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)

Applicant's or agent's file reference 29679/PCT	Date of mailing *(day/month/year)* **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

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 Facsimile No. (571)273-8300	Authorized officer: HARRY C. KIM 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.

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:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2019/031591

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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/713,798
	Filing Date	12/13/2019
	First Named Inventor	César Douady
	Art Unit	0000
Page 1 of 3	**Matter Number**	46DG-026085

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	9787902	10/10/2017	BEYSSERIE SEBASTIEN X	
	10	10262691	04/16/2019	GILMOUR NICHOLAS RYAN	
	11	10284794	05/07/2019	FRANCOIS BRUNO	
	12	10341564	07/02/2019	DERBANNE THOMAS	
	13	10432864	10/01/2019	DOUADY CