the audio visual Panoramic camera that is composed of a 64 channel spherical microphone array combined with a 5 element video camera array. The combined sensor is capable of real-time audio visual panoramic image generation using state of the art NVidia Graphics cards. It also provides an order-7 ambisonic description of the scene.

1. Introduction

Nearly every biological creature senses the world with both eyes and ears. This is due to the tremendous amount of complementary information in each of these modalities. The visual system conveys pinpoint geometric information about objects in our environment. The acoustic environment conveys information such as speech and does not suffer as badly as vision from issues such as occlusions. For these reasons and many others it is attractive to investigate utilizing both modalities in problems of scene understanding. Microphone arrays have been an attractive tool for audio processing as they provide geometric information about acoustic sources in an environment as well as the ability to spatially suppress noise. However, it is often difficult to calibrate and utilize both microphone arrays and video cameras to perform multi-modal scene understanding. We take the approach that both microphone arrays and video cameras are central projection devices [1] and therefore can be treated in a common imaging framework. This allows the creation of a pre-calibrated multimodal panoramic sensor, The Panoramic Audio Visual Camera, which significantly simplifies the fusion of both audio and visual information.

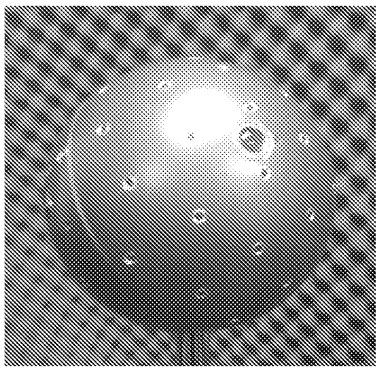


Figure 1: The Audio Visual Panoramic Camera.

2. The Spherical Microphone Array

To generate the acoustic images in the audio visual panoramic camera we utilize the spherical microphone array. There are several benefits to the spherical geometry [2]. The first is that it provides equal spatial resolution in all directions. Additionally, several mathematical simplifications presented in [3] provide efficient algorithms for processing the acoustic information in parallel on commercial graphics cards thus providing real-time capability. The array consists of 64 microphones distributed over the surface of an 8 inch sphere. The microphone signals are then amplified via individual pre-amp circuits and sent to an array of analog to digital converters. The digitized acoustic data is sampled at 44.1 kHz per channel and collected by an FPGA where it is interleaved into a single USB 2.0 Stream. This provides the interface to the PC where the data can be immediately shipped to the graphics processor for real-time processing. Figure 1 shows the Audio Visual Panoramic Camera.

3. Auditory Scene Capture and Playback

The auditory scene can be decomposed into its spherical harmonic components up to order 7. Further, the scene can

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Figure 2: Example of the panoramic video image acquired by our device.

also be decomposed into its filtered plane-wave components [4]. These can be used as inputs to creating ambisonic displays using spherical arrays or mixed with HRTFs as discussed in [5] and recreate the auditory scene over headphones.

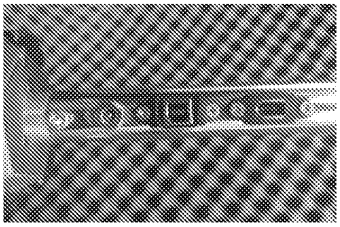


Figure 3. External ports of the Audio Visual Camera.

4. Panorama Stitching

Due to the fact that the spherical microphone array provides an omni-directional acoustic image of the environment it is highly beneficial to have an omni-directional image of the visual environment as well. In order to generate a panoramic image of the scene we utilize a 5 camera array. The placement of the cameras was selected to avoid all microphones in the spherical microphone array via a spatial optimization. Additionally, the placement was selected such that all directions except those present around the mounting handle are seen by at least one camera. Each of the 5 video cameras are 752x480 color Firewire cameras. The frame acquisition is triggered by the internal audio FPGA to provide synchronization of both the audio and video components of the device. The 5 camera image streams are collected via an internal Firewire that allows an interface to the PC consisting of a single Firewire cable. Figure 2 shows an example of the stitch achieved using our 5 camera panoramic video camera.

5. The Panoramic Audio Visual Camera

Given both the omni-directional acoustic and video images we perform a one time joint audio visual calibration to bring both modalities into a single global coordinate system [1]. Because both the audio and visual cameras are collocated and share a common center of projection we can perform acoustic image transfer onto the video stream as described in [3] to provide a final image that represents both acoustic and visual information present in the environment. The extent of the external cable connections of the device consist of a single USB 2.0 port and a single Firewire port as well as external power. Figure 3 shows the interface ports present at the base of the handle.

6. Conclusion

We present a multimodal panoramic audio-visual camera. We demonstrate that we can present both acoustic and visual panoramic video streams in real-time. By combining both the spherical microphone array and an omni-directional camera array we provide a simple means of sensing the world of light and sound using a single common framework. Many applications of the device are possible, including in auditory display.

Acknowledgement: Partial ONR support is gratefully acknowledged.

7. References

[1] A. O'Donovan, R. Duraiswami, J. Neumann, Microphone arrays as Generalized Cameras for Integrated Audio Visual Processing. IEEE Conference on Computer Vision and Pattern Recognition, Minneapolis, 2007

[2] J.Meyer and G. Elko, "A highly scalable spherical microphone array based on an orthonormal decomposition of the soundfield," IEEE ICASSP 2002, 2:1781-1784

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Audio-Visual Panoramas and Spherical Audio Analysis using the Audio Camera

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Abstract

Capturing a scene for later or contemporaneous display needs to capture the complex interactions between the source(s) in the scene and the environment. High order spherical Ambisonics and plane-wave analysis are powerful mathematical tools for such scene analysis. The spherical microphone array (and its embodiment in the Audio Camera) is a useful tool for capture and analysis of scenes. Further information about the environment is available from the visual scene.

We present the audio-visual panoramic camera as a tool that greatly simplifies the task of processing audio visual information by providing one common framework for both modalities. Via the Audio Camera [1], we show that microphone arrays can be viewed as a central projection camera that can effectively image the audible acoustic frequency spectrum. We demonstrate a new device, the audio visual Panoramic camera that is composed of a 64 channel spherical microphone array combined with a 5 element video camera array. The combined sensor is capable of real-time audio visual panoramic image generation using state of the art NVidia Graphics cards. It also provides an order-7 ambisonic description of the scene.

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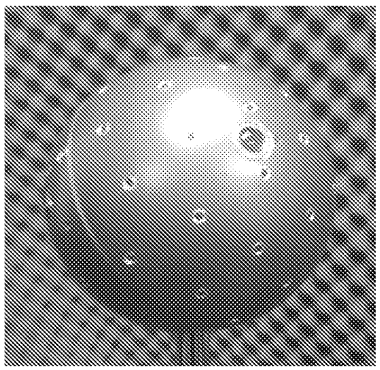


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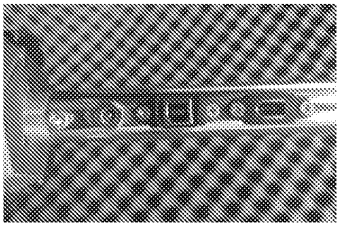


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Due to the fact that the spherical microphone array provides an omni-directional acoustic image of the environment it is highly beneficial to have an omni-directional image of the visual environment as well. In order to generate a panoramic image of the scene we utilize a 5 camera array. The placement of the cameras was selected to avoid all microphones in the spherical microphone array via a spatial optimization. Additionally, the placement was selected such that all directions except those present around the mounting handle are seen by at least one camera. Each of the 5 video cameras are 752x480 color Firewire cameras. The frame acquisition is triggered by the internal audio FPGA to provide synchronization of both the audio and video components of the device. The 5 camera image streams are collected via an internal Firewire that allows an interface to the PC consisting of a single Firewire cable. Figure 2 shows an example of the stitch achieved using our 5 camera panoramic video camera.

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REAL TIME CAPTURE OF AUDIO IMAGES AND THEIR USE WITH VIDEO

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ABSTRACT

Spherical microphone arrays provide an ability to compute the acoustical intensity corresponding to different spatial directions in a given frame of audio-data. These intensities may be exhibited as an image and these images updated at a high frame rate to achieve a video stream if the data capture and intensity computations can be performed sufficiently quickly, there by creating a frame-rate audio camera. We describe how such a camera can be built and the processing done sufficiently quickly using graphics processors. The joint processing of captured frame-rate audio and video images enables applications such as visual identification of noise sources, beamforming and noise-suppression in video conferencing and others, provided it is possible to account for the spatial differences in the location of the audio and the video cameras. Based on the recognition that the spherical array can be viewed as a central projection camera it is possible to perform such joint analysis. We provide several examples of real-time applications.

1. INTRODUCTION

Over the past few years there have been several publications that deal with the use of spherical microphone arrays (see e.g. [9, 1, 16, 4, 15]). Such arrays are seen by some researchers as a means to capture a representation of the sound field in the vicinity of the array [2], and by others as a means to digitally beamform sound from different directions using the array with a relatively high order beampattern [10, 6], or for nearby sources [7]. Variations to the usual solid spherical arrays have been suggested, including hemispherical arrays [5], open arrays [1], concentric arrays and others. We refer the interested reader to these papers for discussions.

A particularly exciting use of these arrays is to steer it to various directions and create an intensity map of the acoustic power in various frequency bands via beamforming. The resulting image, since it is linked with direction can be used to identify source location (direction), be related with physical objects in the world and identify sources of sound and be used in several applications that we discuss at the end of the paper. This brings up the exciting possibility of creating a "sound camera."

To be useful, two difficulties must be overcome. The first, is that the beamforming requires the weighted sum of the Fourier coefficients of all the microphone signals, and multichannel sound capture, and it has been difficult to achieve frame-rate performance, as would be desirable in applications such as videoconferencing, noise detection, etc. Second, while qualitative identification of sound sources with real-world objects (speaking humans, noisy machines, gunshots) can be done via a human observer who has knowledge of the environment geometry, for precision and automation the sound images must be captured in conjunction with video, and the two must be automatically analyzed to determine correspondence and identification of the sound sources. For this a formulation for the geometrically correct warping of the two images, taken from an array and cameras at different locations is necessary.

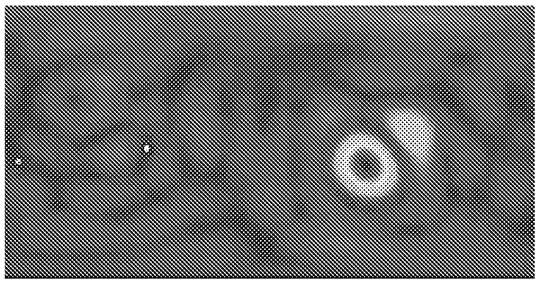


Figure 1: A sound image created by beamforming along a set of 8192 directions (a 128×64grid in azimuth and elevation), and quantizing the steered response power according to a color map.

By recognizing that the spherical array derived sound images satisfy central projection, a property crucial to geometric analysis of multi-camera systems [3], we showed [11] how it was possible to calibrate camera-spherical array systems, and perform vision-guided beamforming. Here, we extend that system to achieve frame-rate sound image creation, beamforming, and the processing of the sound image stream along with a simultaneously acquired video-camera image stream, to achieve "image-transfer," i.e., the ability to warp one image onto the other to determine correspondence. The key innovation that enables speed is to use modern graphics processors (GPUs) to do the processing at frame-rate. In Sec. 2 we provide some background and notation for both spherical arrays and GPUs. In Sec. 3 we briefly describe our experimental setup. In Sec. 4 we provide details that allow us to achieve high frame-rates. Sec. 5 provides experimental results.

2. BACKGROUND

Beamforming with Spherical Microphone Arrays: Let sound be captured at N microphones at locations $\Theta_s = (\theta_s, \varphi_s)$ on the surface of a solid spherical array. Two approaches to the beamforming weights are possible. The modal approach relies on orthogonality of the spherical harmonics and quadrature on the sphere, and decomposes the frequency dependence. It however requires knowledge of quadrature weights, and theoretically for a quadrature order P (whose square is related to the number of micro-

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phones S) can only achieve beampatterns of order $P/2$ [9, 16]. The other requires the solution of interpolation problems of size S (potentially at each frequency), and building of a table of weights [6]. In each case, to beamform the signal in direction $\Theta = (\theta, \varphi)$ at frequency f (corresponding to wavenumber $k = 2\pi f/c$, where c is the sound speed), we sum up the Fourier transform of the pressure at the different microphones, d_s^k as

$$\psi(\Theta; k) = \sum_{s=1}^{S} w_N(\Theta, \Theta_s, ka) d_s^k(\Theta_s). \quad (1)$$

In the modal case [9] the weights w_N are related to the quadrature weights C_n^m for the locations $\{\Theta_s\}$, and the b_n coefficients obtained from the scattering solution of a plane wave off a solid sphere

$$w_N(\Theta, \Theta_s, ka) = \sum_{n=0}^{N} \frac{1}{2i^n b_n(ka)} \sum_{m=-n}^{n} Y_n^{m*}(\Theta) Y_n^m(\Theta_s) C_n^m(\Theta_s). \quad (2)$$

For the placement of microphones at special quadrature points, a set of unity quadrature weights C_n^m are achieved. In practice, it was observed [6] that for $\{\Theta_s\}$ at the the so-called Fliege points, higher order beampatterns were achieved with some noise (approaching that achievable by interpolation $(N+1) = \sqrt{S}$). In our beamformer, we use one order lower than this limit, and the Fliege microphone locations, though we also consider the case where weights are generated separately and stored in a table.

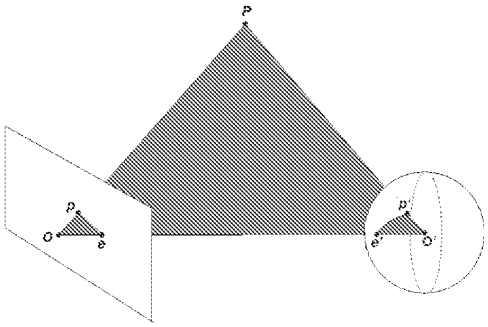


Figure 2: Epipolar geometry between a video camera (left), and a spherical array sound camera. The world point P and its image point p on the left are connected via a line passing through PO. Thus, in the right image the corresponding image point p' lies on a curve which is the image of this line (and vice versa, for image points in the right camera).

Joint Audio-Video processing and Calibration: In [11] we provide a detailed outline of how to use cameras and spherical arrays together and determine the geometric location of a source. The key observation was that the intensity image at different frequencies created via beamforming using a spherical array could be treated as a central projection (CP) camera, since the intensity at each "pixel" is associated with a ray (or its spherical harmonic reconstruction to a certain order). When two CP cameras observe a scene, they share an "epipolar geometry" (Fig. 2, also see [3]). Given two cameras and several correspondences (via a calibration object such as in Fig. 3), a fundamental matrix that encodes the calibration parameters of the camera and the parameters of the relative transformation (rotation and translation) between the two camera frames can be computed. Given a fundamental matrix of a stereo rig it is possible to take points in one cameras coordinate system and relate them to directly to pixels in the second cameras coordinate system. Given more video cameras, a complete solution of the 3D scene structure common to the two cameras can be made, and "image transfer" that allows the transfer of the audio intensity information to actual scene objects made precisely. Given a single camera and a microphone array, the transfer can be accomplished if we assume that the world is planar (or that it is on the surface of a sphere) at a certain range.

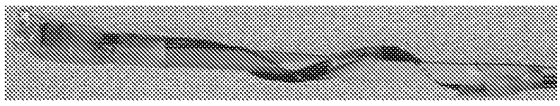


Figure 3: A calibration wand consisting of a Knowles microspeaker and an LED collocated at the end of a pencil was used to obtain the fundamental matrix.

General Purpose GPU Processing: Recently GPUs have become an incredibly powerful computing workhorse for processing computationally intensive highly parallel tasks. Recently NVidia released the Compute Unified Device Architecture (CUDA) along with the G8800 GPU with a theoretical peak speed of 330 Gflops, which is over two orders of magnitude larger than that of a state of the art Intel processor. This release provides a C-like API for coding the individual processors on the GPU that makes general purpose GPU programming much more accessible. CUDA programming, however still requires much trial and error, and understanding of the nonuniform memory architecture to map a problem onto it. In this paper we map the beamforming, image creation, image transfer, and beamformed signal computation problems to the GPU to achieve a frame-rate audio-video camera.

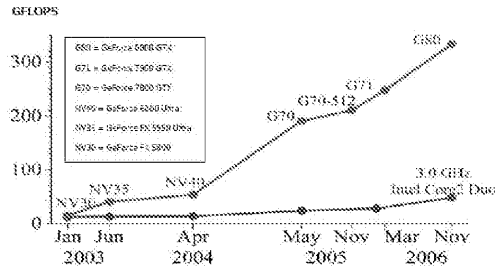


Figure 4: Peak GFlops for NVIDIA GPUs vs Intel CPUs. GPU capabilities have been advancing much faster.

3. EXPERIMENTAL SETUP

Audio information was acquired using a previously developed [6] solid spherical microphone array of radius 10cm whose surface was embedded with 60 microphones. The signals from the microphones are amplified and filtered using two custom 32 channel

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preamplifiers and fed to two National Instruments PCIe-6259 multi function data acquisition cards. Each audio stream is sampled at a rate of 31250 samples per second. The acquired audio is then shipped to an NVidia G8800 GTX GPU installed in a computer running Windows XP with an Intel Core2 processor and a clock speed of 2.4GHz with 2GB of Ram. The NVidia G8800 GTX GPU utilizes a 16 SIMD multiprocessors with On-Chip Shared memory. Each of these Multiprocessors is composed of 8 separate processors that operate at 1.35GHz for a total of 128 parallel processors. The G8800 is also equipped with 768 MB of onboard memory. In addition to audio acquisition we also acquire video frames from an orange micro IBot USB2.0 web camera at a resolution of 640 x 480 pixels and a frame rate of 10 frames per second. The images are acquired using OpenCV and are also immediately shipped to the onboard memory of the GPU.

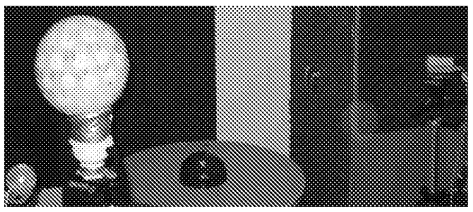


Figure 5: A 2- camera, 2-spherical array system consisting of a webcam and spherical array on the left, a hemispherical array on the centre table, and a video camera on the right. This paper reports results with the single array and camera on the left.

4. REAL-TIME PROCESSING

Since both pre-computed weights [5] and analytically prescribed weights [9] capable of being generated "on-the-fly" are used, we present the generation of images for both cases.

Pre-computed weights: This algorithm proceeds in a two stage fashion: a precomputation phase (run on the CPU) and a run-time GPU component. In stage 1 pixel locations are defined prior to run-time and the weights are computed using any optimization method as described in the literature. These weights are stored on disk and loaded only at Runtime. In general the number of weights that must be computed for a given audio image is equal to PMF where P is the number of audio pixels, M is the number of microphones, and F is the number of frequencies to analyze. Each of these weights is a complex number of size 8 bytes.

After pre-computation and storage of the beamformer weights in the run-time component the weights are read from disk and shipped to the onboard memory of the GPU. A circular buffer of size 2048 x 64 is allocated in the CPU memory to temporarily store the incoming audio in a double buffering configuration. Every time 1024 samples are written to this buffer they are immediately shipped to a pre-allocated buffer on the GPU. While the GPU processes this frame the second half of the buffer is populated. This means that in order to process all of the data in real-time all of the processing must be completed in less then 33ms, to not miss any data.

Once audio data is on the GPU we begin by performing an in place FFT using the cuFFT library in the NVidia CUDA SDK. A matrix vector product is then performed with each frequency's weight matrix and the corresponding row in the FFT data, using the NVidia CuBlas linear algebra library. The output image is segmented into 16 sub-images for each multi-processor to handle. Each multiprocessor is responsible for compiling the beamformed response power in three frequency bands into the RGB channels of the final pixel buffer object. Once this is completed control is restored to the CPU and the final image is displayed to the screen as a texture mapped quad in OpenGL.

On the fly weight computation: In this implementation there is a much smaller memory footprint. Whereas we needed space to be allocated for weights on the GPU in the previous algorithm, this one only needs to store the location of the microphones. At start up these locations are read from disk and shipped to the GPU memory. Efficient processing is achieved by making use of the addition theorem which states that

$$P_n(\cos\gamma) = \frac{4\pi}{2n+1} \sum_{m=-n}^{n} Y_n^{-m}(\Theta) Y_n^m(\Theta_s) \qquad (3)$$

where Θ is the spherical coordinate of the audio pixel and Θ_s is the location of the sth microphone, γ is the angle between these two locations and P_n is the Legendre polynomial of order n. This observation reduces the order n^2 sum in Eq. (2) to an order n sum. The P_n are defined by a simple recursive formula that is quickly computed on the GPU for each audio pixel.

The computation of the audio proceeds as follows. First we load the audio signal onto the GPU and perform an inplace FFT. We then segment the audio image into 16 tiles and assign each tile to a multiprocessor of the GPU. Each thread in the execution is responsible for computing the response power of a single pixel in the audio image. The only data that the kernel needs to access is the location of the microphone in order to compute γ and the Fourier coefficients of the 60 microphone signals for all frequencies to be displayed. The weights can then be computed using simple recursive formula for each of the Hankel, Bessel, and Legendre polynomials in Eq. (2).

While performance of the beamformer may be a bit worse, there are several benefits to the on-the-fly approach: 1) frequencies of interest can be changed at runtime with no additional overhead; 2) pixel locations can be changed at runtime with little additional overhead; 3) memory requirements are drastically lower then storing pre-computed weights.

Beamforming: Once a source location of interest is identified, we can isolated audio signal associated with that direction. The intensity of the audio pixel for a given direction is proportional to the Fourier component of the corresponding frequency in the acoustic signal. By computing the intensity of the audio pixels for a given location for all frequencies in the microphone array effective frequency band we can recover and isolate signal. For frequencies outside the effective range of the array we simply append the Fourier coefficients of the raw audio signal from the closest microphone.

5. RESULTS

Vision guided beamforming: Several authors have in the past proposed vision guided beamforming (see e.g., [12]). The idea is that vision based constraints can help us to not steer the beamformer in directions that are not promising. Often these constraints require the source to lie in some constrained region. One crucial difference here is that the quality of the geometric constraints provided by the epipolar geometry is much stronger. We illustrate in

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Fig. 6 this example with a case where a speaker's voice is beamformed in the presence of severe noise using location information from vision. Using a calibrated array-camera combination, we applied a standard face detection algorithm to the vision image and then used the epipolar line induced by the mouth region of the vision image to search for the source in the audio image.

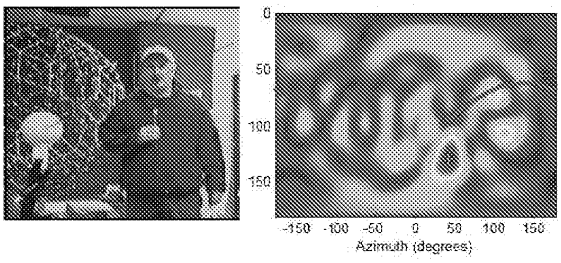


Figure 6: A loudspeaker source was played that overwhelmed the sound of the speaking person, whose face was detected with a face detector [8] and the epipolar line corresponding to the mouth location in the vision image was drawn in the audio image. A search for a local audio intensity peak along this line in the audio image allowed precise steering of the beam, and made the speaker audible. www.umiacs.umd.edu/~ramani/pubs/face_beamform.wmv

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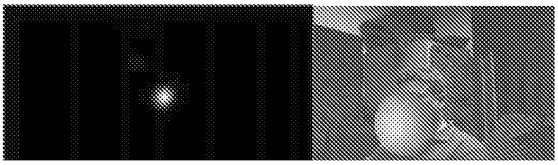
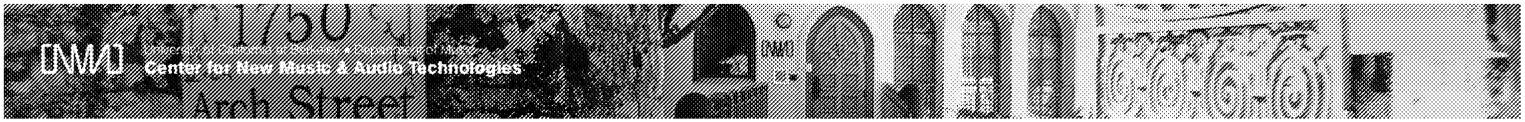


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REAL TIME CAPTURE OF AUDIO IMAGES AND THEIR USE WITH VIDEO

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ABSTRACT

Spherical microphone arrays provide an ability to compute the acoustical intensity corresponding to different spatial directions in a given frame of audio-data. These intensities may be exhibited as an image and these images updated at a high frame rate to achieve a video stream if the data capture and intensity computations can be performed sufficiently quickly, there by creating a frame-rate audio camera. We describe how such a camera can be built and the processing done sufficiently quickly using graphics processors. The joint processing of captured frame-rate audio and video images enables applications such as visual identification of noise sources, beamforming and noise-suppression in video conferencing and others, provided it is possible to account for the spatial differences in the location of the audio and the video cameras. Based on the recognition that the spherical array can be viewed as a central projection camera it is possible to perform such joint analysis. We provide several examples of real-time applications.

1. INTRODUCTION

Over the past few years there have been several publications that deal with the use of spherical microphone arrays (see e.g. [9, 1, 16, 4, 15]). Such arrays are seen by some researchers as a means to capture a representation of the sound field in the vicinity of the array [2], and by others as a means to digitally beamform sound from different directions using the array with a relatively high order beampattern [10, 6], or for nearby sources [7]. Variations to the usual solid spherical arrays have been suggested, including hemispherical arrays [5], open arrays [1], concentric arrays and others. We refer the interested reader to these papers for discussions.

A particularly exciting use of these arrays is to steer it to various directions and create an intensity map of the acoustic power in various frequency bands via beamforming. The resulting image, since it is linked with direction can be used to identify source location (direction), be related with physical objects in the world and identify sources of sound and be used in several applications that we discuss at the end of the paper. This brings up the exciting possibility of creating a "sound camera."

To be useful, two difficulties must be overcome. The first, is that the beamforming requires the weighted sum of the Fourier coefficients of all the microphone signals, and multichannel sound capture, and it has been difficult to achieve frame-rate performance, as would be desirable in applications such as videoconferencing, noise detection, etc. Second, while qualitative identification of sound sources with real-world objects (speaking humans, noisy machines, gunshots) can be done via a human observer who has knowledge of the environment geometry, for precision and automation the sound images must be captured in conjunction with video, and the two must be automatically analyzed to determine correspondence and identification of the sound sources. For this a formulation for the geometrically correct warping of the two images, taken from an array and cameras at different locations is necessary.

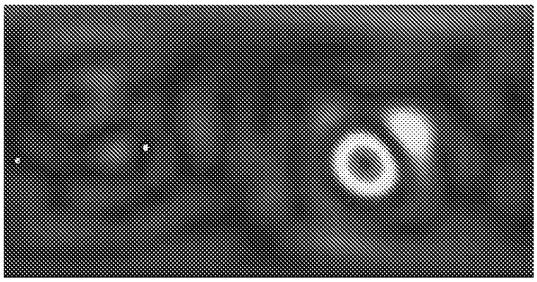


Figure 1: A sound image created by beamforming along a set of 8192 directions (a 128×64grid in azimuth and elevation), and quantizing the steered response power according to a color map.

By recognizing that the spherical array derived sound images satisfy central projection, a property crucial to geometric analysis of multi-camera systems [3], we showed [11] how it was possible to calibrate camera-spherical array systems, and perform vision-guided beamforming. Here, we extend that system to achieve frame-rate sound image creation, beamforming, and the processing of the sound image stream along with a simultaneously acquired video-camera image stream, to achieve "image-transfer," i.e., the ability to warp one image onto the other to determine correspondence. The key innovation that enables speed is to use modern graphics processors (GPUs) to do the processing at frame-rate. In Sec. 2 we provide some background and notation for both spherical arrays and GPUs. In Sec. 3 we briefly describe our experimental setup. In Sec. 4 we provide details that allow us to achieve high frame-rates. Sec. 5 provides experimental results.

2. BACKGROUND

Beamforming with Spherical Microphone Arrays: Let sound be captured at N microphones at locations $\mathbf{\Theta}_s = (\theta_s, \varphi_s)$ on the surface of a solid spherical array. Two approaches to the beamforming weights are possible. The modal approach relies on orthogonality of the spherical harmonics and quadrature on the sphere, and decomposes the frequency dependence. It however requires knowledge of quadrature weights, and theoretically for a quadrature order P (whose square is related to the number of micro-

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phones S) can only achieve beampatterns of order $P/2$ [9, 16]. The other requires the solution of interpolation problems of size S (potentially at each frequency), and building of a table of weights [6]. In each case, to beamform the signal in direction $\mathbf{\Theta} = (\theta, \varphi)$ at frequency f (corresponding to wavenumber $k = 2\pi f/c$, where c is the sound speed), we sum up the Fourier transform of the pressure at the different microphones, d_s^k as

$$\psi(\Theta; k) = \sum_{s=1}^{S} w_N(\mathbf{\Theta}, \mathbf{\Theta}_s, ka) d_s^k(\mathbf{\Theta}_s). \quad (1)$$

In the modal case [9] the weights w_N are related to the quadrature weights C_n^m for the locations $\{\mathbf{\Theta}_s\}$, and the b_n coefficients obtained from the scattering solution of a plane wave off a solid sphere

$$w_N(\mathbf{\Theta}, \mathbf{\Theta}_s, ka) = \sum_{n=0}^{N} \frac{1}{2i^n b_n(ka)} \sum_{m=-n}^{n} Y_n^{m*}(\mathbf{\Theta}) Y_n^m(\mathbf{\Theta}_s) C_n^m(\mathbf{\Theta}_s). \quad (2)$$

For the placement of microphones at special quadrature points, a set of unity quadrature weights C_n^m are achieved. In practice, it was observed [6] that for $\{\mathbf{\Theta}_s\}$ at the the so-called Fliege points, higher order beampatterns were achieved with some noise (approaching that achievable by interpolation $(N+1) = \sqrt{S}$). In our beamformer, we use one order lower than this limit, and the Fliege microphone locations, though we also consider the case where weights are generated separately and stored in a table.

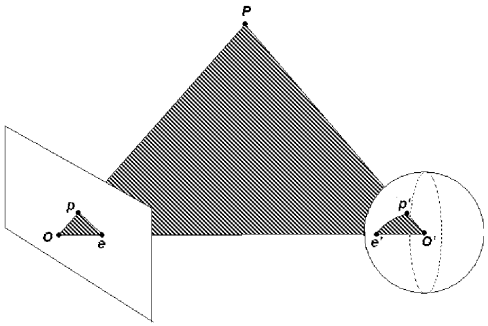


Figure 2: Epipolar geometry between a video camera (left), and a spherical array sound camera. The world point P and its image point p on the left are connected via a line passing through PO.Thus, in the right image the corresponding image point p' lies on a curve which is the image of this line (and vice versa, for image points in the right camera).

Joint Audio-Video processing and Calibration: In [11] we provide a detailed outline of how to use cameras and spherical arrays together and determine the geometric location of a source. The key observation was that the intensity image at different frequencies created via beamforming using a spherical array could be treated as a central projection (CP) camera, since the intensity at each "pixel" is associated with a ray (or its spherical harmonic reconstruction to a certain order). When two CP cameras observe a scene, they share an "epipolar geometry" (Fig. 2, also see [3]). Given two cameras and several correspondences (via a calibration object such as in Fig. 3), a fundamental matrix that encodes the calibration parameters of the camera and the parameters of the relative transformation (rotation and translation) between the two camera frames can be computed. Given a fundamental matrix of a stereo rig it is possible to take points in one cameras coordinate system and relate them to directly to pixels in the second cameras coordinate system. Given more video cameras, a complete solution of the 3D scene structure common to the two cameras can be made, and "image transfer" that allows the transfer of the audio intensity information to actual scene objects made precisely. Given a single camera and a microphone array, the transfer can be accomplished if we assume that the world is planar (or that it is on the surface of a sphere) at a certain range.

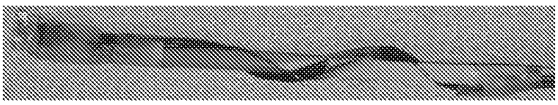


Figure 3: A calibration wand consisting of a Knowles microspeaker and an LED collocated at the end of a pencil was used to obtain the fundamental matrix.

General Purpose GPU Processing: Recently GPUs have become an incredibly powerful computing workhorse for processing computationally intensive highly parallel tasks. Recently NVidia released the Compute Unified Device Architecture (CUDA) along with the G8800 GPU with a theoretical peak speed of 330 Gflops, which is over two orders of magnitude larger than that of a state of the art Intel processor. This release provides a C-like API for coding the individual processors on the GPU that makes general purpose GPU programming much more accessible. CUDA programming, however still requires much trial and error, and understanding of the nonuniform memory architecture to map a problem onto it. In this paper we map the beamforming, image creation, image transfer, and beamformed signal computation problems to the GPU to achieve a frame-rate audio-video camera.

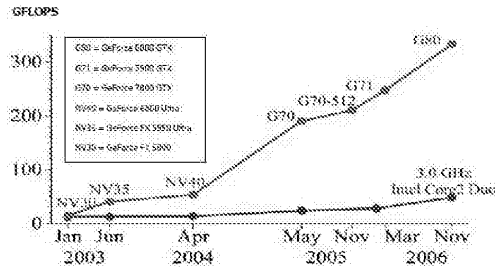


Figure 4: Peak GFlops for NVIDIA GPUs vs Intel CPUs. GPU capabilities have been advancing much faster.

3. EXPERIMENTAL SETUP

Audio information was acquired using a previously developed [6] solid spherical microphone array of radius 10cm whose surface was embedded with 60 microphones. The signals from the microphones are amplified and filtered using two custom 32 channel

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preamplifiers and fed to two National Instruments PCIe-6259 multi function data acquisition cards. Each audio stream is sampled at a rate of 31250 samples per second. The acquired audio is then shipped to an NVidia G8800 GTX GPU installed in a computer running Windows XP with an Intel Core2 processor and a clock speed of 2.4GHz with 2GB of Ram. The NVidia G8800 GTX GPU utilizes a 16 SIMD multiprocessors with On-Chip Shared memory. Each of these Multiprocessors is composed of 8 separate processors that operate at 1.35GHz for a total of 128 parallel processors. The G8800 is also equipped with 768 MB of onboard memory. In addition to audio acquisition we also acquire video frames from an orange micro IBot USB2.0 web camera at a resolution of 640 x 480 pixels and a frame rate of 10 frames per second. The images are acquired using OpenCV and are also immediately shipped to the onboard memory of the GPU.

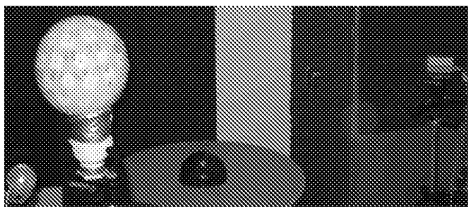


Figure 5: A 2- camera, 2-spherical array system consisting of a webcam and spherical array on the left, a hemispherical array on the centre table, and a video camera on the right. This paper reports results with the single array and camera on the left.

4. REAL-TIME PROCESSING

Since both pre-computed weights [5] and analytically prescribed weights [9] capable of being generated "on-the-fly" are used, we present the generation of images for both cases.

Pre-computed weights: This algorithm proceeds in a two stage fashion: a precomputation phase (run on the CPU) and a run-time GPU component. In stage 1 pixel locations are defined prior to run-time and the weights are computed using any optimization method as described in the literature. These weights are stored on disk and loaded only at Runtime. In general the number of weights that must be computed for a given audio image is equal to PMF where P is the number of audio pixels, M is the number of microphones, and F is the number of frequencies to analyze. Each of these weights is a complex number of size 8 bytes.

After pre-computation and storage of the beamformer weights in the run-time component the weights are read from disk and shipped to the onboard memory of the GPU. A circular buffer of size 2048 x 64 is allocated in the CPU memory to temporarily store the incoming audio in a double buffering configuration. Every time 1024 samples are written to this buffer they are immediately shipped to a pre-allocated buffer on the GPU. While the GPU processes this frame the second half of the buffer is populated. This means that in order to process all of the data in real-time all of the processing must be completed in less then 33ms, to not miss any data.

Once audio data is on the GPU we begin by performing an in place FFT using the cuFFT library in the NVidia CUDA SDK. A matrix vector product is then performed with each frequency's weight matrix and the corresponding row in the FFT data, using the NVidia CuBlas linear algebra library. The output image is segmented into 16 sub-images for each multi-processor to handle. Each multiprocessor is responsible for compiling the beamformed response power in three frequency bands into the RGB channels of the final pixel buffer object. Once this is completed control is restored to the CPU and the final image is displayed to the screen as a texture mapped quad in OpenGL.

On the fly weight computation: In this implementation there is a much smaller memory footprint. Whereas we needed space to be allocated for weights on the GPU in the previous algorithm, this one only needs to store the location of the microphones. At start up these locations are read from disk and shipped to the GPU memory. Efficient processing is achieved by making use of the addition theorem which states that

$$P_n(\cos\gamma) = \frac{4\pi}{2n+1} \sum_{m=-n}^{n} Y_n^{-m}(\Theta) Y_n^m(\Theta_s) \qquad (3)$$

where Θ is the spherical coordinate of the audio pixel and Θ_s is the location of the sth microphone, γ is the angle between these two locations and P_n is the Legendre polynomial of order n. This observation reduces the order n^2 sum in Eq. (2) to an order n sum. The P_n are defined by a simple recursive formula that is quickly computed on the GPU for each audio pixel.

The computation of the audio proceeds as follows. First we load the audio signal onto the GPU and perform an inplace FFT. We then segment the audio image into 16 tiles and assign each tile to a multiprocessor of the GPU. Each thread in the execution is responsible for computing the response power of a single pixel in the audio image. The only data that the kernel needs to access is the location of the microphone in order to compute γ and the Fourier coefficients of the 60 microphone signals for all frequencies to be displayed. The weights can then be computed using simple recursive formula for each of the Hankel, Bessel, and Legendre polynomials in Eq. (2).

While performance of the beamformer may be a bit worse, there are several benefits to the on-the-fly approach: 1) frequencies of interest can be changed at runtime with no additional overhead; 2) pixel locations can be changed at runtime with little additional overhead; 3) memory requirements are drastically lower then storing pre-computed weights.

Beamforming: Once a source location of interest is identified, we can isolated audio signal associated with that direction. The intensity of the audio pixel for a given direction is proportional to the Fourier component of the corresponding frequency in the acoustic signal. By computing the intensity of the audio pixels for a given location for all frequencies in the microphone array effective frequency band we can recover and isolate signal. For frequencies outside the effective range of the array we simply append the Fourier coefficients of the raw audio signal from the closest microphone.

5. RESULTS

Vision guided beamforming: Several authors have in the past proposed vision guided beamforming (see e.g., [12]). The idea is that vision based constraints can help us to not steer the beamformer in directions that are not promising. Often these constraints require the source to lie in some constrained region. One crucial difference here is that the quality of the geometric constraints provided by the epipolar geometry is much stronger. We illustrate in

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Fig. 6 this example with a case where a speaker's voice is beamformed in the presence of severe noise using location information from vision. Using a calibrated array-camera combination, we applied a standard face detection algorithm to the vision image and then used the epipolar line induced by the mouth region of the vision image to search for the source in the audio image.

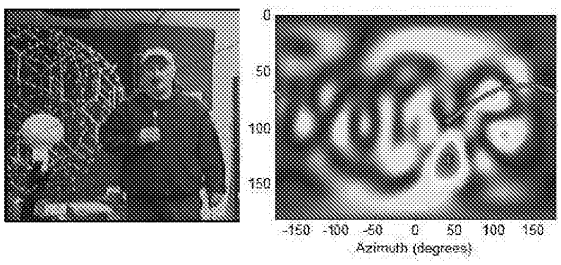


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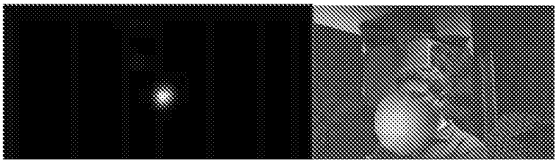


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(PCT Rule 44.1)

Date of mailing *(day/month/year)*	29 SEP 2015
Applicant's or agent's file reference: 29679/PCT	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No.: PCT/US15/38913	International filing date *(day/month/year)*: 01 July 2015 (01.07.2015)
Applicant: GOPRO, INC.	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46).

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 - 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   - ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   - ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national** phase before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **19 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 29679/PCT	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US15/38913	International filing date *(day/month/year)* 01 July 2015 (01.07.2015)	(Earliest) Priority Date *(day/month/year)* 03 July 2014 (03.07.2014)
Applicant GOPRO, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into ..... which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.*6bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the title,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the drawings,

a. the figure of the **drawings** to be published with the abstract is Figure No. 6

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US15/38913

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G10L 19/008 (2015.01)
CPC - G10L 19/008
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) Classification(s): G10L 19/008; G10L 25/03; H04N 21/2368 (2015.01)
CPC Classification(s): G10L 19/008; G10L 2021/02166; H04R 1/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Google/ GooglePatents; IEEE; EBSCO; Espacenet.
Keywords: camera; spherical video; audio; channel; tetrahedron; cube; perpendicular; direction.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2010/0299630 A1 (MCCUTCHEN, D et al.) 25 November 2010; Abstract; paragraphs [0050], [0069], [0092].	1, 7 and 13 --- 2-6, 8-12 and 14-18
Y	WO 2014/096277 A1 (NOKIA CORPORATION) 19 June 2014; Abstract; page 2, lines 9-10; page 13, lines 5-7; page 28, lines 5-6.	2, 8 and 14
Y	US 2013/0177168 A1 (NOKIA CORPORATION) 11 July 2013; Abstract; paragraph [0059].	3, 9, and 15
Y	US 2011/0013778 A1 (TAKUMAI, S) 20 January 2011; Abstract; Figure 12; paragraphs [0068], [0096].	4, 10 and 16
Y	US 2013/0058532 A1 (SPORTVISION, INC.) 7 March 2013; Abstract; paragraphs [0029], [0072].	5, 6, 11, 12, 17 and 18
A	US 2004/0010804 A1 (HENDRICKS, J et al.) 15 January 2004; whole document.	1-18
A	US 2014/0039884 A1 (MICROSOFT CORPORATION) 6 February 2014; whole document.	1-18

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 September 2015 (08.09.2015)	29 SEP 2015
Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3300	Authorized officer Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: Jason E. Amsel
Fenwick & West LLP
Silicon Valley Center
801 California Street
Mountain View, CA 94041
United States of America

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	29 SEP 2015
Applicant's or agent's file reference 29679/PCT	FOR FURTHER ACTION See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US15/38913	01 July 2015 (01.07.2015)	03 July 2014 (03.07.2014)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - G10L 19/008 (2015.01)
CPC - G10L 19/008

Applicant GOPRO, INC.

1. This opinion contains indications relating to the following items:

- [X] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [X] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [X] Box No. VII Certain defects in the international application
- [X] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	8 September 2015 (08.09.2015)	Shane Thomas PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/38913

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a. ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b. ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c. ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/38913

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	2-6, 8-12 and 14-18	YES
	Claims	1, 7 and 13	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-18	NO
Industrial applicability (IA)	Claims	1-18	YES
	Claims	NONE	NO

2. Citations and explanations:

Claims 1, 7 and 13 lack novelty under PCT Article 33(2) as being anticipated by US 2010/0299630 A1 to MCCUTCHEN, D et al. (hereinafter "MCCUTCHEN").

As per claim 1, MCCUTCHEN discloses a method for generating a video with corresponding audio (a plug in service may involve generating an appropriate formatted output image to the HMD device in which the streamed AAC stereo audio channels are synchronized to the video, paragraphs [0066], [0092]), comprising: receiving a spherical video (a spherical immersive image may be displayed, paragraph [0050]); receiving a plurality of audio channels representing audio captured concurrently with the spherical video (an immersive camera may capture a spherical video image in a server-client system for live immersive streaming and the streamed +AAC stereo audio channels may be synchronized to the video by the application of a delay to compensate for the latency of the video encoding, paragraphs [0089], [0092]), each of the plurality of audio channels comprising directional audio corresponding to a different direction (the streamed AAC stereo audio channels are synchronized to the video in which a synchronized audio input is provided by external balanced audio stereo line level inputs or the embedded microphones in the camera head and audio 238 may be from four directional (different direction) microphones, paragraphs [0091], [0092]); mapping different spatial regions of the spherical video to different audio channels (mapping system may include immersive video display in which the streamed AAC stereo audio channels may be synchronized to the video and immersive imaging may include spherical imaging in which the Augmentation plug in service may involve augmentation objects arranged using a scene graph, spatial partitioning using a quad tree, Figure 20; paragraphs [0029], [0039], [0074], [0092]); for each of a plurality of frames of the spherical video, extracting a sub-frame having a reduced field of view relative to a field of view of the spherical video (a reduced worldview image of all or most of the spherical image may be displayed in which the Frame Capture plug in service may provide functionality to extract videos and images 116 from immersive motion pictures based on the viewing angles chosen over time, paragraphs [0009], [0050], [0071], [0074]); for each of the sub-frames, determining, by a processor, one or more of the spatial regions overlapping the sub-frame (spatial portioning may be performed and continuous streaming of immersive video may be done such as encoding image at 30 frames/ sec in which the processing steps in the server may include Automatic Sensor Luminance Balance detection based on camera image overlap zones with auto correction, paragraphs [0074], [0092]) and generating a portion of an audio stream from one or more different audio channels corresponding to the one or more spatial regions overlapping the sub-frame (the streamed AAC stereo audio channels may be synchronized to the video and several simultaneous encodings of the continuously streaming immersive video may be done, for example a Flash H.264 audio/video may encode a high quality equirectangular image at 30 frames/sec at a 4 mbps-5 mbps compressed target bit rate, paragraph [0092]); and outputting the generated video and the audio stream (the digital sensor readings from the camera may be processed in a server to make the final streaming video result in which synchronized audio input may be provided, paragraph [0092]).

-***-Continued Within the Next Supplemental Box-***-

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WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/38913

Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims 8-11 are objected to under PCT Rule 66.2(a)(iii) as containing the following defects in the form or contents thereof: due to their placement and the variance in their preamble language with that of Claim 1, Claims 8-11 have been best understood to depend on Claim 7, not Claim 1.

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WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/38913

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Claim 6 is objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because Claim 6 is indefinite for the following reason: "content relevant to the target path" lacks antecedent basis; Claim 6 has been best understood to depend on Claim 5.

Claim 12 is objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because Claim 12 is indefinite for the following reason: "content relevant to the target path" lacks antecedent basis; Claim 12 has been best understood to depend on depend on Claim 11.

Claim 18 is objected to under PCT Rule 66.2(a)(v) as lacking clarity under PCT Article 6 because Claim 18 is indefinite for the following reason: "content relevant to the target path" lacks antecedent basis. Claim 18 has been best understood to depend on depend on Claim 17.

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WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/38913

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

-***-Continued from Box V: Citations and Explanations-***-
As per claim 7, MCCUTCHEN discloses a non-transitory computer-readable storage medium storing instructions for generating a video with corresponding audio (a data management service for receiving data from the servers may including identification information, and to store the received data in the memory of the computer host in which a plug in service may involve generating an appropriate formatted output image to the HMD device in which the streamed AAC stereo audio channels are synchronized to the video, paragraphs [0044], [0068], [0092]), the instructions when executed by one or more processors causing the one or more processors to perform steps including: receiving a spherical video (a spherical immersive image may be displayed, paragraph [0050]); receiving a plurality of audio channels representing audio captured concurrently with the spherical video (an immersive camera may capture a spherical video image in a server-client system for live immersive streaming and the streamed AAC stereo audio channels may be synchronized to the video by the application of a delay to compensate for the latency of the video encoding, paragraphs [0089], [0092]), each of the plurality of audio channels comprising directional audio corresponding to a different direction (the streamed AAC stereo audio channels are synchronized to the video in which a synchronized audio input is provided by external balanced audio stereo line level inputs or the embedded microphones in the camera head and audio 238 may be from four directional (different direction) microphones, paragraphs [0091], [0092]); mapping different spatial regions of the spherical video to different audio channels (mapping system may include immersive video display in which the streamed AAC stereo audio channels may be synchronized to the video and immersive imaging may include spherical imaging in which the Augmentation plug in service may involve augmentation objects arranged using a scene graph, spatial partitioning using a quad tree, Figure 20; paragraphs [0029], [0039], [0074], [0092]); for each of a plurality of frames of the spherical video, extracting a sub-frame having a reduced field of view relative to a field of view of the spherical video (a reduced worldview image of all or most of the spherical image may be displayed in which the Frame Capture plug in service may provide functionality to extract videos and images 116 from immersive motion pictures based on the viewing angles chosen over time, paragraphs [0009], [0071]); for each of the sub-frames, determining one or more of the spatial regions overlapping the sub-frame (spatial portioning may be performed and continuous streaming of immersive video may be done such as encoding image at 30 frames/ sec in which the processing steps in the server may include Automatic Sensor Luminance Balance detection based on camera image overlap zones with auto correction, paragraphs [0074], [0092]) and generating a portion of an audio stream from one or more different audio channels corresponding to the one or more spatial regions overlapping the sub-frame (the streamed AAC stereo audio channels may be synchronized to the video and several simultaneous encodings of the continuously streaming immersive video may be done, for example a Flash H.264 audio/video may encode a high quality equirectangular image at 30 frames/sec at a 4 mbps-5 mbps compressed target bit rate, paragraph [0092]); and outputting the generated video and the audio stream (the digital sensor readings from the camera may be processed in a server to make the final streaming video result in which synchronized audio input may be provided, paragraph [0092]).

As per claim 13, MCCUTCHEN discloses a media server system for generating a video with corresponding audio (a plug in service may involve generating an appropriate formatted output image to the HMD device in which the streamed AAC stereo audio channels are synchronized to the video, paragraphs [0068], [0092]), the video server system comprising: one or more processors (a server-client system may include the streaming Media Processor, paragraph [0089]); and a non-transitory computer-readable storage medium storing instructions that when executed by the one or more processors causes the one or more processors (a server-client system may include the streaming Media Processor and a data management service for receiving data from the servers that may include identification information for storing the received data in the memory of the computer host, paragraphs [0044], [0089]) to perform steps including: receiving a spherical video (a spherical immersive image may be displayed, paragraph [0050]); receiving a plurality of audio channels representing audio captured concurrently with the spherical video (an immersive camera may capture a spherical video image in a server-client system for live immersive streaming and the streamed AAC stereo audio channels may be synchronized to the video by the application of a delay to compensate for the latency of the video encoding, paragraphs [0089], [0092]), each of the plurality of audio channels comprising directional audio corresponding to a different direction (the streamed AAC stereo audio channels are synchronized to the video in which a synchronized audio input is provided by external balanced audio stereo line level inputs or the embedded microphones in the camera head and audio 238 may be from four directional (different direction) microphones, paragraphs [0091], [0092]); mapping different spatial regions of the spherical video to different audio channels (mapping system may include immersive video display in which the streamed AAC stereo audio channels may be synchronized to the video and immersive imaging may include spherical imaging in which the Augmentation plug in service may involve augmentation objects arranged using a scene graph, spatial partitioning using a quad tree, Figure 20; paragraphs [0029], [0039], [0074], [0092]); for each of a plurality of frames of the spherical video, extracting a sub-frame having a reduced field of view relative to a field of view of the spherical video (a reduced worldview image of all or most of the spherical image may be displayed in which the Frame Capture plug in service may provide functionality to extract videos and images 116 from immersive motion pictures based on the viewing angles chosen over time, paragraphs [0009], [0071]); for each of the sub-frames, determining one or more of the spatial regions overlapping the sub-frame (spatial portioning may be performed and continuous streaming of immersive video may be done such as encoding image at 30 frames/ sec in which the processing steps in the server may include Automatic Sensor Luminance Balance detection based on camera image overlap zones with auto correction, paragraphs [0074], [0092]) and generating a portion of an audio stream from one or more different audio channels corresponding to the one or more spatial regions overlapping the sub-frame (the streamed AAC stereo audio channels may be synchronized to the video and several simultaneous encodings of the continuously streaming immersive video may be done, for example a Flash H.264 audio/video may encode a high quality equirectangular image at 30 frames/sec at a 4 mbps-5 mbps compressed target bit rate, paragraph [0092]); and outputting the generated video and the audio stream (the digital sensor readings from the camera may be processed in a server to make the final streaming video result in which synchronized audio input may be provided, paragraph [0092]).

-***-Continued Within the Next Supplemental Box-***-

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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

-***-Continued from Previous Supplemental Box-***-
Claims 2, 8 and 14 lack an inventive step under PCT Article 33(3) as being obvious over MCCUTCHEN in view of WO 2014/090277 A1 to NOKIA CORPORATION (hereinafter NOKIA'277).

As per claims 2, 8 and 14, MCCUTCHEN discloses the method of claim 1, the non-transitory computer-readable storage medium of claim 7 and the media server system of claim 13. However, MCCUTCHEN fails to disclose wherein generating the portion of the audio stream comprises: weighting each of the plurality of audio channels based on an amount of overlap between the spatial regions and the extracted sub-frame; and combining the weighted plurality of audio channels to generate the portion of the audio stream. NOKIA'277 discloses wherein generating the portion of the audio stream (a surround sound processor instance may be configured to output a multichannel output audio signal track, page 2, lines 8-10); comprises: weighting each of the plurality of audio channels based on an amount of overlap between the spatial regions and the extracted sub-frame (the number of channels output that may be of audio signal may at least one of the two processor instances be selected determining a spatial region within which at least one of the two processor instances may apply spatial processing and in which each audio frame may be 20 milliseconds long and may have an overlap of 10 milliseconds (amount of overlap) between frames, page 2, lines 9-10; page 13, lines 5-7; page 28, lines 5-6); and combining the weighted plurality of audio channels to generate the portion of the audio stream (a surround sound processor instance may be configured to output a multichannel output audio signal track in which the mixer may be configured to generate a difference between the tracks or instances or a weighted additive combination, page 2, lines 8-10; page 37, lines 13-15). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the system of MCCUTCHEN to include wherein generating the portion of the audio stream comprises: weighting each of the plurality of audio channels based on an amount of overlap between the spatial regions and the extracted sub-frame; and combining the weighted plurality of audio channels to generate the portion of the audio stream, as taught in NOKIA'277, for the benefit of using an advanced signal processing for recording and or amplifying real multi-channel audio from the desired direction.

Claims 3, 9 and 15 lack an inventive step under PCT Article 33(3) as being obvious over MCCUTCHEN in view of US 2013/0177168 A1 to NOKIA CORPORATION (hereinafter "NOKIA'168).

As per claims 3, 9 and 15, MCCUTCHEN discloses the method of claim 1, the non-transitory computer-readable storage medium of claim 7 and the media server system of claim 13. MCCUTCHEN further discloses wherein each of the plurality of audio channels corresponds to a direction (the streamed AAC stereo audio channels are synchronized to the video in which a synchronized audio input is provided by external balanced audio stereo line level inputs or the embedded microphones in the camera head and audio 238 may be from four directional microphones, paragraphs [0091], [0092]). However, MCCUTCHEN fails to disclose wherein each of the plurality of audio channels corresponds to a direction perpendicular to a face of a tetrahedron. NOKIA'168 discloses wherein each of the plurality of audio channels corresponds to a direction perpendicular to a face of a tetrahedron (each microphone may be considered to be directed perpendicular to a face of a tetrahedron, paragraph [0059]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the system of MCCUTCHEN to include wherein each of the plurality of audio channels corresponds to a direction perpendicular to a face of a tetrahedron, as taught in NOKIA'168, for the benefit of providing a method and apparatus for enhancing audio capture and recording flexibility with respect to microphones orientation and positioning.

Claims 4, 10 and 16 lack an inventive step under PCT Article 33(3) as being obvious over MCCUTCHEN in view of US 2011/0013778 A1 to TAKUMAI, S (hereinafter "TAKUMAI").

As per claims 4, 10 and 16, MCCUTCHEN discloses the method of claim 1, the non-transitory computer-readable storage medium of claim 7 and the media server system of claim 13. MCCUTCHEN further discloses wherein each of the plurality of audio channels corresponds to a direction (the streamed AAC stereo audio channels are synchronized to the video in which a synchronized audio input is provided by external balanced audio stereo line level inputs or the embedded microphones in the camera head and audio 238 may be from four directional microphones, paragraphs [0091], [0092]). However, MCCUTCHEN fails to disclose wherein each of the plurality of audio channels corresponds to a direction perpendicular to a face of a cube. TAKUMAI discloses wherein each of the plurality of audio channels corresponds to a direction perpendicular to a face of a cube (the speaker array apparatus may be installed in a shape such as a cube and the gain of the audio beams of respective channels that may be of the test sound output from speaker array 10 while sweeping may be the highest in a recommended listening position of the user such as perpendicular to the front surface (face of a cube) of the speaker array 10, Figure 12; paragraphs [0007], [0068], [0076], [0096]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the system of MCCUTCHEN, to include wherein each of the plurality of audio channels corresponds to a direction perpendicular to a face of a cube, as taught in TAKUMAI, for the benefit of providing speaker array apparatus to adjust audio beams for high quality sound output.

-***-Continued Within the Next Supplemental Box-***-

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Exhibit 1003 Page 337

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US15/38913

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

-***-Continued from Previous Supplemental Box-***-
Claims 5, 6, 11, 12, 17 and 18 lack an inventive step under PCT Article 33(3) as being obvious over MCCUTCHEN in view of US 2013/0058532 A1 to SPORTVISION, INC. (hereinafter "SPORTVISION").

As per claim 5, MCCUTCHEN discloses the method of claim 1. MCCUTCHEN further discloses wherein a camera capturing the spherical video (an immersive camera may capture a spherical video image in a server-client system for live immersive streaming, paragraph [0089]). However, MCCUTCHEN fails to disclose wherein comprising: receiving video metadata including location data pertaining to a location of a camera capturing the spherical video and timing data pertaining to a time of capture of the spherical video; receiving user metadata representing a target path, the target path comprising a sequence of time-stamped locations corresponding to a target; determining the sub-frame as having content relevant to the target path. SPORTVISION discloses comprising: receiving video metadata including location data pertaining to a location of a camera capturing the spherical video (two or more cameras may be positioned to capture images of the event that may be at the locations in the event facility, paragraphs [0025], [0028]) and timing data pertaining to a time of capture of the spherical video (images may be received that can be from video of a sporting event such that of the moving object from multiple cameras at different time points during a time interval, paragraph [0004]); receiving user metadata representing a target path (the position and/or path of an object may be determined and the user interface display may provide information to a human operator based on the data received from the cameras, paragraphs [0003], [0072]), the target path comprising a sequence of time-stamped locations corresponding to a target (the processing facility 140 may include equipment which receives and stores the captured images, time stamps the captured images using a common clock, and processes the captured images to determine the position and/ or path of the object, paragraph [0029]); determining the sub-frame as having content relevant to the target path (the path of the object may be determined and the technique may include measuring the position of the ball in multiple video frames from multiple cameras, paragraphs [0043], [0045]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the system of MCCUTCHEN to include wherein comprising: receiving video metadata including location data pertaining to a location of a camera capturing the spherical video and timing data pertaining to a time of capture of the spherical video; receiving user metadata representing a target path, the target path comprising a sequence of time-stamped locations corresponding to a target; determining the sub-frame as having content relevant to the target path, as taught in SPORTVISION, for the benefit of providing a method to determine position and path of an object using asynchronous camera by capturing images at various time points.

As per claims 6, 12 and 18, a combination of MCCUTCHEN and SPORTVISION discloses the method of claim 5, the non-transitory computer-readable storage medium of claim 11 and the media server system of claim 17. However, MCCUTCHEN discloses wherein determining the sub-frame as having content relevant to the target path comprises: determining a direction of the target relative to the camera based on the video metadata and the user metadata; and selecting the sub-frame based on the direction. SPORTVISION discloses wherein determining the sub-frame as having content relevant to the target path comprises: determining a direction of the target relative to the camera based on the video metadata and the user metadata (series of images can be combined to depict different locations of the object along the path and the statistical information regarding the object can be also be obtained, including speed, direction, distance traveled, height, time in the air and so forth and measuring the position of the ball in multiple video frames may be from multiple cameras, paragraphs [0030], [0046]); and selecting the sub-frame based on the direction (Cameras may be used to track an object [0025] and the rate of image capture may be needed (selecting) such as for example thirty frames or sixty fields per second that may be to determine the position and/or path (direction) of the object which is a function of the speed of the object, paragraphs [0025], [0026]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the system of MCCUTCHEN to include wherein determining the sub-frame as having content relevant to the target path comprises: determining a direction of the target relative to the camera based on the video metadata and the user metadata; and selecting the sub-frame based on the direction, as taught in SPORTVISION, for the benefit of providing a method to track object accurately at desired locations using cameras and capturing images at different times and determine its path.

-***-Continued Within the Next Supplemental Box-***-

Insta360
Exhibit 1003 Page 338

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

-***-Continued from Previous Supplemental Box-***-
As per claims 11 and 17, MCCUTCHEN discloses the non-transitory computer-readable storage medium of claim 7 and the media server system of claim 13. MCCUTCHEN further discloses wherein the instructions when executed further causing the one or more processors (a server-client system may include the streaming Media Processor and a data management service for receiving data from the servers that may include identification information for storing the received data in the memory of the computer host, paragraphs [0044], [0089]) to perform steps including: a camera capturing the spherical video (an immersive camera may capture a spherical video image in a server-client system for live immersive streaming, paragraph [0089]). However, MCCUTCHEN fails to disclose wherein steps including: receiving video metadata including location data pertaining to a location of a camera capturing the spherical video and timing data pertaining to a time of capture of the spherical video; receiving user metadata representing a target path, the target path comprising a sequence of time-stamped locations corresponding to a target; determining the sub-frame as having content relevant to the target path. SPORTVISION discloses wherein steps including: receiving video metadata including location data pertaining to a location of a camera capturing the spherical video (two or more cameras may be positioned to capture images of the event that may be at the locations in the event facility, paragraphs [0025], [0028]) and timing data pertaining to a time of capture of the spherical video (images may be received that can be from video of sporting event such that of the moving object from multiple cameras at different time points during a time interval, paragraph [0004]); receiving user metadata representing a target path (the position and/or path of an object may be determined and the user interface display may provide information to a human operator based on the data received from the cameras, paragraphs [0003], [0072]), the target path comprising a sequence of time-stamped locations corresponding to a target (the processing facility 140 may include equipment which receives and stores the captured images, time stamps the captured images using a common clock, and processes the captured images to determine the position and/ or path of the object, paragraph [0029]); determining the sub-frame as having content relevant to the target path (the path of the object may be determined and the technique may include measuring the position of the ball in multiple video frames from multiple cameras, paragraphs [0043], [0045]). It would have been obvious to one of ordinary skill in the art at the time of the invention to modify the system of MCCUTCHEN to include wherein steps including: receiving video metadata including location data pertaining to a location of a camera capturing the spherical video and timing data pertaining to a time of capture of the spherical video; receiving user metadata representing a target path, the target path comprising a sequence of time-stamped locations corresponding to a target; determining the sub-frame as having content relevant to the target path, as taught in SPORTVISION, for the benefit of providing a method to determine position and path of an object using asynchronous camera by capturing images at various time points.

Claims 1-18 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used in industry.

PCT Recordation of Search History

Case/PCT Application Number: PCT/US15/38913

CLIN Number/Technical Field of PCT Application: 5

Date(s) During Which the Search was Conducted: 4 September 2015 (04.09.2015) – 8 September 2015 (08.09.2015)

Date of Completion of Recordation of Search History Form: 8 September 2015 (08.09.2015)

Research Analyst Initials: DMB

Search Approval Official (SAO) Initials: CEH

Field of Search/Classification Information:

IPC(8) Classification(s): G10L 19/008; G10L 25/03; H04N 21/2368 (2015.01)

CPC Classification(s): G10L 19/008; G10L 2021/02166; H04R 1/02

Database(s) Searched (Patent and Non-Patent Literature (NPL), Including Sub-Databases and Files Searched) and Search Terms Used:

PatSeer (US, EP, WO, JP, DE, GB, CN, FR, KR, ES, AU, IN, CA, INPADOC Data); Google/ GooglePatents; IEEE; EBSCO; Espacenet.

Keywords: camera; spherical video; audio; channel; tetrahedron; cube; perpendicular; direction.

Database Search String Recordation, Including Dates of Searches):

Patent Database Search Strategy/Results:

ID	Search String	Records	Created Date
L25	TACD:((audio w2 channel*) and direction and (perpendicular w4 tetrahedron))	0	8-Sep-15
L24	TACD:(audio and (direction w4 perpendicular w4 tetrahedron))	0	8-Sep-15
L21	TACD:(camera* and server* and (audio w5 channel*) and frame* and (weight* w4 channel*)) NOT (medical or brain or health) AND IC: (G10L19/008 or G10L25/03 or H04N21/2368)	2	8-Sep-15
L20	TACD:(camera* and server* and (audio w5 channel*) and frame* and (weight* w4 channel*)) NOT (medical or brain or health) AND CPC: (G10L19/008 or G10L2021/02166 or H04R1/02)	10	8-Sep-15
L19	TACD:(audio and (direction w4 perpendicular w4 cube))	2	4-Sep-15
L18	TACD:(((audio and (direction w4 perpendicular w4 cube)))) AND PNC:(WO2014090277)	0	4-Sep-15
L17	TACD:(((audio w2 channel*) and (direction w4 perpendicular w4 cube))) AND PNC:(WO2014090277)	0	4-Sep-15
L16	PNC:(WO2014090277)	1	4-Sep-15
L15	TACD:(camera* and server* and (audio w5 channel*) and frame* and (weight* w4 channel*) and (overlap* w4 spatial w4 (region* or area*))) NOT (medical or brain or health)	0	4-Sep-15
L14	TACD:(camera* and server* and (audio w5 channel*) and frame* and (weight* w4 channel*) and (amount w4 overlap*) and (spatial w4 (region* or area*))) NOT (medical or brain or health)	0	4-Sep-15
L13	TACD:(camera* and server* and (audio w5 channel*) and frame* and (weight* w4 channel*) and (amount w4 overlap* w4 spatial w4 (region* or area*))) NOT (medical or brain or health)	0	4-Sep-15
L12	TACD:(camera* and server* and (audio w5 channel*) and frame* and (weight* w4 channel*)) NOT (medical or brain or health)	95	4-Sep-15
L11	TACD:(camera* and (spherical w5 video*) and server* and (audio w5 channel*) and frame* and (weight* w4 channel*)) NOT (medical or brain or health)	0	4-Sep-15
L10	TACD:(camera* and (spherical w5 video*) and server* and (audio w5 channel*) and frame*) NOT (medical or brain or health)	12	4-Sep-15
L9	TACD:(camera* and (spherical w5 video*) and server* and (audio w5 channel*) and (subframe* or sub-frame*)) NOT (medical or brain or health)	0	4-Sep-15
L8	TACD:(camera* and (spherical w5 video*) and server* and (audio w5 channel*)) NOT (medical or brain or health)	12	4-Sep-15

L7	TACD:(camera* and (spherical w5 video*) and server*) NOT (medical or brain or health)	298	4-Sep-15
L6	TACD:((camera* and (spherical w5 video*) and server*))	352	4-Sep-15
L5	TACD:((camera* and (spherical w5 video*)))	1759	4-Sep-15
L4	TACD:((spherical w4 video) and audio and (sub-frame* or subframe*))	1	4-Sep-15
L3	TAC:((spherical w4 video) and audio and sub-frame*)	0	4-Sep-15
L2	TAC:((spherical w4 video) and audio)	63	4-Sep-15
L1	TA:((spherical w4 video) and audio)	6	4-Sep-15

Non-Patent Literature (NPL) Search Strategy/Results:

Google/ GooglePatents

8 September 2015 (08.09.2015)

- Camera and spherical video
- Audio and channels and direction
- Audio and channels and tetrahedron

IEEE

8 September 2015 (08.09.2015)

- Camera and spherical video
- Audio and channels and direction
- Audio and channels and tetrahedron

EBSCO

8 September 2015 (08.09.2015)

- Camera and spherical video
- Audio and channels and direction
- Audio and channels and tetrahedron

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: Jason E. Amsel
Fenwick & West LLP
Silicon Valley Center
801 California Street
Mountain View, CA 94041
United States of America

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)*
Applicant's or agent's file reference 29679/PCT	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US15/38913	International filing date *(day/month/year)* 01 July 2015 (01.07.2015)
Applicant GOPRO, INC.	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 - 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **19 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/ Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450	Authorized officer Shane Thomas
Facsimile No. 571-273-8300	Telephone No. PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/789,706	07/01/2015	Scott Patrick Campbell	23769-29679/US	4601

132055 2590 06/07/2016

GoPro/Fenwick
801 California Street
Mountain View, CA 94041

EXAMINER
DANG, HUNG Q

ART UNIT	PAPER NUMBER
2484	

NOTIFICATION DATE	DELIVERY MODE
06/07/2016	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ptoc@fenwick.com
fwgopropatents@fenwick.com

PTOL-90A (Rev. 04/07)

Office Action Summary	Application No. 14/789,706	Applicant(s) CAMPBELL ET AL.	
	Examiner HUNG DANG	Art Unit 2484	AIA (First Inventor to File) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *07/01/2015*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-18* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-18* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *07/01/2015* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.

4) ☐ Other: _____.

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

DETAILED ACTION

Claim Rejections - 35 USC § 112

The following is a quotation of 35 U.S.C. 112(b):
(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:
The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

Claims 6, 12, and 18 are rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor, or for pre-AIA the applicant regards as the invention.

Claims 6, 12, and 18 recite, "wherein determining the sub-frame as having content relevant to the target path comprises …." There is insufficient antecedent basis for this limitation in the claims. The claims are therefore indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor, or for pre-AIA the applicant regards as the invention.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(a)(1) the claimed invention was patented, described in a printed publication, or in public use, on sale or otherwise available to the public before the effective filing date of the claimed invention.

Claims 1-4, 7-10, and 13-16 are rejected under 35 U.S.C. 102(a)(1) as being anticipated by Charlier et al. (US 2003/0160862 A1 – hereinafter Charlier).

Regarding claim 1, Charlier discloses a method for generating a video with corresponding audio, comprising: receiving a spherical video *([0028] – receiving a video stream having a field of view ranging to about 360 degrees)*; receiving a plurality of audio channels representing audio captured concurrently with the spherical video, each of the plurality of audio channels comprising directional audio corresponding to a different direction *([0066]-[0069] – audio sources in different directions depending on speakers and non-human audio sources as shown in Fig. 1 and described in at least [0058]-[0061])*; mapping different spatial regions of the spherical video to different audio channels *([0066]-[0069] – via a video mapping technique, spatial regions and corresponding audio sources within the spatial regions are determined as a correspondence, e.g. each spatial region corresponds to a number of identified audio sources)*; for each of a plurality of frames of the spherical video, extracting a sub-frame having a reduced field of view relative to a field of view of the spherical video *(Fig. 8; [0067] – either sub-frame244 or sub-frame 246 is extracted, either of these frames has a reduced field of view)*; for each of the sub-frames, determining, by a processor, one or more of the spatial regions overlapping the sub-frame and generating a portion of an audio stream from one or more different audio channels corresponding to the one or more spatial regions overlapping the sub-frame *([0067]-[0069] – determining spatial regions corresponding to the sub-frame via a video mapping technique to locate the audio sources within the spatial regions)*; and outputting the generated video and the

audio stream *([0069] – the incoming audio data is zoomed in (or out) to focus on the spatial regions and outputted)*.

Regarding claim 2, Charlier also discloses generating the portion of the audio stream comprises: weighting each of the plurality of audio channels based on an amount of overlap between the spatial regions and the extracted sub-*frame ([0069] – performing gradual audio zooming in to weigh more heavily on audio sources located close the determined spatial regions)*; and combining the weighted plurality of audio channels to generate the portion of the audio stream *frame ([0069] – performing gradual audio zooming in to weigh more heavily on audio sources located close the determined spatial regions)*.

Regarding claim 3, Charlier also discloses each of the plurality of audio channels corresponds to a direction perpendicular to a face of a tetrahedron *(Figs. 5-7; Fig. 1; [0056]; [0071] – each audio source and a microphone establishes a direction – each direction is perpendicular to a face of a tetrahedron by arranging the layout of the microphone array around the audio source)*.

Regarding claim 4, Charlier also discloses each of the plurality of audio channels corresponds to a direction perpendicular to a face of a cube *(Figs. 5-7; Fig. 1; [0056]; [0071] – each audio source and a microphone establishes a direction – each direction is perpendicular to a face of a cube by arranging the layout of the microphone array around the audio source)*.

Claim 7 is rejected for the same reason as discussed in claim 1 above.

Claim 8 is rejected for the same reason as discussed in claim 2 above.

Claim 9 is rejected for the same reason as discussed in claim 3 above.

Claim 10 is rejected for the same reason as discussed in claim 4 above.

Claim 13 is rejected for the same reason as discussed in claim 1 above.

Claim 14 is rejected for the same reason as discussed in claim 2 above.

Claim 15 is rejected for the same reason as discussed in claim 3 above.

Claim 16 is rejected for the same reason as discussed in claim 4 above.

Claim Rejections - 35 USC § 103

The following is a quotation of 35 U.S.C. 103 which forms the basis for all obviousness rejections set forth in this Office action:

> A patent for a claimed invention may not be obtained, notwithstanding that the claimed invention is not identically disclosed as set forth in section 102 of this title, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains. Patentability shall not be negated by the manner in which the invention was made.

Claims 5-6, 11-12, and 17-18 are rejected under 35 U.S.C. 103 as being unpatentable over Charlier as applied to claims 1-4, 7-10, and 13-16 above, and further in view of Karydis (WO 2009/047572 A1 – hereinafter Karydis).

Regarding claim 5, see the teachings of Charlier as discussed in claim 1 above. However, Charlier does not disclose receiving video metadata including location data pertaining to a location of a camera capturing the spherical video and timing data pertaining to a time of capture of the spherical video; receiving user metadata representing a target path, the target path comprising a sequence of time-stamped locations corresponding to a target; determining the sub-frame as having content relevant to the target path.

Karydis discloses receiving video metadata including location data pertaining to a location of a camera capturing the spherical video and timing data pertaining to a time of capture of the spherical video *(page 12, lines 18-45 – the location of the camera corresponds to argument video1 in command play(video1) since each video stream corresponds to a camera located at a given location as described in at least Fig. 8 and page 4, lines 13-18 – timing data is the timestamps associated with video frames and audio samples that can be queried by time = channel.position command)*; receiving user metadata representing a target path, the target path comprising a sequence of time-stamped locations corresponding to a target *(page 12, lines 18-45 – receiving user input to select switching from the current camera to another camera specified by play(video1) command and sound.play())*; determining the sub-frame as having content relevant to the target path *(page 12, lines 18-45 – determining the position of the video content to be switched to)*.

One of ordinary skill in the art at the time the invention was made would have been motivated to incorporate the teachings of Karydis into the method taught by Charlier to facilitate switching of the view.

Regarding claim 6, see the teachings of Charlier as discussed in claim 1 above. However, Charlier does not disclose determining the sub-frame as having content relevant to the target path comprises: determining a direction of the target relative to the camera based on the video metadata and the user metadata; and selecting the sub-frame based on the direction.

Karydis also discloses determining the sub-frame as having content relevant to the target path comprises: determining a direction of the target relative to the camera based on the video metadata and the user metadata *(page 12, lines 18-45 – receiving user input to select switching from the current camera to another camera specified by play(video1) command and sound.play())*; and selecting the sub-frame based on the direction *(page 12, lines 18-45 – determining the position of the video content to be switched to)*.

One of ordinary skill in the art at the time the invention was made would have been motivated to incorporate the teachings of Karydis into the method taught by Charlier to facilitate switching of the view.

Claim 11 is rejected for the same reason as discussed in claim 5 above.

Claim 12 is rejected for the same reason as discussed in claim 6 above.

Claim 17 is rejected for the same reason as discussed in claim 5 above.

Claim 18 is rejected for the same reason as discussed in claim 6 above.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to HUNG DANG whose telephone number is (571)270-1116. The examiner can normally be reached on IFT.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, THAI Q. TRAN can be reached on 571-272-7382. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/HUNG DANG/
Primary Examiner, Art Unit 2484

Notice of References Cited	Application/Control No. 14/789,706	Applicant(s)/Patent Under Reexamination CAMPBELL ET AL.	
	Examiner HUNG DANG	Art Unit 2484	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-2003/0160862 A1	08-2003	Charlier, Michael L.	H04N5/23238	348/14.08
	B	US-				
	C	US-				
	D	US-				
	E	US-				
	F	US-				
	G	US-				
	H	US-				
	I	US-				
	J	US-				
	K	US-				
	L	US-				
	M	US-				

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N	WO 2009/047572 A1	04-2009	WIPO	Karydis	H04N 5/232
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Electronic Patent Application Fee Transmittal

Application Number:	16548453
Filing Date:	22-Aug-2019
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Filer:	Vadim Polonichko/Sandra Streams
Attorney Docket Number:	46DG-026061

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	240	240
		Total in USD ($)		**240**

Electronic Acknowledgement Receipt

EFS ID:	37235953
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	Vadim Polonichko/Sandra Streams
Filer Authorized By:	Vadim Polonichko
Attorney Docket Number:	46DG-026061
Receipt Date:	23-SEP-2019
Filing Date:	22-AUG-2019
Time Stamp:	01:18:41
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	GP-46DG-026061_SyncIDS-Form.pdf	64469 6dd60175a4d29cc3217761715a9b7e5276629b27	no	3

Warnings:

Information:					
This is not an USPTO supplied IDS fillable form					
2	Transmittal Letter	GP-46DG-026061_Transmittal-Letter.pdf	504822 3fbdaf05e14051208f97c43f313a7e6f22630f09	no	1
Warnings:					
Information:					
3	Foreign Reference	GP-46DG-026061-Foreign-045.pdf	6803311 9e3ec683ecea6392b75ae26eb08a94bf9bcbb39d	no	25
Warnings:					
Information:					
4	Foreign Reference	GP-46DG-026061-Foreign-046.pdf	1594055 0b21692a1458e0e0ea4e95153aae7eb552dc9981	no	35
Warnings:					
Information:					
5	Foreign Reference	GP-46DG-026061-Foreign-047.pdf	13931289 d72de15b6bed72cd88aa4419b1c729a09fb1d798	no	85
Warnings:					
Information:					
6	Non Patent Literature	GP-46DG-026061-NPL-048.pdf	85530 6d9905da865baef7ac4f8a08910e0efaa17b0274	no	1
Warnings:					
Information:					
7	Non Patent Literature	GP-46DG-026061-NPL-049.pdf	459989 097acd55b8745e677036ee42acd471569c3c376f	no	12
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Information:					
8	Non Patent Literature	GP-46DG-026061-NPL-050.pdf	1432671 a6e4bc69940301e041791d2e9f12ac8e2e794bed	no	7
Warnings:					
Information:					

9	Non Patent Literature	GP-46DG-026061-NPL-051.pdf	532032 426a89bd2da3b2caf38b7012d6534a3cd8898dc5	no	4
Warnings:					
Information:					
10	Non Patent Literature	GP-46DG-026061-NPL-052.pdf	443270 b2ef5052ce34d841dc60a448de9118c46a9d0141	no	10
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11	Non Patent Literature	GP-46DG-026061-NPL-053.pdf	1541988 339143fe73c03c5697286e1397ebec254132b806	no	12
Warnings:					
Information:					
12	Non Patent Literature	GP-46DG-026061-NPL-054.pdf	226779 562594e18726392299a35942ef69b40e293eabeb	no	4
Warnings:					
Information:					
13	Other Reference-Patent/App/Search documents	GP-46DG-026061-NPL-055-Other.pdf	8806728 664e26ff8e5ae5c281e59f4fca57cc170cab630d	no	16
Warnings:					
Information:					
14	Other Reference-Patent/App/Search documents	GP-46DG-026061-NPL-056-Other.pdf	2061956 e108ee7664aa8d4ae5daf2408e51df1166c6d53d	no	10
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Information:					
15	Fee Worksheet (SB06)	fee-info.pdf	30720 07b84ed9eb24541db31809bfb8792387a7c103e3	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	38519609		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Patent Application Fee Transmittal	
Application Number:	16548453
Filing Date:	22-Aug-2019
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
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Attorney Docket Number:	46DG-026061
Filed as Large Entity	
Filing Fees for Utility under 35 USC 111(a)	

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	240	240
		Total in USD ($)		**240**

Electronic Acknowledgement Receipt	
EFS ID:	37277711
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	Vadim Polonichko/Julie Jager
Filer Authorized By:	Vadim Polonichko
Attorney Docket Number:	46DG-026061
Receipt Date:	25-SEP-2019
Filing Date:	22-AUG-2019
Time Stamp:	18:12:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$240
RAM confirmation Number	E20199OI12377748
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Fee Worksheet (SB06)	fee-info.pdf	30768 36d16872a1094dfdf330e5207e7c87d0eed932bc	no	2

Warnings:	
Information:	
Total Files Size (in bytes):	30768

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/548,453	08/22/2019	Thomas Derbanne	46DG-026061	2987

137002 7590 11/04/2019

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008

EXAMINER	
SEGURA, CYNTHIA	

ART UNIT	PAPER NUMBER
2698	

NOTIFICATION DATE	DELIVERY MODE
11/04/2019	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

docketing@esplin.legal

PTOL-90A (Rev. 04/07)

Applicant-Initiated Interview Summary	**Application No.** 16/548,453	**Applicant(s)** Derbanne et al.		
	Examiner CYNTHIA SEGURA	**Art Unit** 2698	**AIA (First Inventor to File) Status** Yes	**Page** **1 of** 2

All participants (applicant, applicants representative, PTO personnel):

1. CYNTHIA SEGURA (Primary Examiner); Telephonic

2. DAE HEE CHO (Attorney: REG. NO. 67,769); Telephonic

Date of Interview: 29 October 2019

Claims Discussed: Claims 1, 7 and 21-23.

Prior Art Discussed: Beysserie (US Patent 9,787,902)

Issues Discussed:

Proposed Amendments:
Discussed proposed amendments for claims 1 and 7, including further adding that "the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing".

The examiner pointed out that Beysserie discloses motion sensors including a gyroscope and accelerometers to measure rotational velocity and rotational acceleration and stabilize the image data in accordance to such measurements (see col. 3, lines 1-8; col. 5, line 50 to col. 6, line 36; col. 9, lines 1-34; col. 10, lines 1-30; col. 12, line 59 to col. 13, line 5; col. 20, lines 40-67; col. 21, lines 58-67).

Discussed new claims 21-23. Beysserie appears to not disclose the specific details of weighting in multiple ways the rotational velocity and rotational acceleration; neither discloses the additional details of the intra-frame motion. Thus, the proposed amendtments of claims 21-23 appear to overcome the cited art.

No agreement was reached.

Further search and consideration shall be provided pending an official response.

Attachment(s): Agenda,

/CYNTHIA SEGURA/ Primary Examiner, Art Unit 2698	

Applicant is reminded that a complete written statement as to the substance of the interview must be made of record in the application file. It is the applicants responsibility to provide the written statement, unless the interview was initiated by the Examiner and the Examiner has indicated that a written summary will be provided. See MPEP 713.04
Please further see:
MPEP 713.04
Title 37 Code of Federal Regulations (CFR) § 1.133 Interviews, paragraph (b)
37 CFR § 1.2 Business to be transacted in writing

U.S. Patent and Trademark Office
PTOL-413/413b (Rev. 01/01/2015) **Interview Summary** Paper No. 20191029

Applicant recordation instructions: The formal written reply to the last Office action must include the substance of the interview. (See MPEP section 713.04). If a reply to the last Office action has already been filed, applicant is given a non-extendable period of the longer of one month or thirty days from this interview date, or the mailing date of this interview summary form, whichever is later, to file a statement of the substance of the interview.

Examiner recordation instructions: Examiners must summarize the substance of any interview of record. A complete and proper recordation of the substance of an interview should include the items listed in MPEP 713.04 for complete and proper recordation including the identification of the general thrust of each argument or issue discussed, a general indication of any other pertinent matters discussed regarding patentability and the general results or outcome of the interview, to include an indication as to whether or not agreement was reached on the issues raised.

NOT INTENDED FOR ENTRY INTO THE OFFICIAL RECORD

Attorney Docket: 46DG-026061

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE PATENT APPLICATION OF	:	Thomas Derbanne, *et al.*
SERIAL NO.	:	16/548,453
FILING DATE	:	August 22, 2019
ART UNIT	:	2698
EXAMINER	:	SEGURA, CYNTHIA
FOR	:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS

PROPOSED AGENDA

Via EMAIL
Examiner SEGURA, CYNTHIA
United States Patent & Trademark Office

Examiner:

The following is submitted as a Proposed Agenda for an Examiner's Interview regarding the above-identified patent application. It should be appreciated that this document is provided solely as a reference for the Examiner and is not intended for entry into the Official Record.

We have previously discussed conducting the interview on for Tuesday, October 29, 2019 at 2:00 PM Eastern. We will call you at the number listed in the Office Action (571-270-3580). Attendees to the call may include: D. Benjamin Esplin (Reg. No. 58,297), Dae Hee Cho (Reg. No. 67,769).

Let us know if you have any questions.

Best Regards,

D. Benjamin Esplin
760.206.3256
ben@esplin.legal

NOT INTENDED FOR ENTRY INTO THE OFFICIAL RECORD

PROPOSED TOPICS

1. Discussion of perceived patentable features of present disclosure.

    a. Observed trajectory of a housing of an image capture device during a capture duration is determined based on a position sensor.

    b. A capture trajectory is determined to include smoother changes than the observed trajectory. Orientations of punchout of the images are determined based on the capture trajectory of the housing

    c. The capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing. The combination of the rotational velocity and rotational acceleration may weigh the velocity and acceleration components equally or differently.

    d. The capture trajectory is determined to preserve intra-frame motion based on intra-frame motion of the housing during frame exposure such that the capture trajectory follows the intra-frame motion. The capture trajectory following the intra-frame motion includes motion of the capture trajectory being aligned with motion blur caused by the intra-frame motion.

    e. See Application Paragraphs 53-57, FIGS. 4, 6A-6B

NOT INTENDED FOR ENTRY INTO THE OFFICIAL RECORD

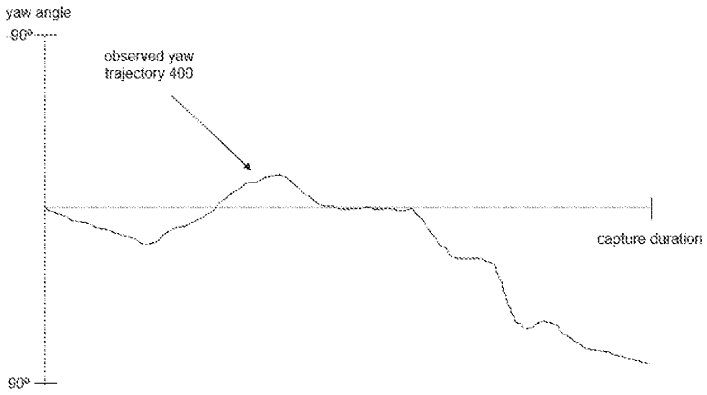


FIG. 4

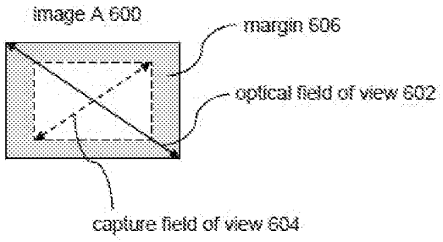


FIG. 6A

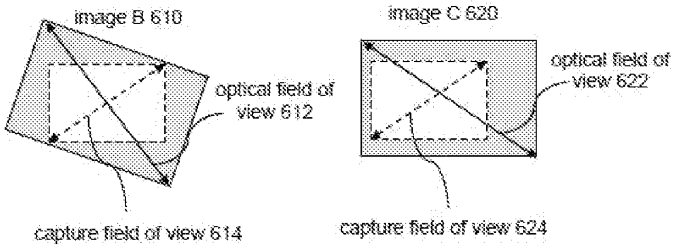


FIG. 6B

f. Proposed amendments to claims 1 and 7, and proposed new claims 21-23 are included in Attachment I.

2. Discussion of the reference used to reject independent claims in the September 13, 2019 Office Action ("Office Action"): U.S. Patent No. 9,787,902 to Beysserie ("Beysserie").

CONCLUSION

Thus, Applicant has provided the Examiner with a detailed Agenda for the aforementioned Interview. If there is any other information that would be of assistance to the Examiner in preparation for the Interview, the Examiner is invited to contact the undersigned at the number provided below.

Respectfully submitted,

D. Benjamin Esplin
Reg. No. 58,297

Customer No. 137002

ESPLIN & ASSOCIATES, PC
5411 Avenida Encinas, Suite 100
Carlsbad, CA 92008
(760) 249-2133

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ATTACHMENT I

1. (**Proposed Amendment**) A system that stabilizes videos, the system comprising:

a housing of an image capture device;

an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content;

the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;

a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; and

one or more physical processors configured by machine-readable instructions to:

determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;

NOT INTENDED FOR ENTRY INTO THE OFFICIAL RECORD

determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory, wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing;

determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and

generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.

7. (**Proposed Amendment**) The system of claim 1, wherein the capture trajectory of the housing is determined to minimize inter-frame motion while preserving intra-frame motion, wherein the intra-frame motion is preserved based on intra-frame motion of the housing during frame exposure such that the capture trajectory follows the intra-frame motion.

21. (**Proposed New**) The system of claim 1, wherein the combination of rotational velocity and rotational acceleration of the housing weighs the rotational velocity and the rotational acceleration equally.

22. (**Proposed New**) The system of claim 1, wherein the combination of rotational velocity and rotational acceleration of the housing weighs the rotational velocity and the rotational acceleration differently.

23. (**Proposed New**) The system of claim 7, wherein the capture trajectory following the intra-frame motion includes motion of the capture trajectory being aligned with motion blur caused by the intra-frame motion.

Doc Code: DIST.E.FILE **Document Description: Electronic Terminal Disclaimer - Filed**	PTO/SB/25 PTO/SB/26 U.S. Patent and Trademark Office Department of Commerce

Electronic Petition Request	**TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION AND TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT**
Application Number	16548453
Filing Date	22-Aug-2019
First Named Inventor	Thomas Derbanne
Attorney Docket Number	46DG-026061
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS

☒ Filing of terminal disclaimer does not obviate requirement for response under 37 CFR 1.111 to outstanding Office Action

☒ This electronic Terminal Disclaimer is not being used for a Joint Research Agreement.

Owner	Percent Interest
GOPRO, INC.	100 %

The owner(s) of percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending reference Application Number(s)

15987786 filed on 05/23/2018

16418203 filed on 05/21/2019

as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the reference application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said reference application, "as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application," in the event that any such patent granted on the pending reference application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

The owner(s) with percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of prior patent number(s)

10341564

as the term of said prior patent is presently shortened by any terminal disclaimer. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the prior patent are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the prior patent, "as the term of said prior patent is presently shortened by any terminal disclaimer," in the event that said prior patent later:
- expires for failure to pay a maintenance fee;
- is held unenforceable;
- is found invalid by a court of competent jurisdiction;
- is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
- has all claims canceled by a reexamination certificate;
- is reissued; or
- is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

◉ Terminal disclaimer fee under 37 CFR 1.20(d) is included with Electronic Terminal Disclaimer request.

○ I certify, in accordance with 37 CFR 1.4(d)(4), that the terminal disclaimer fee under 37 CFR 1.20(d) required for this terminal disclaimer has already been paid in the above-identified application.

Applicants claims the following fee status:

○ Small Entity

○ Micro Entity

◉ Regular Undiscounted

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

◉ An attorney or agent registered to practice before the Patent and Trademark Office who is of record in this application

Registration Number 58297

○ A sole inventor

○ A joint inventor; I certify that I am authorized to sign this submission on behalf of all of the inventors as evidenced by the power of attorney in the application

○ A joint inventor; all of whom are signing this request

Signature	/D. Benjamin Esplin/

Name	D. Benjamin Esplin

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this certification. See MPEP § 324.

Electronic Patent Application Fee Transmittal

Application Number:	16548453
Filing Date:	22-Aug-2019
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Filer:	D. Benjamin Esplin/Mario Giraldo
Attorney Docket Number:	46DG-026061

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
STATUTORY OR TERMINAL DISCLAIMER	1814	1	160	160
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**160**

Doc Code: DISQ.E.FILE
Document Description: Electronic Terminal Disclaimer – Approved

Application No.: 16548453

Filing Date: 22-Aug-2019

Applicant/Patent under Reexamination: Derbanne

Electronic Terminal Disclaimer filed on October 31, 2019

☒ APPROVED

This patent is subject to a terminal disclaimer

☐ DISAPPROVED

Approved/Disapproved by: Electronic Terminal Disclaimer automatically approved by EFS-Web

U.S. Patent and Trademark Office

Electronic Acknowledgement Receipt	
EFS ID:	37624725
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	D. Benjamin Esplin/Mario Giraldo
Filer Authorized By:	D. Benjamin Esplin
Attorney Docket Number:	46DG-026061
Receipt Date:	31-OCT-2019
Filing Date:	22-AUG-2019
Time Stamp:	17:17:39
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$160
RAM confirmation Number	E20190UH17369315
Deposit Account	602731
Authorized User	Mario Giraldo
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Terminal Disclaimer-Filed (Electronic)	eTerminal-Disclaimer.pdf	37071 05b27cf3d9ee6822c9ac28ef991c9f3c4dadf93b	no	3
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30705 0f9ca521297e136b515690f95234c611512d1803	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	67776		

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Acknowledgement Receipt

EFS ID:	37624816
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	D. Benjamin Esplin/Mario Giraldo
Filer Authorized By:	D. Benjamin Esplin
Attorney Docket Number:	46DG-026061
Receipt Date:	31-OCT-2019
Filing Date:	22-AUG-2019
Time Stamp:	17:22:06
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	46DG-026061_Response_to_NFOA_2019-09-13.pdf	202019 4cb6a54de76227e35036008d5d4742d59e13d7a5	no	14

Warnings:

Information:	
Total Files Size (in bytes):	202019

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New Applications Under 35 U.S.C. 111
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National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Attorney Docket: 46DG-026061

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE PATENT APPLICATION OF	:	Thomas Derbanne, *et al.*
SERIAL NO.	:	16/548,453
FILING DATE	:	August 22, 2019
ART UNIT	:	2698
EXAMINER	:	SEGURA, CYNTHIA
FOR	:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS

RESPONSE TO NON-FINAL OFFICE ACTION

Mail Stop AMENDMENT
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Commissioner:

In response to the Non-Final Office Action dated **September 13, 2019** ("Office Action"), please consider the following amendments and remarks in the above-identified application:

Amendments to the Claims are reflected in the listing of claims beginning on page **2** of this paper.

Remarks/Arguments begin on page **10** of this paper.

It is believed no extensions of time or fees for net addition of claims are required beyond those which may otherwise be provided for in documents accompanying this paper. However, if additional extensions of time are necessary to prevent abandonment of this application, then such extensions of time are hereby petitioned for under 37 C.F.R. § 1.136(a), and any fees required therefore (including fees for net addition of claims) are hereby authorized to be charged to our Deposit Account No. 602731 (Ref. No. 46DG-026061).

CLAIM AMENDMENTS

This **listing of claims** will replace all prior versions, and listings, of claims in the application:

1. (**Currently Amended**) A system that stabilizes videos, the system comprising:

a housing of an image capture device;

an optical element carried by the housing and configured to guide light within an optical field of view to an image sensor, the optical field of view being greater than a capture field of view for generating video content;

the image sensor carried by the housing and configured to generate an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;

a position sensor carried by the housing and configured to generate a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing; and

one or more physical processors configured by machine-readable instructions to:

determine an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within

the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;

determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory, wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently;

determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and

generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides

stabilization that creates a more stable view than use of entire visual content of the images.

2. (**Original**) The system of claim 1, wherein the determination of the capture trajectory of the housing based on the look ahead of the observed trajectory preserves a user's intended motion of the image capture device during the capture duration.

3. (**Original**) The system of claim 2, wherein past positions of the image capture device supply context for the user's intended motion of the image capture device.

4. (**Original**) The system of claim 1, wherein the positions of the housing further include translational positions of the housing, and at least some of the virtual positions of the housing are translationally offset from the actual positions of the housing.

5. (**Original**) The system of claim 1, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.

6. (**Canceled**)

7. (**Currently Amended**) The system of claim 1, wherein the capture trajectory of the housing is determined to minimize inter-frame motion while preserving intra-frame motion, wherein the intra-frame motion is preserved based on intra-frame motion of the

housing during frame exposure such that the capture trajectory follows the intra-frame motion.

8. (**Original**) The system of claim 1, wherein the images are stored in a buffer during capture trajectory generation.

9. (**Original**) The system of claim 8, wherein the images are stored in the buffer during the capture trajectory generation such that individual ones of the images corresponding to the portion of the capture trajectory are stored in the buffer during the determination of the portion of the capture trajectory using the lookahead of the observed trajectory, and the visual content of the individual ones of the images stored in the buffer are used after the determination of the portion of the capture trajectory to generate the video content.

10. (**Original**) The system of claim 9, wherein the one or more physical processors are, to generate the video content based on the punch-out of the visual content of the images within the capture field of view, further configured by machine-readable instructions to crop the visual content of the images based on the capture field of view.

11. (**Currently Amended**) A method for stabilizing videos, the method performed by an image capture device including a housing and one or more processors, the housing carrying an optical element, an image sensor, and a position sensor, the optical element configured to guide light within an optical field of view to the image sensor, the optical

field of view being greater than a capture field of view for generating video content, the method comprising:

generating, by the image sensor, an image output signal based on light that becomes incident thereon during a capture duration, the image output signal conveying image information that defines images with the optical field of view;

generating, by the position sensor, a position output signal based on positions of the housing during the capture duration, the position output signal conveying position information that characterizes the positions of the housing at different moments within the capture duration, the positions of the housing including rotational positions of the housing;

determining, by the one or more processors, an observed trajectory of the housing during the capture duration based on the position information, the observed trajectory reflecting the positions of the housing at the different moments within the capture duration, the observed trajectory including a first portion corresponding to a first moment within the capture duration and a second portion corresponding to a second moment subsequent to the first moment within the capture duration;

determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory,

which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory, wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently;

determining, by the one or more processors, the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and

generating, by the one or more processors, the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images.

12. (**Original**) The method of claim 11, wherein determining the capture trajectory of the housing based on the look ahead of the observed trajectory preserves a user's intended motion of the image capture device during the capture duration.

13. (**Original**) The method of claim 12, wherein past positions of the image capture device supply context for the user's intended motion of the image capture device.

14. (**Original**) The method of claim 11, wherein the positions of the housing further include translational positions of the housing, and at least some of the virtual positions of the housing are translationally offset from the actual positions of the housing.

15. (**Original**) The method of claim 11, wherein the position sensor includes a gyroscope, an accelerometer, and/or an inertial measurement unit, and the position information is determined independent of the image information.

16. (**Canceled**)

17. (**Currently Amended**) The method of claim 11, wherein the capture trajectory of the housing is determined to minimize inter-frame motion while preserving intra-frame motion, wherein the intra-frame motion is preserved based on intra-frame motion of the housing during frame exposure such that the capture trajectory follows the intra-frame motion.

18. (**Original**) The method of claim 11, wherein the images are stored in a buffer during capture trajectory generation.

19. (**Original**) The method of claim 18, wherein the images are stored in the buffer during the capture trajectory generation such that individual ones of the images corresponding to the portion of the capture trajectory are stored in the buffer during the

determination of the portion of the capture trajectory using the lookahead of the observed trajectory, and the visual content of the individual ones of the images stored in the buffer are used after the determination of the portion of the capture trajectory to generate the video content.

20. (**Original**) The method of claim 19, wherein generating the video content based on the punch-out of the visual content of the images within the capture field of view includes cropping the visual content of the images based on the capture field of view.

21. (**New**) The system of claim 7, wherein the capture trajectory following the intra-frame motion includes motion of the capture trajectory being aligned with motion blur caused by the intra-frame motion.

22. (**New**) The method of claim 17, wherein the capture trajectory following the intra-frame motion includes motion of the capture trajectory being aligned with motion blur caused by the intra-frame motion.

REMARKS

By this paper, claims 1, 7, 11, and 17 are amended, claims 21 and 22 are added, and claims 6 and 16 are cancelled without prejudice and without disclaimer. Accordingly, claims 1-5, 7-15, 17-22 are all of the pending claims. Support for the amendments presented above is provided throughout the specification and claims as originally filed. Applicant expressly reserves the right to prosecute the subject matter of the unamended and/or cancelled claims, or any other subject matter supported by the Specification, in one or more continuation applications. In view of the foregoing amendments and the following remarks, reconsideration and allowance of all the pending claims is anticipated.

Examiner Interview

Applicant expresses appreciation for the courtesies extended by the Examiner to the Applicant's representative during the telephonic interview conducted on October 29, 2019. In compliance with 37 C.F.R. § 1.133 and M.P.E.P. § 713.04, a record of the substance of the interview is summarized or otherwise incorporated into the following remarks.

Claim Interpretation

Office Action states that claim limitation "optical element" is being interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph because the claim limitations allegedly use "a generic placeholder that is coupled with functional language without reciting sufficient structure to perform the recited function and the generic placeholder is not preceded by a structural modifier." (Office Action, page 4) Applicant submits that this claim limitation is not a generic placeholder and should not be interpreted under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. This claim limitation does not use the word "means" or similar generic placeholders, and cannot be considered to invoke interpretation under 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. In addition, the claim limitation is not written as functions to be performed, but is instead recited as sufficient structure to preclude application of 35 U.S.C. 112(f) or pre-AIA 35 U.S.C. 112, sixth paragraph. "Optical element" is a recognized term for structure, and there is no indication that these this should be given

any other meaning than its plain meaning in the art.

Double Patenting Rejection

Claims 1-20 currently stand provisionally rejected under the judicially created doctrine of obviousness-type double patenting as being allegedly unpatentable over claims 1-20 of U.S. Patent Application No. 15/987,786 ("the '786 application"); and claims 1-20 currently stand provisionally rejected under the judicially created doctrine of obviousness-type double patenting as being allegedly unpatentable over claims 1-20 of U.S. Patent Application No. 16/418,203 ("the '203 application"). Solely in an effort to expedite prosecution and without acknowledging the propriety of the alleged rejections, a Terminal Disclaimer executed by the undersigned the Applicant's representative in compliance with 37 C.F.R. § 1.321(c) is submitted herewith to disclaim the term of a patent resulting from the present application from extending beyond that of patent granted on the '786 application and the '203 application. Accordingly, Applicant requests that the above provisional obviousness-type double patent rejection be withdrawn.

Claims 1-20 stand rejected under the judicially created doctrine of obviousness-type double patenting as being unpatentable over claims 1-20 of U.S. Patent No. 10,341,564 ("the '564 patent"). Solely in an effort to expedite prosecution and without acknowledging the propriety of the alleged rejections, a Terminal Disclaimer executed by the undersigned the Applicant's representative in compliance with 37 C.F.R. § 1.321(c) is submitted herewith to disclaim the term of a patent resulting from the present application from extending beyond that of the '564 patent. Accordingly, Applicant requests that the above obviousness-type double patent rejection be withdrawn.

The Terminal Disclaimer fee required under 37 C.F.R. § 1.20(d) is hereby authorized to be charged to our Deposit Account No. 602731 (Ref. No. 46DG-026061).

Rejections Under 35 U.S.C. § 102

Claims 1-20 currently stand rejected under AIA 35 U.S.C. § 102(a)(2) as allegedly being anticipated by U.S. Patent Application No. 9,787,902 to Beysserie, *et al*. Applicant traverses the rejection under § 102 at least because Beysserie fails to

disclose each and every claimed feature. However, solely in an effort to expedite prosecution and without acknowledging the propriety of the alleged rejections, Applicant has amended independent claims 1 and 11 and have canceled claims 6 and 16.

Beysserie fails to disclose each and every claimed feature of the amended independent claims related to, for example, **determining a capture trajectory to include a path that minimizes a combination of rotational velocity and rotational acceleration of a housing**, with the **rotational velocity** and the **rotational acceleration** being **weighed equally or differen**tly within the combination.

In pertinent parts, amended claim 1 recites:

> . . . **determine a capture trajectory** of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, wherein the capture trajectory is determined **to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing**, the combination of the rotational velocity and the rotational acceleration of the housing **weighing the rotational velocity and the rotational acceleration equally or differently** . . .

Amended claim 11 recites similar limitations.

The Office Action relies on col. 5, lines 43-50 and col. 9, lines 18-34 of Beysserie for allegedly disclosing determination of a capture trajectory. (Office Action, pages 21-22) Beysserie describes weighing frames for trajectory determination based on proximity of the frames to a framing being stabilized. Weighing a frame more results in the stabilization trajectory being steered more towards the frame's position. (See Beysserie, col. 6, line 62 to col. 7, line 24).

However, the independent claims have been amended to recite the capture trajectory being determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of a housing, with the rotational velocity and the rotational acceleration being weighed equally or differently within the combination. (See Application Paragraphs 53-57) Beysserie fails to disclose including in a capture trajectory a path that minimizes a combination of rotational velocity and rotational acceleration of a housing. Beysserie fails to disclose combinations of rotational velocity and rotational acceleration of a housing with the rotational velocity and the rotational acceleration being weighed equally or differently.

For at least the reasons presented above, independent claims 1 and 11 are not anticipated or rendered obvious by Beysserie. In addition, claims 2-5, 7-10, 12-15, 17-20 are also not anticipated or rendered obvious at least due to their dependency from one of independent claims 1 or 11, in addition to the features they individually recite. Accordingly, Applicant requests that the above rejection of claims under § 102 be withdrawn.

Newly Added Claims

Claims 21 and 22 are newly added by this application. New claims 21 and 22 are not anticipated or rendered obvious by the cited references at least due to their dependency from one of independent claims 1 or 11, in addition to the features they individually recite.

CONCLUSION

Having addressed each of the foregoing objections and rejections, it is submitted that a full and complete response has been made to the outstanding Office Action and, as such, the application is in condition for allowance. Notice to that effect is anticipated.

If the Examiner believes, for any reason, that personal communication will expedite prosecution of this application, the Examiner is invited to telephone the undersigned at the number provided.

Date: October 31, 2019

Respectfully submitted,

By: /D. Benjamin Esplin/
D. Benjamin Esplin
Reg. No. 58,297

Customer No. 137002

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To: docketing@esplin.legal,,
From: PAIR_eOfficeAction@uspto.gov
Cc: PAIR_eOfficeAction@uspto.gov
Subject: Private PAIR Correspondence Notification for Customer Number 137002

Nov 04, 2019 03:51:55 AM

Dear PAIR Customer:

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

The following USPTO patent application(s) associated with your Customer Number, 137002 , have new outgoing correspondence. This correspondence is now available for viewing in Private PAIR.

The official date of notification of the outgoing correspondence will be indicated on the form PTOL-90 accompanying the correspondence.

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Application	Document	Mailroom Date	Attorney Docket No.
16548453	INTV.SUM.APP	11/04/2019	46DG-026061
	EXIN	11/04/2019	46DG-026061
	OA.APPENDIX	11/04/2019	46DG-026061

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Thank you for prompt attention to this notice,

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PATENT APPLICATION INFORMATION RETRIEVAL SYSTEM

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 16/548,453	Filing Date 08/22/2019	☐ To be Mailed

ENTITY: ☑ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED - PART I

	(Column 1)	(Column 2)			
FOR	NUMBER FILED	NUMBER EXTRA		RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A		N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A		N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*		x $100 =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*		x $460 =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).				
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT	10/31/2019	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0		x $100 =	0
	Independent (37 CFR 1.16(h))	* 2	Minus	*** 3	= 0		x $460 =	0
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	0

		(Column 1)		(Column 2)	(Column 3)			
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=		x $0 =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=		x $0 =	
	☐ Application Size Fee (37 CFR 1.16(s))							
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							
							TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.	LIE
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".	/ANTHONY TYSON/
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".	
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.	

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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NOTICE OF ALLOWANCE AND FEE(S) DUE

137002 7590 11/29/2019

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008

EXAMINER
SEGURA, CYNTHIA

ART UNIT	PAPER NUMBER
2698	

DATE MAILED: 11/29/2019

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/548,453	08/22/2019	Thomas Derbanne	46DG-026061	2987

TITLE OF INVENTION: SYSTEMS AND METHODS FOR STABILIZING VIDEOS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	03/02/2020

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PTOL-85 (Rev. 02/11)

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

137002 7590 11/29/2019
Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

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nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	03/02/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
SEGURA, CYNTHIA	2698	348-208200

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑Issue Fee ❑Publication Fee (if required) ❑Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

Insta360
Exhibit 1003 Page 402

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
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Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

PTOL-85 (Rev. 02/11)

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 16/548,453	Applicant(s) Derbanne et al.	
	Examiner CYNTHIA SEGURA	Art Unit 2698	AIA (FITF) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to 10/31/2019.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 1-5,7-15 and 17-22 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information , please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☑ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/CYNTHIA SEGURA/
Primary Examiner, Art Unit 2698

DETAILED ACTION

Notice of Pre-AIA or AIA Status

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Notice of Amendment

2. The Examiner acknowledges the amended claims filed on 10/31/2019. Claims 1, 7, 11 and 17 have been amended. Claims 6 and 16 have been cancelled. Claims 21-22 have been added.

3. The Examiner withdraws the 35 USC 112(f) claim interpretation in view of the remarks filed on 10/31/2019 (see page 10).

Terminal Disclaimer

4. The terminal disclaimer filed on 10/31/2019 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of **any patent granted on Application Numbers 15/987,786 and 16/418,203** has been reviewed and is accepted. The terminal disclaimer has been recorded.

5. The terminal disclaimer filed on 10/31/2019 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of **US Patent 10,341,564** has been reviewed and is accepted. The terminal disclaimer has been recorded.

Allowable Subject Matter

6. Claims 1-5, 7-15 and 17-22 are allowed.

7. The following is an examiner's statement of reasons for allowance:

8. Regarding **claim 1**, the prior art does not teach or fairly suggest "…determine a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory, wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently; determine the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the capture trajectory of the housing; and generate the video content based on a punch-out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire

visual content of the images…" **and used in combination with all of the other limitations of claim 1.**

9. **Claims 2-5, 7-10 and 21** depend on allowable claim 1. Therefore, the dependent claims are also held allowable.

10. Regarding **claim 11**, the prior art does not teach or fairly suggest "…determining, by the one or more processors, a capture trajectory of the housing based on a look ahead of the observed trajectory, the capture trajectory reflecting actual and/or virtual positions of the housing from which orientations of the capture field of view with respect to the optical field of view of the images are determined, the look ahead of the observed trajectory including use of a subsequent portion of the observed trajectory to determine a preceding portion of the capture trajectory such that a portion of the capture trajectory corresponding to the first portion of the observed trajectory, which corresponds to the first moment within the capture duration, is determined based on the second portion of the observed trajectory, which corresponds to the second moment within the capture duration, the capture trajectory having smoother changes than the observed trajectory, wherein the capture trajectory is determined to include a path that minimizes a combination of rotational velocity and rotational acceleration of the housing, the combination of the rotational velocity and the rotational acceleration of the housing weighing the rotational velocity and the rotational acceleration equally or differently; determining, by the one or more processors, the orientations of the capture field of view for the images with respect to the optical field of view of the images based on the

capture trajectory of the housing; and generating, by the one or more processors, the video content based on a punch- out of visual content of the images within the capture field of view, wherein use of the visual content of the images within the capture field of view to generate the video content provides stabilization that creates a more stable view than use of entire visual content of the images…" **and used in combination with all of the other limitations of claim 11.**

11. **Claims 12-15, 17-20 and 22** depend on allowable claim 11. Therefore, the dependent claims are also held allowable.

12. Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Citation of Pertinent Art

13. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Wakamatsu (US-PGPUB 2018/0041705) discloses an image shake correcting apparatus in which a first calculating unit calculates a correction coefficient using information corresponding to an angular velocity from a first shake detecting unit and information corresponding to an acceleration output from a second shake detecting unit.

Haruna (US-PGPUB 2019/0124267) discloses an image blur correction device comprising a determination unit that performs a first processing using a frame at a time when the subject is detected in a state in which a focus lens is not being driven and an angular velocity of the subject weighted with respect to the angular velocity acquired at the in-focus frame.

Contact Information

14. Any inquiry concerning this communication or earlier communications from the examiner should be directed to CYNTHIA SEGURA whose telephone number is (571)270-3580. The examiner can normally be reached on Monday - Friday; 9:00am to 6:00pm.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, TWYLER L HASKINS can be reached on (571)272-7406. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR.

Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/CYNTHIA SEGURA/
Primary Examiner, Art Unit 2698
11/21/2019

Notice of References Cited	Application/Control No. 16/548,453	Applicant(s)/Patent Under Reexamination Derbanne et al.	
	Examiner CYNTHIA SEGURA	Art Unit 2698	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20130250047-A1	09-2013	Hollinger; Steven J.	H04N5/2252	348/36
*	B	US-20190124267-A1	04-2019	Haruna; Kohta	H04N5/23287	1/1
*	C	US-20180041705-A1	02-2018	Wakamatsu; Nobushige	H04N5/23254	1/1
*	D	US-20130210563-A1	08-2013	Hollinger; Steven J.	H04N5/2252	473/570
*	E	US-10432864-B1	10-2019	Douady; Cesar	H04N5/2254	1/1
	F					
	G					
	H					
	I					
	J					
	K					
	L					
	M					

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	**Art Unit**
	CYNTHIA SEGURA	2698

CPC							
Symbol						**Type**	**Version**
H04N	/	5	/	23258		F	2013-01-01
H04N	/	5	/	23267		I	2013-01-01
H04N	/	5	/	2252		A	2013-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 20	
/CYNTHIA SEGURA/ Primary Examiner, Art Unit 2698 (Primary Examiner)	21 November 2019 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 5C

U.S. Patent and Trademark Office — Part of Paper No.: 20191119

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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	**Art Unit**
	CYNTHIA SEGURA	2698

INTERNATIONAL CLASSIFICATION				
CLAIMED				
H04N	/	5	/	232
H04N	/	5	/	225

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	**SUBCLASS**

CROSS REFERENCES(S)						
CLASS	**SUBCLASS (ONE SUBCLASS PER BLOCK)**					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	20	
/CYNTHIA SEGURA/ Primary Examiner, Art Unit 2698	21 November 2019	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5C

U.S. Patent and Trademark Office — Part of Paper No.: 20191119

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Exhibit 1003 Page 414

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	**Art Unit**
	CYNTHIA SEGURA	2698

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☑ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	10	10	19	19										
2	2	11	11	20	20										
3	3	12	12	7	21										
4	4	13	13	17	22										
5	5	14	14												
	6	15	15												
6	7		16												
8	8	16	17												
9	9	18	18												

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	20	
/CYNTHIA SEGURA/ Primary Examiner, Art Unit 2698	21 November 2019	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5C

U.S. Patent and Trademark Office — Part of Paper No.: 20191119

Insta360
Exhibit 1003 Page 415

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	**Art Unit**
	CYNTHIA SEGURA	2698

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☑ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	09/10/2019	11/21/2019							
1	1	✓	=							
2	2	✓	=							
3	3	✓	=							
4	4	✓	=							
5	5	✓	=							
	6	✓	-							
6	7	✓	=							
8	8	✓	=							
9	9	✓	=							
10	10	✓	=							
11	11	✓	=							
12	12	✓	=							
13	13	✓	=							
14	14	✓	=							
15	15	✓	=							
	16	✓	-							
16	17	✓	=							
18	18	✓	=							
19	19	✓	=							
20	20	✓	=							
7	21		=							
17	22		=							

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Exhibit 1003 Page 416

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	Art Unit
	CYNTHIA SEGURA	2698

CPC - Searched*		
Symbol	Date	Examiner

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	Date	Examiner
Inventor search	09/06/2019	CS
East search: H04N5/23258; H04N5/23267; H04N5/2252 plus key words	09/06/2019	CS
East text search	09/06/2019	CS
East text search	09/10/2019	CS
Refs checked: applns 15987786, 16150066, 16418203	09/06/2019	CS
Inventor search	11/19/2019	CS
East text search	11/19/2019	CS
Ref checked: Appln 16/392,501	11/20/2019	CS
East search: H04N5/23258; H04N5/23267; H04N5/2252 plus key words	11/20/2019	CS
East text search	11/20/2019	CS

/CYNTHIA SEGURA/ Primary Examiner, Art Unit 2698	

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Exhibit 1003 Page 417

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	16/548,453	Derbanne et al.
	Examiner	Art Unit
	CYNTHIA SEGURA	2698

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
All	US-PGPUB text search	11/20/2019	CS

/CYNTHIA SEGURA/ Primary Examiner, Art Unit 2698	

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Exhibit 1003 Page 418

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CONFIRMATION NO. 2987

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
16/548,453	08/22/2019	348	2698	46DG-026061

APPLICANTS
GoPro, Inc., San Mateo, CA;

INVENTORS
Thomas Derbanne, Paris, FRANCE;
César Douady, Les Molieres, FRANCE;
Maxim Karpushin, Paris, FRANCE;

**** CONTINUING DATA **************************
This application is a CON of 16/418,203 05/21/2019
which is a CON of 16/150,066 10/02/2018 PAT 10341564
which is a CON of 15/987,786 05/23/2018
which claims benefit of 62/673,388 05/18/2018

**** FOREIGN APPLICATIONS **************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****
09/03/2019

Foreign Priority claimed ❑ Yes ☑ No 35 USC 119(a-d) conditions met ❑ Yes ☑ No Verified and Acknowledged /CYNTHIA SEGURA/ Examiner's Signature	❑ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		FRANCE	8	20	2

ADDRESS
Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

TITLE
SYSTEMS AND METHODS FOR STABILIZING VIDEOS

FILING FEE RECEIVED		
1720	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	❑ All Fees ❑ 1.16 Fees (Filing) ❑ 1.17 Fees (Processing Ext. of time) ❑ 1.18 Fees (Issue) ❑ Other _____ ❑ Credit

BIB (Rev. 05/07).

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 1 of 3	**Matter Number**	46DG-026061

U.S. PATENT/PUBLICATION DOCUMENTS					
Initials	**Cite No.**	**Document Number**	**Issue/Publication Date**	**First Named Inventor**	**Relevant Pages, Columns, etc.**
	1	6654019	11/25/2003	Gilbert	
	2	8022948	09/20/2011	Garbow	
	3	8237787	08/07/2012	HOLLINGER STEVEN J	
	4	9144714	09/29/2015	HOLLINGER STEVEN J	
	5	9279983	03/08/2016	DAVIS BENJAMIN	
	6	9363569	06/07/2016	Arthur Van Hoff	
	7	9374532	06/21/2016	GRUNDMANN MATTHIAS	
	8	9426430	08/23/2016	AGUILAR FRANCISCO	
	9	10262691	04/16/2019	GILMOUR NICHOLAS RYAN	
	10	10284794	05/07/2019	FRANCOIS BRUNO	
	11	10341564	07/02/2019	DERBANNE THOMAS	
	12	20030160862	08/28/2003	Michael Charlier	
	13	20030210327	11/13/2003	Mory	
	14	20040010804	01/15/2004	John Hendricks	
	15	20040125133	07/01/2004	Pea	
	16	20060291841	12/28/2006	FUKUMOTO SHINPEI	
	17	20090278917	11/12/2009	Dobbins	
	18	20100277617	11/04/2010	HOLLINGER STEVEN J	
	19	20100281375	11/04/2010	Colleen Pendergast	
	20	20100299630	11/25/2010	David McCutchen	
	21	20110013778	01/20/2011	Susumu Takumai	
	22	20110242352	10/06/2011	HIKOSAKA KENTARO	
	23	20120206565	08/16/2012	Jason Villmer	
	24	20130058535	03/07/2013	Gabriel Othmezouri	
	25	20130177168	07/11/2013	Kai Inha	
	26	20130210563	08/15/2013	Steven J. Hollinger	
	27	20130250047	09/26/2013	HOLLINGER STEVEN J	
	28	20130329132	12/12/2013	TICO MARIUS	
	29	20140028876	01/30/2014	MILLS CHRISTOPHER L	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.S/

Examiner Signature	/CYNTHIA SEGURA/	**Date Considered**	11/21/2019

Examiner: Please initial if citation considered, whether or not citation is in conformance with MPEP Section 609. Please draw a line through the citation if it is not in conformance and it is not considered. Please include a copy of this form with the next communication to the applicant.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 2 of 3	Matter Number	46DG-026061

U.S. PATENT/PUBLICATION DOCUMENTS					
Initials	Cite No.	Document Number	Issue/Publication Date	First Named Inventor	Relevant Pages, Columns, etc.
	30	20140039884	02/06/2014	Wei-ge Chen	
	31	20140266773	09/18/2014	AGUILAR FRANCISCO	
	32	20140267586	09/18/2014	AGUILAR FRANCISCO	
	33	20140267590	09/18/2014	MCCLATCHIE IAIN RICHARD TYRONE	
	34	20150146014	05/28/2015	BLACK ROBERT A	
	35	20150159846	06/11/2015	HOLLINGER STEVEN J	
	36	20160360109	12/08/2016	LAROIA RAJIV	
	37	20170070689	03/09/2017	SILVERSTEIN D AMNON	
	38	20170084086	03/23/2017	David Young Joon Pio	
	39	20170085964	03/23/2017	Yan Chen	
	40	20170094169	03/30/2017	YOSHIKAWA HIROMI	
	41	20170289454	10/05/2017	PETTERSSON GUSTAF	
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	43	20180199025	07/12/2018	HOLZER STEFAN JOHANNES JOSEF	
	44	20180324358	11/08/2018	YAMADA HIDESHI	

FOREIGN PATENT DOCUMENTS						
Initials	Cite No.	Document Number	Publication Date	Country	Relevant Pages, Columns, etc.	T
	45	2009047572A1	04/16/2009	WO		
	46	2014042104A1	03/20/2014	WO		
	47	2014090277A1	06/19/2014	WO		

OTHER DOCUMENTS			
Initials	Cite No.	Author, Title, Date, Pages, etc.	T
	48	"Spatial Audio Lecture Series," Regents of the University of California at Berkeley, Center for New Music and Audio Technologies, 2015, 1 Page, [online] [retrieved on August 20, 2015] Retrieved from the internet <URL:http:l/cnmat.berkelev.edu/spatialaudiolectures>.	
	49	International Search Report and Written Opinion for Application No. PCT/US2019/020241, date of mailing June 3, 2019, 12 pages.	

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Examiner Signature	/CYNTHIA SEGURA/	Date Considered	11/21/2019

Examiner: Please initial if citation considered, whether or not citation is in conformance with MPEP Section 609. Please draw a line through the citation if it is not in conformance and it is not considered. Please include a copy of this form with the next communication to the applicant.

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 3 of 3	**Matter Number**	46DG-026061

OTHER DOCUMENTS			
Initials	**Cite No.**	**Author, Title, Date, Pages, etc.**	**T**
	50	International Search Report and Written Opinion for Application No. PCT/US2019/031591, date of mailing June 18, 2019, 7 pages.	
	51	Kamali et al., "Stabilizing Omnidirectional Videos Using 3D Structure and Spherical Image Warping", MVA2011 IAPR Conference on Machine Vision Applications, June 13-15, 2011, Nara, JAPAN, pp. 177-180. (Year: 2011)	
	52	KOPF et al., "First-person Hyper-Lapse Videos" ACM Transactions on Graphics (Proceedings of SIGGRAPH 2014), 33(4), Article No. 78, 2014 (10 pages).	
	53	O'DONOVAN, A., et al., "Audio-Visual Panoramas and Spherical Audio Analysis using the Audio Camera," C1 Proceedings of the 16th International Conference on Auditory Display, June 9-15, 2010, Pages ICAD-167- 168, can be retrieved at <URL: https://smartech.gatech.edu/bitstream/handle/1853/49858/0%27DonovanDuraiswami201 O.pdf?sequence=1 >	
	54	O'DONOVAN, A., et al., "Real Time Capture of Audio Images and their Use with Video," 2007 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics, October 21-24, 2007, Pages 10-13.	
	55	PCT International Search Report and Written Opinion for PCT/US15/38913, September 29, 2015, 15 Pages	
	56	United States Office Action, U.S. Application No. 14/789,706, June 7, 2016, ten pages.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.S/

Examiner Signature	/CYNTHIA SEGURA/	**Date Considered**	11/21/2019
Examiner: Please initial if citation considered, whether or not citation is in conformance with MPEP Section 609. Please draw a line through the citation if it is not in conformance and it is not considered. Please include a copy of this form with the next communication to the applicant.			

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	0	16/548453.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 15:56
S2	137	Derbanne-Thomas.in. Douady-Cesar.in. Karpushin-Maxim.in.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 15:59
S3	0	(weigh$5 with rotat$4).clm. and S2	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:00
S7	223165	(weigh$5 with (rotat$4 angular))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:03
S9	1548	((image video) with (stabiliz$4 ((motion movement) near3 (compensat$4 correct$4)))) and S7	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:04
S10	0	S9 and ((housing enclosure casing) with (position$4 movement$4 motion) with ("ahead" futur$4 preceding) with (path trajectory course))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:07
S11	0	S9 and ((housing enclosure casing) with ("ahead" futur$4 preceding) with (path trajectory course))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:08
S12	31	S7 and ((housing enclosure casing) with	US-	OR	ON	2019/11/19

		("ahead" futur$4 preceding) with (path trajectory course))	PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB			16:16
S13	2087	((image video) with (stabiliz$4 ((motion movement) near3 (compensat$4 correct$4)))) and ((correct$4 minimiz$4 remov$4 cancel$4) with (angular rotat$4) with (velocity acceleration speed))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:21
S14	324	S13 and ((priority weight$4 coefficient factor$4 normaliz$4) with (angular rotat$4) with (velocity acceleration speed))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:22
S16	6	(weigh$5 with rotat$4).clm. and H04N5/23258.cpc.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:29
S17	38	(weigh$5 with angular) and H04N5/23258.cpc.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:30
S18	2479	((image video) with (stabiliz$4 ((motion movement) near3 (compensat$4 correct$4)))) and H04N5/23258.cpc.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:31
S20	8054	H04N5/23258.cpc.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:32
S21	105	S20 and S14	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/19 16:33
S22	90	(observ$4 analyz$4 monitor$4 measur$4) with (imaging camera imager housing) with (path trajectory wa$1 track$4 route course flight orbit) with (taken actual captured virtual) with (future look-ahead (look near2 ahead) subsequent)	US-PGPUB; USPAT; FPRS; EPO; JPO;	OR	ON	2019/11/20 11:16

			IBM_TDB			
S23	24927	(H04N5/23258 or H04N5/23267 or H04N5/2252).cpc.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:16
S24	18	S22 and S23	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:17
S25	493	(observ$4 analyz$4 monitor$4 measur$4) with (imaging camera imager housing) with (path trajectory wa$1 track$4 route course flight orbit) with (taken actual captured virtual) with (future look-ahead (look near2 ahead) subsequent$4 succeeding following later)	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:17
S26	26	S25 and S23	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:18
S27	198	(observ$4 analyz$4 monitor$4 measur$4) with (imaging camera imager housing) with (path trajectory wa$1 track$4 route course flight orbit) with (final corrected recorded) with (future look-ahead (look near2 ahead) subsequent$4 succeeding following later)	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:41
S28	3	S27 and ((priority weight$4 coefficient factor$4 normaliz$4) with (angular$4 rotat$4) with (velocity acceleration speed))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:42
S29	0	16/548453.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:54
S30	1	16/150066.app.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 11:55
S31	224834	((priority weight$4 restriction$4 changed changeable constraint$4 coefficient factor$4 normaliz$4 ((lesser greater higher lower) near2 (influence affect$4	US-PGPUB; USPAT; FPRS;	OR	ON	2019/11/20 13:08

		effect$4))) with (derivatives ((angular$4 rotat$4) with (velocity speed) with acceleration)))	EPO; JPO; IBM_TDB			
S32	3800	((imag$4 picture frame camera imager video) with (stabiliz$4 anti-shak$4 ((motion vibrat$4 jitt$5 movement rotat$4 angular angle shak$4 hand$4 tremb$4) near5 (unintentional intentional compensat$4 correct$4 compensat$4 remov$4 cancel$4 fixing fixed)))) and S31	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:19
S33	177	(H04N5/232$3 or H04N5/225$2).cpc. and S32	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:20
S34	18	((observ$4 analyz$4 monitor$4 measur$4 initial first) with (imaging camera imager housing) with (path trajectory wa$1 track$4 route course flight orbit) with (taken actual captured virtual) with (future look-ahead (look near2 ahead) subsequent)) and S33	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:22
S35	4	("20150350548" | "20160006935" | "9787902").PN.	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:40
S36	201	(G06T7/20 or G06T5/003 or G06T7/0038 or G06T2207/10016 or G06T2207/20201).cpc. and S32	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:42
S37	10009	((priority weight$4 restriction$4 changed changeable constraint$4 coefficient factor$4 normaliz$4 ((lesser greater higher lower) near2 (influence affect$4 effect$4))) with ((second near3 derivative$4) ((angular$4 rotat$4) with (velocity speed) with acceleration)))	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:45
S38	658	((imag$4 picture frame camera imager video) with (stabiliz$4 anti-shak$4 ((motion vibrat$4 jitt$5 movement rotat$4 angular angle shak$4 hand$4 tremb$4) near5 (unintentional intentional compensat$4 correct$4 compensat$4 remov$4 cancel$4 fixing fixed)))) and S37	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:50
S39	96	(H04N5/232$3 or H04N5/225$2).cpc. and S38	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:51

S40	65	(G06T7/20 or G06T5/003 or G06T7/0038 or G06T2207/10016 or G06T2207/20201).cpc. and S38	US-PGPUB; USPAT; FPRS; EPO; JPO; IBM_TDB	OR	ON	2019/11/20 13:58
S48	44	(US-10262691-$ | US-10284794-$ | US-10341564-$ | US-20030160862-$ | US-20030210327-$ | US-20040010804-$ | US-20040125133-$ | US-20060291841-$ | US-20090278917-$ | US-20100277617-$ | US-20100281375-$ | US-20100299630-$ | US-20110013778-$ | US-20110242352-$ | US-20120206565-$ | US-20130058535-$ | US-20130177168-$ | US-20130210563-$ | US-20130250047-$ | US-20130329132-$ | US-20140028876-$ | US-20140039884-$ | US-20140266773-$ | US-20140267586-$ | US-20140267590-$ | US-20150146014-$ | US-20150159846-$ | US-20160360109-$ | US-20170070689-$ | US-20170084086-$ | US-20170085964-$ | US-20170094169-$ | US-20170289454-$ | US-20170359534-$ | US-20180199025-$ | US-20180324358-$ | US-6654019-$ | US-8022948-$ | US-8237787-$ | US-9144714-$ | US-9279983-$ | US-9363569-$ | US-9374532-$ | US-9426430-$).DID.	US-PGPUB; USPAT	OR	ON	2019/11/21 10:28

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S41	1819	((priority weight$4 coefficient factor$4 normaliz$4) with (angular$4 rotat$4) with (velocity acceleration speed)).clm.	US-PGPUB	OR	ON	2019/11/20 11:49
S42	40	((imag$4 picture frame camera imager video) with (stabiliz$4 anti-shak$4 ((motion vibrat$4 jitt$5 movement rotat$4 angular angle shak$4 hand$4) near3 (unintentional intentional compensat$4 correct$4 compensat$4 remov$4 cancel$4 fixing fixed)))).clm. and S41	US-PGPUB	OR	ON	2019/11/20 11:55
S43	47	((imag$4 picture frame camera imager video) with (stabiliz$4 anti-shak$4 ((motion vibrat$4 jitt$5 movement rotat$4 angular angle shak$4 hand$4 tremb$4) near5 (unintentional intentional compensat$4 correct$4 compensat$4 remov$4 cancel$4 fixing fixed)))).clm. and S41	US-PGPUB	OR	ON	2019/11/20 11:55
S44	8263	((lesser greater higher lower) with (angular$4 rotat$4) with (velocity acceleration speed)).clm.	US-PGPUB	OR	ON	2019/11/20 12:59
S45	123	((imag$4 picture frame camera imager video) with (stabiliz$4 anti-shak$4 ((motion vibrat$4 jitt$5 movement rotat$4 angular angle shak$4 hand$4 tremb$4) near5 (unintentional intentional compensat$4 correct$4 compensat$4 remov$4 cancel$4 fixing fixed)))).clm. and S44	US-PGPUB	OR	ON	2019/11/20 12:59
S46	159	((priority weight$4 coefficient factor$4	US-	OR	ON	2019/11/20

		normaliz$4 ((lesser greater higher lower) near2 (influence affect$4 effect$4))) with (angular$4 rotat$4) with (velocity speed) with acceleration).clm.	PGPUB			13:03
S47	5	((imag$4 picture frame camera imager video) with (stabiliz$4 anti-shak$4 ((motion vibrat$4 jitt$5 movement rotat$4 angular angle shak$4 hand$4 tremb$4) near5 (unintentional intentional compensat$4 correct$4 compensat$4 remov$4 cancel$4 fixing fixed)))).clm. and S46	US-PGPUB	OR	ON	2019/11/20 13:04

11/ 21/ 2019 11:40:29 AM
C:\ Users\ ccalderon\ Documents\ EAST\ Workspaces\ 16548453_amend_b.wsp

To: docketing@esplin.legal,,
From: PAIR_eOfficeAction@uspto.gov
Cc: PAIR_eOfficeAction@uspto.gov
Subject: Private PAIR Correspondence Notification for Customer Number 137002

Nov 29, 2019 03:39:51 AM

Dear PAIR Customer:

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

The following USPTO patent application(s) associated with your Customer Number, 137002 , have new outgoing correspondence. This correspondence is now available for viewing in Private PAIR.

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Application	Document	Mailroom Date	Attorney Docket No.
16548453	NOA	11/29/2019	46DG-026061
	892	11/29/2019	46DG-026061
	1449	11/29/2019	46DG-026061

To view your correspondence online or update your email addresses, please visit us anytime at https://sportal.uspto.gov/secure/myportal/privatepair.

If you have any questions, please email the Electronic Business Center (EBC) at EBC@uspto.gov with 'e-Office Action' on the subject line or call 1-866-217-9197 during the following hours:

Monday - Friday 6:00 a.m. to 12:00 a.m.

Thank you for prompt attention to this notice,

UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION INFORMATION RETRIEVAL SYSTEM

Electronic Patent Application Fee Transmittal					
Application Number:	16548453				
Filing Date:	22-Aug-2019				
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS				
First Named Inventor/Applicant Name:	Thomas Derbanne				
Filer:	Vadim Polonichko/Julie Jager				
Attorney Docket Number:	46DG-026061				
Filed as Large Entity					
Filing Fees for Utility under 35 USC 111(a)					
Description		**Fee Code**	**Quantity**	**Amount**	**Sub-Total in USD($)**
Basic Filing:					
Pages:					
Claims:					
Miscellaneous-Filing:					
Petition:					
Patent-Appeals-and-Interference:					
Post-Allowance-and-Post-Issuance:					
Extension-of-Time:					

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	240	240
		Total in USD ($)		**240**

Electronic Acknowledgement Receipt	
EFS ID:	37954780
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	Vadim Polonichko/Julie Jager
Filer Authorized By:	Vadim Polonichko
Attorney Docket Number:	46DG-026061
Receipt Date:	06-DEC-2019
Filing Date:	22-AUG-2019
Time Stamp:	14:15:48
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$240
RAM confirmation Number	E2019B6E16166660
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Fee Worksheet (SB06)	fee-info.pdf	30768 cd472c1e37c3239ca2d903d46488e0fb1e90187f	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	30768		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 1 of 1	**Matter Number**	46DG-026061

U.S. PATENT/PUBLICATION DOCUMENTS					
Initials	**Cite No.**	**Document Number**	**Issue/Publication Date**	**First Named Inventor**	**Relevant Pages, Columns, etc.**
	1	20130002813	01/03/2013	VAUGHT BENJAMIN I	
	2	20170041545	02/09/2017	MURGIA CARLO	
	3	20170142337	05/18/2017	KOKARAM ANIL CHRISTOPHER	
	4	20180048821	02/15/2018	SEGAPELLI LOIC	
	5	20180220073	08/02/2018	KEAL WILLIAM KERRY	

FOREIGN PATENT DOCUMENTS						
Initials	**Cite No.**	**Document Number**	**Publication Date**	**Country**	**Relevant Pages, Columns, etc.**	**T**

OTHER DOCUMENTS			
Initials	**Cite No.**	**Author, Title, Date, Pages, etc.**	**T**
	6	International Search Report and Written Opinion for Application No. PCT/US2019/048292, dated September 27, 2019, 7 pages.	
	7	International Search Report for Application No. PCT/US19/48368, date of mailing November 7, 2019, 10 pages.	

Examiner Signature		**Date Considered**	
Examiner: Please initial if citation considered, whether or not citation is in conformance with MPEP Section 609. Please draw a line through the citation if it is not in conformance and it is not considered. Please include a copy of this form with the next communication to the applicant.			

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 1 of 1	**Matter Number**	46DG-026061

GENERAL

Pursuant to 37 C.F.R. 1.97 and 1.98 and to the duty of disclosure set forth in 37 C.F.R. 1.56, the Examiner in charge of the above-identified application is requested to consider and make of record the references listed herewith. A copy of each listed reference, other than U.S. patents/applications and references cited in a parent application, is enclosed.

Although the information submitted herewith may be "material" to the Examiner's consideration of the subject application, this submission is not intended to constitute an admission that such information is "prior art" as to the claimed invention.

In accordance with 37 C.F.R. 1.97(g), the filing of this Information Disclosure Statement shall not be construed to mean that a search has been made.

TIMING

In accordance with 37 CFR 1.97(d), this Information Disclosure Statement is being filed after the period specified in 37 CFR 1.97(c) and on or before payment of the issue fee.

CERTIFICATION STATEMENT

Each item of information contained in this information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this information disclosure statement.

FEE

The Director is hereby authorized to charge $240 (large entity) to Deposit Account No. 601896. Please reference attorney docket number 46DG-026061 for this transaction.

This Information Disclosure Statement is being filed in accordance with 37 CFR 1.97(d). Therefore, this Information Disclosure Statement is subject to the $240 (large entity) fee set forth in 37 CFR 1.17(p).

ADDITIONAL COMMENTS

SIGNATURE

Signature	/ Vadim Polonichko /	**Date**	2019-12-06
Name	Vadim Polonichko	**Registration Number**	62769

SyncIDS.com

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
D. BENJAMIN ESPLIN
C/O ESPLIN & ASSOCIATES, PC
5411 AVENIDA ENCINAS, STE 100
CARLSBAD, CALIFORNIA 92008
UNITED STATES OF AMERICA

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

	Date of mailing *(day/month/year)*
Applicant's or agent's file reference **46DG-026045**	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. **PCT/US2019/048292**	International filing date *(day/month/year)* **27 August 2019 (27.08.2019)**
Applicant **GOPRO, INC.**	

1. ☑ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. Reminders

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

   Within **19 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45bis.1). The procedure for requesting supplementary international search is described in the PCT Applicant's Guide, International Phase, paragraphs 8.006-8.032.

Name and mailing address of the ISA/US **COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA** Facsimile No. **(571)273-8300**	Authorized officer **HARRY C. KIM** Telephone No. **571-272-4300**

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference **46DG-026045**	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. **PCT/US2019/048292**	International filing date *(day/month/year)* **27 August 2019 (27.08.2019)**	(Earliest) Priority Date *(day/month/year)* **23 April 2019 (23.04.2019)**
Applicant **GOPRO, INC.**		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☑ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☑ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☑ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the **drawings** to be published with the abstract is Figure No. 9

☑ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/048292

A. CLASSIFICATION OF SUBJECT MATTER

IPC: H04N 5/232
CPC: H04N 5/23248, 5/23267, 5/23254, 5/23258, 5/23261

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

CPC: CPC: H04N 5/23248, 5/23267, 5/23254, 5/23258, 5/23261/IPC: H04N 5/232

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

US-PGPUB, USPAT: information, and, image, second, rotate, boundary, direction, sensor, track, line, course, orientation, trajectory, path, position, stabilize, smooth, ois, data, output, punch, determine, housing, window, same, extent, view, calculate, first, rotation, moment, cut, punchout, karpushin, derbanne, Thomas, clm, donady, cesar, maxim, frame, accelerometer, detect

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 10,262,691 B1 (GILMOUR ET AL.) 16 April 2019 (16.04.2019), See entire documents.	1-20
A	US 2018/0199025 A1 (HOLZER ET AL.) 12 July 2018 (12.07.2018), See entire documents.	1-20
A	10,284,794 B1 (FRANCOIS ET AL) 07 May 2019 (07.05.2019), See entire documents.	1-20
A	US 2014/0028876 A1 (MILLS) 30 January 2014 (30.01.2014), See entire documents.	1-20
A	US 2015/0159846 A1 (HOLLINGER) 11 June 2015 (11.06.2015), See entire documents.	1-20
A	US 2014/0267599 A1 (MCCLATCHIE ET AL.) 18 September 2014 (18.09.2014), See entire documents.	1-20

☑ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 September 2019 (22.09.2019)	27 SEP 2019

Name and mailing address of the ISA/US	Authorized officer
COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA	HARRY C. KIM
Facsimile No. (571)273-8300	Telephone No. 571-272-4300

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/048292

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2013/0210563 A1 (HOLLINGER) 15 August 2013 (15.08.2013), See entire documents.	1-20

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
D. BENJAMIN ESPLIN
C/O ESPLIN & ASSOCIATES, PC
5411 AVENIDA ENCINAS, STE 100
CARLSBAD, CALIFORNIA 92008
UNITED STATES OF AMERICA

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	27 SEP 2019
Applicant's or agent's file reference: 46DG-026045	FOR FURTHER ACTION: See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2019/048292	27 August 2019 (27.08.2019)	23 April 2019 (23.04.2019)

International Patent Classification (IPC) or both national classification and IPC
IPC: H04N 5/232
CPC: H04N 5/23248, 5/23267, 5/23254, 5/23258, 5/23261

Applicant: GOPRO, INC.

1. This opinion contains indications relating to the following items:

- [x] Box No. I — Basis of the opinion
- [ ] Box No. II — Priority
- [ ] Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV — Lack of unity of invention
- [x] Box No. V — Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI — Certain documents cited
- [ ] Box No. VII — Certain defects in the international application
- [ ] Box No. VIII — Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. BOX 1450 ALEXANDRIA, VA 22313-1450, UNITED STATES OF AMERICA	22 September 2019 (22.09.2019)	HARRY C. KIM
Facsimile No. (571)273-8300		Telephone No. 571-272-4300

Form PCT/ISA/237 (Cover sheet) (January 2015)

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/048292

Box No. I Basis of the opinion

1. With regard to the **language**, this opinion has been established on the basis of:
   - [x] the international application in the language in which it was filed.
   - [ ] a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. [ ] This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. [ ] With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:
   - a. [ ] forming part of the international application as filed:
     - [ ] in the form of an Annex C/ST.25 text file.
     - [ ] on paper or in the form of an image file.
   - b. [ ] furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
   - c. [ ] furnished subsequent to the international filing date for the purposes of international search only:
     - [ ] in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).
     - [ ] on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. [ ] In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Insta360
Exhibit 1003 Page 441

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/048292

Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	1-20	YES
	Claims	NONE	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations :

——— EXPLANATION ———

Claim**S 1-20 meets** the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest **the claims limitations**.

The prior art provides examples of an image capture system that stabilizes videos including a housing, optical element carried by the housing, image sensor carried by the housing, and position sensor to generate a position output signal on positions of the housing during capture, and determine a trajectory of the housing during capture based on position information. For example, U.S. Pub. No. 2013/0210563 teaches a ball-shaped camera thrown or projected into an airborne trajectory and image capture system with network devices collaborating for the purpose of generating panoramic images and video sourced from network ball cameras and capable of capturing stable image and video while spinning, spiraling or processing through a trajectory. U.S. Pub. No. 2018/0199025 to Holzer provides another example of a drone based system for capturing multi-media representation of an entity by capturing a plurality of images having location information and fused to form multi-view interactive digital media representations. However, the prior art does not teach all of the limitations of the currently claimed invention including determining a smoothed trajectory of the housing based on a subsequent portion of the trajectory such that a portion of the smoothed trajectory corresponding to the first portion of the trajectory is determined based on the second portion of the trajectory, and determining a viewing window for the visual content based on the smoothed trajectory of the housing.

Claims **1-20 meets** the criteria set out in PCT Article 33(4), and thus **have** industrial applicability because the subject matter claimed can be made or used in industry.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To: D. BENJAMIN ESPLIN
C/O ESPLIN & ASSOCIATES, PC
5411 AVENIDA ENCINAS, STE 100
CARLSBAD, CA 92008

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 46DG-026044	Date of mailing (day/month/year) 07 NOV 2019 **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. PCT/US 19/48368	International filing date (day/month/year) 27 August 2019 (27.08.2019)
Applicant GOPRO, INC.	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:
   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   How? Directly to the International Bureau of WIPO preferably through ePCT or on paper to, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 – 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:
   - ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.
   - ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

   The applicant may **submit comments on an informal basis on the written opinion of the International Searching Authority** to the International Bureau. These comments will be made available to the public after international publication. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established.

   Shortly after the expiration of **18 months from the priority date, the international application will be published** by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90*bis*.1 and 90*bis*.3).

   Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for **entry into the national phase** before those designated Offices. In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19 months. For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the *PCT Applicant's Guide*, National Chapters.

   Within **22 months from the priority date, the applicant may request that a supplementary international search be carried out** by a different International Searching Authority that offers this service (Rule 45*bis*.1). The procedure for requesting supplementary international search is described in the *PCT Applicant's Guide*, International Phase, paragraphs 8.006–8.032.

Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Lee W. Young PCT Helpdesk: 571-272-4300 Telephone No. PCT OSP: 571-272-7774

Form PCT/ISA/220 (July 2014)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 46DG-026044	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US 19/48368	International filing date *(day/month/year)* 27 August 2019 (27.08.2019)	(Earliest) Priority Date *(day/month/year)* 19 September 2018 (19.09.2018)
Applicant GOPRO, INC.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 2 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed.

☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (see Box No. II).

3. ☐ **Unity of invention is lacking** (see Box No. III).

4. With regard to the **title**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the **drawings**,

a. the figure of the drawings to be published with the abstract is Figure No. 1

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figures is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 19/48368

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04N 5/351; H04N 5/14 (2019.01)
CPC - H04N 5/23258; H04N 5/23251; H04N 5/23264; H04N 5/23267

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018/0048821 A1 (GoPro Inc.) 15 February 2018 (15.02.2018), para [0016], [0017], [0019], [0025]-[0026], [0029], [0033], [0035], [0041].	1-20
A	US 2016/0220073 A1 (Invensense Inc.) 02 August 2016 (02.08.2016), para [0034], [0041], [0044], [0046], [0054]-[0056], [0058].	1-20
A	US 2017/0041545 A1 (Invensense Inc.) 09 February 2017 (09.02.2017), entire document.	1-20
A	US 2017/0142337 A1 (Google Inc.) 18 May 2017 (18.05.2017), entire document.	1-20
A	US 2013/0002813 A1 (Vaught et al.) 03 January 2013 (03.01.2013), entire document.	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2019	07 NOV 2019
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (January 2015)

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To: D. BENJAMIN ESPLIN
C/O ESPLIN & ASSOCIATES, PC
5411 AVENIDA ENCINAS, STE 100
CARLSBAD, CA 92008

PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

	Date of mailing *(day/month/year)*: 07 NOV 2019
Applicant's or agent's file reference: 46DG-026044	FOR FURTHER ACTION: See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US 19/48368	27 August 2019 (27.08.2019)	19 September 2018 (19.09.2018)

International Patent Classification (IPC) or both national classification and IPC
IPC(8) - H04N 5/351; H04N 5/14 (2019.01)
CPC - H04N 5/23258; H04N 5/23251; H04N 5/23264; H04N 5/23267

Applicant: GOPRO, INC.

1. This opinion contains indications relating to the following items:

- [x] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [x] Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. FURTHER ACTION

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1*bis*(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.

For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	16 October 2019	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/237 (cover sheet) (January 2015)

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 19/48368

Box No. 1 Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed.

   ☐ a translation of the international application into _____ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b)).

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a)).

3. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

   a ☐ forming part of the international application as filed:

      ☐ in the form of an Annex C/ST.25 text file.

      ☐ on paper or in the form of an image file.

   b ☐ furnished together with the international application under PCT Rule 13*ter*.1(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.

   c ☐ furnished subsequent to the international filing date for the purposes of international search only:

      ☐ in the form of an Annex C/ST.25 text file (Rule 13*ter*.1(a)).

      ☐ on paper or in the form of an image file (Rule 13*ter*.1(b) and Administrative Instructions, Section 713).

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
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Box No. V **Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

Novelty (N)	Claims	1-20	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	1-20	YES
	Claims	NONE	NO
Industrial applicability (IA)	Claims	1-20	YES
	Claims	NONE	NO

2. Citations and explanations:

Claims 1-20 meet the criteria set forth under PCT Article 33(2)-(3) because the prior art does not teach or fairly suggest the subject matter claimed.

The prior art is exemplified by US 2018/0048821 A1 to GoPro Inc. (hereinafter GoPro) and US 2018/0220073 A1 to Invensense Inc. (hereinafter Invensense).

Regarding claim 1, GoPro discloses an image capture device that stabilizes videos (para [0016]- "Turning now to Figure (FIG. 1, illustrated is an example camera system for motion frequency estimation, according to one embodiment"; para [0017]- "As described in greater detail below, the camera 100 may include sensors to capture metadata associated with video data, such as timing data, motion data, speed data, acceleration data, altitude data, GPS data, and the like. Additionally, the camera 100 may include processors or stabilizers to provide motion compensation by performing electronic image stabilization"), the image capture device comprising:

a housing (camera body; see figure 1; para [0016]- "Turning now to Figure (FIG. 1, illustrated is an example camera system for motion frequency estimation, according to one embodiment. The camera system 100 may include a camera body, one or more a camera lenses, various indicators on the camera body)");

an optical element carried by the housing and configured to guide light within a field of view to an image sensor (lens 112; para [0019]- "The lens 112 may be, for example, a wide angle lens, hemispherical, or hyper hemispherical lens that focuses light entering the lens to the image sensor 114 which captures images and/or video frames");

the image sensor carried by the housing and configured to generate a visual output signal conveying visual information based on light that becomes incident thereon during a capture duration, the visual information defining visual content having the field of view (para [0019]- "The lens 112 may be, for example, a wide angle lens, hemispherical, or hyper hemispherical lens that focuses light entering the lens to the image sensor 114 which captures images and/or video frames. The image sensor 114 may capture high-definition images having a resolution of, for example, 720p, 1080p, 4 k, or higher. In one embodiment, spherical video is captured as a 5760 pixels by 2880 pixels with a 360 degree horizontal field of view and a 180 degree vertical field of view. For video, the image sensor 114 may capure video at frame rates of, for example, 30 frames per second, 60 frames per second, or higher");

an angular acceleration sensor carried by the housing and configured to generate an angular acceleration output signal based on angular accelerations of the housing during the capture duration, the angular acceleration output signal conveying angular acceleration information that characterizes the angular accelerations of the housing at different moments within the capture duration (angular acceleration; para [0026]- "In addition to the generic sensors, a specialized sensor may be included such as the gyroscope 160. The gyroscope may be used to generate motion metadata, comprising velocity representative of motion of the camera 100, acceleration vectors may be derived from the motion metadata received from the gyroscope. The gyroscope sensor data may include sensing vibrations on the camera produced by external factors that is measured along three axes representing three directions. The gyroscope data is discussed in detail below with respect to FIG. 2. The gyroscope sensor data is transmitted by the sensors to the image processor 116 for processing the image/video frame"; para [0026]- "FIG. 2 illustrates an example of gyroscope sample data, according to one embodiment. The image sensor 114 captures an image/video frame. Simultaneously, the gyroscope 160 gathers motion data along three axes, i.e. a pitch (lateral) axis, a roll (longitudinal) axis and a yaw (perpendicular) axis. The three axes represent the angles of rotation of the camera in three dimensions about the camera's center of gravity"; para [0029]- "FIG. 3 illustrates an example implementation of a method for estimating motion frequency, according to one embodiment. The example shows gyroscope data for three video frames. The Y-axis primarily represents three regions, a noise threshold region 302, a positive displacement region 304 and a negative displacement region 306. In the noise threshold region 302, the camera is generally stable and not moving with high velocity. In the positive displacement region 304, the gyroscope data shows that the camera is moving to the left. In the negative displacement region 306, the gyroscope data shows that the camera is moving to the right"); and

(continued of claim 1)

---see continuation on supplemental page---

WRITTEN OPINION OF THE
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Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
Box No. V.2: Citations and Explanations:
(continued of claim 1)
one or more physical processors configured by machine-readable instructions (para [0041]- "FIG. 6 is a block diagram illustrating components of an example machine able to read instructions from a machine-readable medium and execute them in a processor (or controller). Specifically, FIG. 6 shows a diagrammatic representation of a machine in the example form of a computer system 600 within which instructions 624 (e.g., software) for causing the machine to perform any one or more of the methodologies discussed herein may be executed") to:

determine a viewing window for the visual content as the function of progress through the capture duration based on the motion (determining viewing window based on motion; para [0033]- "FIG. 4 illustrates an example capture window and view window used for electronic image stabilization of a video frame, according to one embodiment. An image processor captures a video frame in a capture window 402 that is greater than an output view window 404. For example, the capture window is 3840-times-2160 pixels and the output view window is 2000 times 1128 pixels. Based on the motion data analyzed from the gyroscope for a given frame relative to a reference frame, the output view window is adjusted within the capture window to compensate for the camera motion between the reference frame and the given frame. For example, if the gyroscope data indicates motion to the right by x pixels, the output view window is moved to the left by x pixels or vice versa to compensate for the motion. Thus stationary objects in the scene may appear stationary despite the camera movement").

GoPro does not disclose to determine intentionality of motion of the housing as a function of progress through the capture duration based on the angular acceleration information; to determine the viewing window for the visual content as the function of progress through the capture duration based on the intentionality of the motion of the housing, the viewing window defining one or more extents of the visual content; and generate stabilized visual content of a video based on the viewing window, the stabilized visual content including a punchout of the one or more extents of the visual content within the viewing window.

Invensense discloses an image capture device that stabilizes videos (para [0034]- "As shown, the example device 100 comprises a communication interface 105, an application (or host) processor 110, application (or host) memory 111, a camera unit 116 with an image sensor 118, and a standalone electronic image stabilization (S-EIS) unit 120 with at least one motion sensor 150 such as a gyroscope 151), the image capture device comprising:

a housing (see figure 1 for device housing);

an optical element carried by the housing and configured to guide light within a field of view to an image sensor (para [0041]- "Camera unit 116, when included, typically includes an optical element, such as a lens which projects an image onto an image sensor 118 of camera unit 116");

the image sensor carried by the housing and configured to generate a visual output signal conveying visual information based on light that becomes incident thereon during a capture duration, the visual information defining visual content having the field of view (para [0044]- "Image sensor 118 is a sensor that electrically detects and conveys the information that constitutes an image. The detection is performed by converting light waves that reach the image sensor into electrical signals representative of the image information that the light waves contain. Any suitable sensor may be utilized as image sensor 118, including, but not limited to a charge coupled device or a metal oxide semi-conductor device. Camera unit 116 may comprise an image processor (not depicted) which may be used for control of the image sensor and any type of local image processing");

an angular acceleration sensor carried by the housing and configured to generate an angular acceleration output signal based on angular accelerations of the housing during the capture duration, the angular acceleration output signal conveying angular acceleration information that characterizes the angular accelerations of the housing at different moments within the capture duration (para [0055]- "As discussed herein, various aspects of this disclosure may, for example, comprise processing various sensor signals indicative of device motion and/or orientation. These signals are generally referred to as "motion data" herein. Non-limiting examples of such motion data are signals that indicate accelerometer, gyroscope, and/or magnetometer data in a coordinate system. The motion data may refer the processed or non-processed data from the motion sensor(s)"; para [0056]- "In an example implementation, data from an accelerometer, gyroscope, and/or magnetometer may be combined in a so-called data fusion process, performed, for example, by processor 130, in order to output motion data in the form of a vector indicative of device orientation and/or indicative of a direction of device motion. Such a vector may, for example, initially be expressed in a body (or device) coordinate system. Such a vector may be processed by a transformation function that transforms the orientation vector to a world coordinate system. The motion and/or orientation data may be represented in any suitable reference frame most adapted for the image stabilization, and may be represented in any suitable form, such as for example, but not limited to, quaternions, orientation matrices, or Euler angles"); and

one or more physical processors configured by machine-readable instructions (para [0054]- "As will be appreciated, the application (or host) processor 110 and/or processor 130 may be one or more microprocessors, central processing units (CPUs), microcontrollers or other processors which run software programs for electronic device 100 and/or for other applications related to the functionality of the device 100. For example, different software application programs such as menu navigation software, games, camera function control, navigation software, and phone or a wide variety of other software and functional interfaces can be provided. In some embodiments, multiple different applications can be provided on a single device 100, and in some of those embodiments, multiple applications can run simultaneously on the device 100. Multiple layers of software can, for example, be provided on a computer readable medium such as electronic memory or other storage medium such as hard disk, optical disk, flash drive, etc., for use with application processor 110 and processor 130") to:
(continued of claim 1)
---see continuation on supplemental page---

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

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PCT/US 19/48368

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
Box No. V.2. Citations and Explanations:
(continued of claim 1)
stabilize image based on motion (para [0046]- "Electronic device 100 may include a Standalone Electronic Image Stabilization (S-EIS) unit 120. In S-EIS unit 120, the image stabilization is performed using one or more stabilization correction techniques, a variety of which are described herein. For example, during image capture, the motion of electronic device 100 and/or image sensor 118 may result in portions of the image data within a frame of image data being displaced relative to other portions of the image data within frame and/or displaced in whole due to the angle of tilt of image sensor 118 relative to a horizontal plane or horizon that is perpendicular to gravity. The S-EIS unit 120 analyzes these displacements (as measured by motion sensors such as gyroscope 151 and/or accelerometer 153) using image processing techniques, and corrects for this motion by transforming the image data of a frame so that it aligns and is motion stabilized. The displacement vectors may also be determined using one or more motion sensors 150. For example, gyroscope data, in the form of angular velocities measured by gyroscope 151 are used to help determine the displacement vector from one image section to the next image section, for example from one line to the next line, or from one frame to the next frame. Similarly, a gravity vector may be determined by a gyroscope 151 and/or accelerometer 153 to determine the roll displacement of the image frame on the optical axis. The required image processing may be performed by processor 130, host processor 110, or any other processor of electronic device 100 that is not a specialized graphical processor").

Invensense does not disclose to determine intentionality of motion of the housing as a function of progress through the capture duration based on the angular acceleration information; determine a viewing window for the visual content as the function of progress through the capture duration based on the intentionality of the motion of the housing, the viewing window defining one or more extents of the visual content; and generate stabilized visual content of a video based on the viewing window, the stabilized visual content including a punchout of the one or more extents of the visual content within the viewing window.

Therefore the prior art of record does not teach or fairly suggest the subject matter claimed. Specifically, none of the prior art, alone or in combination, teaches or fairly suggests to determine intentionality of motion of the housing as a function of progress through the capture duration based on the angular acceleration information; to determine the viewing window for the visual content as the function of progress through the capture duration based on the intentionality of the motion of the housing, the viewing window defining one or more extents of the visual content; and generate stabilized visual content of a video based on the viewing window, the stabilized visual content including a punchout of the one or more extents of the visual content within the viewing window.

Therefore since the prior art of record does not disclose all of the elements of claim 1, claim 1 meets the criteria set out in PCT Article 33(2)-(3).

Claims 2-10 depend either directly or indirectly from claim 1, and, therefore, meet the criteria set out in PCT Article 33(2)-(3), as well.

Regarding claim 11, GoPro discloses a method for stabilizing videos (para [0035]- "FIG. 5 illustrates a flowchart of a method for controlling electronic image stabilization, according to one embodiment. An image sensor of a camera system captures 505 a video stream that includes a plurality of video frames"), the method performed by an image capture device including one or more processors, an optical element, an image sensor and an angular acceleration sensor, the optical element configured to guide light within a field of view to the image sensor (para [0017]- "As described in greater detail below, the camera 100 may include sensors to capture metadata associated with video data, such as timing data, motion data, speed data, acceleration data, altitude data, GPS data, and the like. Additionally, the camera 100 may include processors or stabilizers to provide motion compensation by performing electronic image stabilization"; para [0018]- "Referring now to the details of FIG. 1, the camera 100 comprises a camera core 110 comprising a lens 112, an image sensor 114, and an image processor 116. The camera 100 additionally includes a system controller 120 (e.g., a microcontroller or microprocessor) that controls the operation and functionality of the camera 100 and system memory 130 configured to store executable computer instructions that, when executed by the system controller 120 and/or the image processors 116, perform the camera functionalities described herein. In some embodiments, a camera 100 may include multiple camera cores 110 to capture fields of view in different directions which may then be stitched together to form a cohesive image"), the method comprising:

generating, by the image sensor, a visual output signal conveying visual information based on light that becomes incident thereon during a capture duration, the visual information defining visual content having the field of view (para [0019]- "The lens 112 may be, for example, a wide angle lens, hemispherical, or hyper hemispherical lens that focuses light entering the lens to the image sensor 114 which captures images and/or video frames. The image sensor 114 may capture high definition images having a resolution of, for example, 720p, 1080p, 4 k, or higher. In one embodiment, spherical video is captured as a 5760 pixels by 2880 pixels with a 360 degree horizontal field of view and a 180 degree vertical field of view. For video, the image sensor 114 may capture video at frame rates of, for example, 30 frames per second, 60 frames per second, or higher");

generating, by the angular acceleration sensor, an angular acceleration output signal based on angular accelerations of the image capture device during the capture duration, the angular acceleration output signal conveying angular acceleration information that characterizes the angular accelerations of the image capture device at different moments within the capture duration (angular acceleration; para [0025]- "In addition to the generic sensors, a specialized sensor may be included such as the gyroscope 180. The gyroscope may be used to generate motion metadata, comprising velocity representative of motion of the camera 100, acceleration vectors may be derived from the motion metadata received from the gyroscope. The gyroscope sensor data may include sensing vibrations on the camera produced by external factors that is measured along three axes representing three directions. The gyroscope data is discussed in detail below with respect to FIG. 2. The gyroscope sensor data is transmitted by the sensors to the image processor 116 for processing the image/video frame"; para [0026]- "FIG. 2 illustrates an example of gyroscope sample data, according to one embodiment. The image sensor 114 captures an image/video frame. Simultaneously, the gyroscope 180 gathers motion data along three axes, i.e. a pitch (lateral) axis, a roll (longitudinal) axis, and a yaw (perpendicular) axis. The three axes represent the angles of rotation of the camera in three dimensions about the camera's center of gravity");
(continued of claim 1)
—see continuation on supplemental page—

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
Box No. V.2. Citations and Explanations:
(continued of claim 11)
determining, by the one or more processors, a viewing window for the visual content as the function of progress through the capture duration based on motion (determining viewing window based on motion; para [0033]- "FIG. 4 illustrates an example capture window and view window used for electronic image stabilization of a video frame, according to one embodiment. An image processor captures a video frame in a capture window 402 that is greater than an output view window 404. For example, the capture window is 3840.times.2160 pixels and the output view window is 2000.times.1128 pixels. Based on the motion data analyzed from the gyroscope for a given frame relative to a reference frame, the output view window is adjusted within the capture window to compensate for the camera motion between the reference frame and the given frame. For example, if the gyroscope data indicates motion to the right by x pixels, the output view window is moved to the left by x pixels or vice versa to compensate for the motion. Thus stationary objects in the scene may appear stationary despite the camera movement").

GoPro does not disclose the steps of determining, by the one or more processors, intentionality of motion of the image capture device as a function of progress through the capture duration based on the angular acceleration information; determining, by the one or more processors, the viewing window for the visual content as the function of progress through the capture duration based on the intentionality of the motion of the image capture device, the viewing window defining one or more extents of the visual content; and generating, by the one or more processors, stabilized visual content of a video based on the viewing window, the stabilized visual content including a punchout of the one or more extents of the visual content within the viewing window.

Invensense discloses a method for stabilizing videos (para [0056]- "FIG. 2 illustrates an example of the flow of data during image stabilization performed with a standalone electronic image stabilization (S-EIS) unit 120, in accordance with various aspects of the present disclosure. When an image data request 291 is made for image data 210, the camera unit 116 with image sensor 118 outputs the image data 210. The image data request will go through the operating system and may come from any program or application executed, for example, by application processor 110. The image data 210 may be output, for example, line by line, or section by section, or as fast as the image sensor 118 can capture and output the image data 210), the method performed by an image capture device including one or more processors, an optical element, an image sensor, and an angular acceleration sensor, the optical element configured to guide light within a field of view to the image sensor (para [0041]- "Camera unit 116, when included, typically includes an optical element, such as a lens which projects an image onto an image sensor 118 of camera unit 116"; para [0044]- "Image sensor 118 is a sensor that electrically detects and conveys the information that constitutes an image. The detection is performed by converting light waves that reach the image sensor into electrical signals representative of the image information that the light waves contain. Any suitable sensor may be utilized as image sensor 118, including, but not limited to a charge coupled device or a metal oxide semi-conductor device. Camera unit 116 may comprise an image processor (not depicted) which may be used for control of the image sensor and any type of local image processing. The image processor may also control communication such as sending and/or receiving information, e.g., sync signals, control signals/instructions, messages, counters, image data, and the like. Camera unit 116 or a portion thereof, such as image sensor 116, is coupled with application processor 110, S-EIS unit 120, and GPU 119 (when included) by communication interface 165, or other well-known communication means"), the method comprising:

generating, by the image sensor, a visual output signal conveying visual information based on light that becomes incident thereon during a capture duration, the visual information defining visual content having the field of view (para [0044]- "Image sensor 116 is a sensor that electrically detects and conveys the information that constitutes an image. The detection is performed by converting light waves that reach the image sensor into electrical signals representative of the image information that the light waves contain. Any suitable sensor may be utilized as image sensor 116, including, but not limited to a charge coupled device or a metal oxide semi-conductor device. Camera unit 116 may comprise an image processor (not depicted) which may be used for control of the image sensor and any type of local image processing");

generating, by the angular acceleration sensor, an angular acceleration output signal based on angular accelerations of the image capture device during the capture duration, the angular acceleration output signal conveying angular acceleration information that characterizes the angular accelerations of the image capture device at different moments within the capture duration (para [0055]- "As discussed herein, various aspects of this disclosure may, for example, comprise processing various sensor signals indicative of device motion and/or orientation. These signals are generally referred to as "motion data" herein. Non-limiting examples of such motion data are signals that indicate accelerometer, gyroscope, and/or magnetometer data in a coordinate system. The motion data may refer the processed or non-processed data from the motion sensor(s)"; para [0056]- "In an example implementation, data from an accelerometer, gyroscope, and/or magnetometer may be combined in a so-called data fusion process, performed, for example, by processor 130, in order to output motion data in the form of a vector indicative of device orientation and/or indicative of a direction of device motion. Such a vector may, for example, initially be expressed in a body (or device) coordinate system. Such a vector may be processed by a transformation function that transforms the orientation vector to a world coordinate system"); and

stabilizing the image based on motion (para [0046]- "Electronic device 100 may include a Standalone Electronic Image Stabilization (S-EIS) unit 120. In S-EIS unit 120, the image stabilization is performed using one or more stabilization correction techniques, a variety of which are described herein. For example, during image capture, the motion of electronic device 100 and/or image sensor 118 may result in portions of the image data within a frame of image data being displaced relative to other portions of the image data within frame and/or displaced in whole due to the angle of tilt of image sensor 116 relative to a horizontal plane or horizon that is perpendicular to gravity. The S-EIS unit 120 analyzes these displacements (as measured by motion sensors such as gyroscope 151 and/or accelerometer 153) using image processing techniques, and corrects for this motion by transforming the image data of a frame so that it aligns and is motion stabilized. The displacement vectors may also be determined using one or more motion sensors 150. For example, gyroscope data, in the form of angular velocities measured by gyroscope 151 are used to help determine the displacement vector from one image section to the next image section, for example from one line to the next line, or from one frame to the next frame").
(continued of claim 11)
---see continuation on supplemental page---

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.

Continuation of:
Box No. V.2. Citations and Explanations;
(continued of claim 11)

Invensense does not disclose determining, by the one or more processors, intentionality of motion of the image capture device as a function of progress through the capture duration based on the angular acceleration information; determining, by the one or more processors, a viewing window for the visual content as the function of progress through the capture duration based on the intentionality of the motion of the image capture device, the viewing window defining one or more extents of the visual content; and generating, by the one or more processors, stabilized visual content of a video based on the viewing window, the stabilized visual content including a punchout of the one or more extents of the visual content within the viewing window.

Therefore the prior art of record does not teach or fairly suggest the subject matter claimed. Specifically, none of the prior art, alone or in combination, teaches or fairly suggests determining, by the one or more processors, intentionality of motion of the image capture device as a function of progress through the capture duration based on the angular acceleration information; determining, by the one or more processors, the viewing window for the visual content as the function of progress through the capture duration based on the intentionality of the motion of the image capture device, the viewing window defining one or more extents of the visual content; and generating, by the one or more processors, stabilized visual content of a video based on the viewing window, the stabilized visual content including a punchout of the one or more extents of the visual content within the viewing window.

Therefore since the prior art of record does not disclose all of the elements of claim 11, claim 11 meets the criteria set out in PCT Article 33(2)-(3).

Claims 12-20 depend either directly or indirectly from claim 11, and, therefore, meet the criteria set out in PCT Article 33(2)-(3), as well.

Claims 1-20 have industrial applicability as defined by PCT Article 33(4) because the subject matter can be made or used in industry.

Electronic Patent Application Fee Transmittal

Application Number:	16548453
Filing Date:	22-Aug-2019
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Filer:	Vadim Polonichko/Sandra Streams
Attorney Docket Number:	46DG-026061

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
SUBMISSION- INFORMATION DISCLOSURE STMT	1806	1	240	240
		Total in USD ($)		**240**

Electronic Acknowledgement Receipt

EFS ID:	37957251
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	Vadim Polonichko/Sandra Streams
Filer Authorized By:	Vadim Polonichko
Attorney Docket Number:	46DG-026061
Receipt Date:	06-DEC-2019
Filing Date:	22-AUG-2019
Time Stamp:	15:50:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	GP-46DG-026061_SyncIDS-Form.pdf	45386 a74bbe68aa9ea6bdff6a229e02180dc60b5979640	no	1

Warnings:

Information:					
This is not an USPTO supplied IDS fillable form					
2	Transmittal Letter	GP-46DG-026061_Transmittal-Letter.pdf	504270 7a8ee74dcceed6a466be096f5762cb5e88ee9751	no	1
Warnings:					
Information:					
3	Other Reference-Patent/App/Search documents	GP-46DG-026061-NPL-006-Other.pdf	1259827 067a43999fea788466e16c49ea3f2c3b4c53900e	no	7
Warnings:					
Information:					
4	Other Reference-Patent/App/Search documents	GP-46DG-026061-NPL-007-Other.pdf	2500055 7937c6058419d9e3f434e4fd5cfc9b40a562511b	no	10
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	30721 56667e1454b1cb5d319445bf89d172312723ed11	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	4340259		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
16/548,453	08/22/2019	Thomas Derbanne	46DG-026061

CONFIRMATION NO. 2987

137002
Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008

PUBLICATION NOTICE

OC000000113300880

Title:SYSTEMS AND METHODS FOR STABILIZING VIDEOS

Publication No.US-2019-0379834-A1
Publication Date:12/12/2019

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently https://portal.uspto.gov/pair/PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

To: docketing@esplin.legal,,
From: PAIR_eOfficeAction@uspto.gov
Cc: PAIR_eOfficeAction@uspto.gov
Subject: Private PAIR Correspondence Notification for Customer Number 137002

Dec 13, 2019 03:35:38 AM

Dear PAIR Customer:

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

The following USPTO patent application(s) associated with your Customer Number, 137002 , have new outgoing correspondence. This correspondence is now available for viewing in Private PAIR.

The official date of notification of the outgoing correspondence will be indicated on the form PTOL-90 accompanying the correspondence.

Disclaimer:
The list of documents shown below is provided as a courtesy and is not part of the official file wrapper. The content of the images shown in PAIR is the official record.

Application	Document	Mailroom Date	Attorney Docket No.
16548453	NTC.PUB	12/12/2019	46DG-026061

To view your correspondence online or update your email addresses, please visit us anytime at https://sportal.uspto.gov/secure/myportal/privatepair.

If you have any questions, please email the Electronic Business Center (EBC) at EBC@uspto.gov with 'e-Office Action' on the subject line or call 1-866-217-9197 during the following hours:

Monday - Friday 6:00 a.m. to 12:00 a.m.

Thank you for prompt attention to this notice,

UNITED STATES PATENT AND TRADEMARK OFFICE

PATENT APPLICATION INFORMATION RETRIEVAL SYSTEM

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

137002 7590 11/29/2019
Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/548,453	08/22/2019	Thomas Derbanne	46DG-026061	2987

TITLE OF INVENTION: SYSTEMS AND METHODS FOR STABILIZING VIDEOS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$1000	$0.00	$0.00	$1000	03/02/2020

EXAMINER	ART UNIT	CLASS-SUBCLASS
SEGURA, CYNTHIA	2698	348-208200

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Esplin & Associates, PC
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: GoPro, Inc.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): San Mateo, California

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ☒ Corporation or other private group entity ❑ Government

4a. Fees submitted: ☒ Issue Fee ❑ Publication Fee (if required) ❑ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /D. Benjamin Esplin/ Date December 20, 2019

Typed or printed name D. Benjamin Esplin Registration No. 58297

Insta360
Exhibit 1003 Page 459

Electronic Patent Application Fee Transmittal

Application Number:	16548453
Filing Date:	22-Aug-2019
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Filer:	D. Benjamin Esplin/Chelsea Pearsall
Attorney Docket Number:	46DG-026061

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	1501	1	1000	1000

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1000**

Electronic Acknowledgement Receipt	
EFS ID:	38108384
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	D. Benjamin Esplin/Chelsea Pearsall
Filer Authorized By:	D. Benjamin Esplin
Attorney Docket Number:	46DG-026061
Receipt Date:	20-DEC-2019
Filing Date:	22-AUG-2019
Time Stamp:	16:16:55
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1000
RAM confirmation Number	E2019BJG17118013
Deposit Account	602731
Authorized User	Chelsea Pearsall
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	46DG-026061_Issue_Fee_Transmittal_FINAL.pdf	87299 d74869614fa8274605665ea5c4bbaa69b1419b29	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30666 674e4278033e53b270b744c1525c5820091e43ab	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	117965		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PRINTER RUSH
(PTO ASSISTANCE)

Application: 16548453	**Examiner:** Segura	**GAU:** 2698
From:	**Location:** RTFM	**Creation Date:** 01/22/2020

Week Date: **11/25/2019**

DOC CODE	DOC DATE	MISCELLANEOUS
☐ 1449		☐ Continuing Data
☒ IDS	12/06/2019	☐ Foreign Priority
☐ CLM		☐ Document Legibility
☐ IIFW/FWCLM		☐ Fees
☐ SRFW		☐ Petition (TC)
☐ DRW		☐ Other
☐ OATH		
☐ 312		
☐ SPEC		

[RUSH] Message:

Please respond to the 12/06/19 IDS

thank you

[XRUSH] Response:

Initials: _____

Examiner: PUBS contact - James Leija, (703) 756-1197
NOTE: This form will be included as part of the official USPTO record with the response document coded as XRUSH.
REV: AUG 16

Insta360
Exhibit 1003 Page 464

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/548,453	08/22/2019	Thomas Derbanne	46DG-026061	2987

137002 7590 01/30/2020

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008

EXAMINER	
SEGURA, CYNTHIA	

ART UNIT	PAPER NUMBER
2698	

NOTIFICATION DATE	DELIVERY MODE
01/30/2020	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

docketing@esplin.legal

Corrected ***Notice of Allowability***	**Application No.** 16/548,453	**Applicant(s)** Derbanne et al.	
	Examiner CYNTHIA SEGURA	**Art Unit** 2698	**AIA (FITF) Status** Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to IDS filed on 12/6/2019.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 1-5,7-15 and 17-22 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information , please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/CYNTHIA SEGURA/
Primary Examiner, Art Unit 2698

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/548,453
	Filing Date	08/22/2019
	First Named Inventor	Thomas Derbanne
	Art Unit	2698
Page 1 of 1	**Matter Number**	46DG-026061

U.S. PATENT/PUBLICATION DOCUMENTS					
Initials	**Cite No.**	**Document Number**	**Issue/Publication Date**	**First Named Inventor**	**Relevant Pages, Columns, etc.**
	1	20130002813	01/03/2013	VAUGHT BENJAMIN I	
	2	20170041545	02/09/2017	MURGIA CARLO	
	3	20170142337	05/18/2017	KOKARAM ANIL CHRISTOPHER	
	4	20180048821	02/15/2018	SEGAPELLI LOIC	
	5	20180220073	08/02/2018	KEAL WILLIAM KERRY	

FOREIGN PATENT DOCUMENTS						
Initials	**Cite No.**	**Document Number**	**Publication Date**	**Country**	**Relevant Pages, Columns, etc.**	**T**

OTHER DOCUMENTS			
Initials	**Cite No.**	**Author, Title, Date, Pages, etc.**	**T**
	6	International Search Report and Written Opinion for Application No. PCT/US2019/048292, dated September 27, 2019, 7 pages.	
	7	International Search Report for Application No. PCT/US19/48368, date of mailing November 7, 2019, 10 pages.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /C.S/

Examiner Signature	/CYNTHIA SEGURA/	**Date Considered**	01/27/2020

Examiner: Please initial if citation considered, whether or not citation is in conformance with MPEP Section 609. Please draw a line through the citation if it is not in conformance and it is not considered. Please include a copy of this form with the next communication to the applicant.

PRINTER RUSH
(PTO ASSISTANCE)

Application: 16548453	**Examiner:** Segura	**GAU:** 2698
From:	**Location:** RTFM	**Creation Date:** 01/22/2020

Week Date: **11/25/2019**

DOC CODE	DOC DATE	MISCELLANEOUS
☐ 1449		☐ Continuing Data
☒ IDS	12/06/2019	☐ Foreign Priority
☐ CLM		☐ Document Legibility
☐ IIFW/FWCLM		☐ Fees
☐ SRFW		☐ Petition (TC)
☐ DRW		☐ Other
☐ OATH		
☐ 312		
☐ SPEC		

[RUSH] Message:

Please respond to the 12/06/19 IDS

thank you

[XRUSH] Response:

The IDS filed on 12/6/2019 has been considered and initialed by the examiner.

Initials: /C.S/

Examiner: PUBS contact - James Leija, (703) 756-1197 01/27/2020

NOTE: This form will be included as part of the official USPTO record with the response document coded as XRUSH.

REV: AUG 16

Insta360
Exhibit 1003 Page 468

To: docketing@esplin.legal,,
From: PAIR_eOfficeAction@uspto.gov
Cc: PAIR_eOfficeAction@uspto.gov
Subject: Private PAIR Correspondence Notification for Customer Number 137002

Jan 30, 2020 03:38:23 AM

Dear PAIR Customer:

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

The following USPTO patent application(s) associated with your Customer Number, 137002 , have new outgoing correspondence. This correspondence is now available for viewing in Private PAIR.

The official date of notification of the outgoing correspondence will be indicated on the form PTOL-90 accompanying the correspondence.

Disclaimer:
The list of documents shown below is provided as a courtesy and is not part of the official file wrapper. The content of the images shown in PAIR is the official record.

Application	Document	Mailroom Date	Attorney Docket No.
16548453	NOA	01/30/2020	46DG-026061
	1449	01/30/2020	46DG-026061

To view your correspondence online or update your email addresses, please visit us anytime at https://sportal.uspto.gov/secure/myportal/privatepair.

If you have any questions, please email the Electronic Business Center (EBC) at EBC@uspto.gov with 'e-Office Action' on the subject line or call 1-866-217-9197 during the following hours:

Monday - Friday 6:00 a.m. to 12:00 a.m.

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PATENT APPLICATION INFORMATION RETRIEVAL SYSTEM

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
16/548,453	02/25/2020	10574894	46DG-026061	2987

137002 7590 02/05/2020

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Thomas Derbanne, Paris, FRANCE;
GoPro, Inc., San Mateo, CA;
César Douady, Les Molieres, FRANCE;
Maxim Karpushin, Paris, FRANCE;

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IR103 (Rev. 10/09)

To: docketing@esplin.legal,,
From: PAIR_eOfficeAction@uspto.gov
Cc: PAIR_eOfficeAction@uspto.gov
Subject: Private PAIR Correspondence Notification for Customer Number 137002

Feb 06, 2020 03:30:02 AM

Dear PAIR Customer:

Esplin & Associates (GoPro)
5411 Avenida Encinas
Suite 100
Carlsbad, CA 92008
UNITED STATES

The following USPTO patent application(s) associated with your Customer Number, 137002 , have new outgoing correspondence. This correspondence is now available for viewing in Private PAIR.

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Application	Document	Mailroom Date	Attorney Docket No.
16548453	ISSUE.NTF	02/05/2020	46DG-026061

To view your correspondence online or update your email addresses, please visit us anytime at https://sportal.uspto.gov/secure/myportal/privatepair.

If you have any questions, please email the Electronic Business Center (EBC) at EBC@uspto.gov with 'e-Office Action' on the subject line or call 1-866-217-9197 during the following hours:

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PATENT APPLICATION INFORMATION RETRIEVAL SYSTEM

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APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	REQUEST ID
16/548,453	10574894	2698	115891

PAIR Correspondence Address/Fee Address Change

The following fields have been changed to Customer Number 204 on 07/02/2020 via Private PAIR in view of the certification copied below that authorized the change.

- Maintenance Fee Address

The address for Customer Number 204 is:
204
COMPUTER PACKAGES, INC.
414 HUNGERFORD DRIVE
ROCKVILLE, MD 20850

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

An attorney or Agent of Record registered to practice before the Patent and Trademark Office who has been given power of attorney in this application

Signature:	/D. Benjamin Esplin/
Name:	D. Benjamin Esplin
Registration Number:	58297

Attorney Docket: 46DG-026061

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE PATENT APPLICATION OF	:	Thomas Derbanne, *et al.*
SERIAL NO.	:	16/548,453
FILING DATE	:	August 22, 2019
ART UNIT	:	2698
EXAMINER	:	SEGURA, CYNTHIA
FOR	:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS

REQUEST FOR CERTIFICATE OF CORRECTION

Commissioner for Patents
PO Box 1450
Alexandria, VA 22313-1450

The applicant of the above-identified patent, through its attorneys, hereby requests issuance of a Certificate of Correction.

Applicant requests correction of the errors set forth below.

Applicant submits the required fee herewith. The Commissioner is hereby authorized to charge any additional fees or credit any overpayment to the undersigned's Deposit Account No. 602731 (Reference No. 46DG-026061).

Correction of text in the Patent

Upon reviewing the above-identified patent, Applicant noted errors which should be corrected. These errors are either of a clerical nature, of a typographical nature, or a mistake of minor character. Correction to these errors do not constitute new matter nor require reexamination.

It is certified that errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 9, Line 49, please delete "head" and insert --ahead--, therefor.

In Claim 9, Column 19, Line 12, please replace "lookahead" with --look ahead--, therefor.

In Claim 19, Column 20, Line 55, please replace "lookahead" with --look ahead--, therefor.

CONCLUSION

It is requested that a Certificate of Correction be issued to correct these errors. Form PTO/SB/44 is attached for this purpose.

Date: February 10, 2023

Submitted,

By: /D. Benjamin Esplin/
D. Benjamin Esplin
Reg. No. 58,297

Customer No. 177600
ESPLIN & ASSOCIATES, PC
docketing@esplin.legal
(760) 249-2133

PTO/SB/44 (09-07)
Approved for use through 03/31/2023. OMB 0651-0033
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.
(Also Form PTO-1050)

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

Page _____ of _____

PATENT NO. : 10,574,894

APPLICATION NO.: 16/548,453

ISSUE DATE : February 25, 2020

INVENTOR(S) : Thomas Derbanne, et al.

It is certified that an error appears or errors appear in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In Column 9, Line 49, please delete "head" and insert --ahead--, therefor.

In Claim 9, Column 19, Line 12, please replace "lookahead" with --look ahead--, therefor.

In Claim 19, Column 20, Line 55, please replace "lookahead" with --look ahead--, therefor.

MAILING ADDRESS OF SENDER (Please do not use Customer Number below):

6225 Buckhorn Ridge Place
San Miguel, California 93451

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1.0 hour to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Attention Certificate of Corrections Branch, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Patent Application Fee Transmittal

Application Number:	16548453
Filing Date:	22-Aug-2019
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Filer:	D. Benjamin Esplin/Lynn Han
Attorney Docket Number:	46DG-026061

Filed as Large Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
CERTIFICATE OF CORRECTION	1811	1	160	160

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**160**

Electronic Acknowledgement Receipt	
EFS ID:	47515343
Application Number:	16548453
International Application Number:	
Confirmation Number:	2987
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Thomas Derbanne
Customer Number:	137002
Filer:	D. Benjamin Esplin/Lynn Han
Filer Authorized By:	D. Benjamin Esplin
Attorney Docket Number:	46DG-026061
Receipt Date:	10-FEB-2023
Filing Date:	22-AUG-2019
Time Stamp:	13:55:43
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$160
RAM confirmation Number	E202320D56186151
Deposit Account	602731
Authorized User	Lynn Han
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Certificate of Correction	46DG-026061_Request_Certificate_of_Correction.pdf	207472 e494565af6b403c0f35b5a15949d118ca98917e2	no	2
Warnings:					
Information:					
2	Request for Certificate of Correction	46DG-026061_CoC.pdf	161354 a3b1d66f06a238f61026035680cdca1033003f78	no	2
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	38183 f8778eac4fdb531b6ae2ca1258f1535751ffff77	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	407009		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	REQUEST ID
16/548,453	10574894	2698	185867

PAIR Correspondence Address/Fee Address Change

The following fields have been changed to Customer Number 177600 on 03/16/2023 via Private PAIR in view of the certification copied below that authorized the change.

- Correspondence Address

The address for Customer Number 177600 is:
177600
GoPro Issuance
3025 Clearview Way
San Mateo, CA 94402

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

An attorney or Agent of Record registered to practice before the Patent and Trademark Office who has been given power of attorney in this application

Signature:	/D. Benjamin Esplin/
Name:	D. Benjamin Esplin
Registration Number:	58297

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,574,894 B2
APPLICATION NO. : 16/548453
DATED : February 25, 2020
INVENTOR(S) : Thomas Derbanne et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification

In Column 9, Line 49, please delete “head” and insert --ahead--, therefor.

In the Claims

In Claim 9, Column 19, Line 12, please replace “lookahead” with --look ahead--, therefor.

In Claim 19, Column 20, Line 55, please replace “lookahead” with --look ahead--, therefor.

Signed and Sealed this
Twenty-fourth Day of October, 2023

Katherine Kelly Vidal

Katherine Kelly Vidal
Director of the United States Patent and Trademark Office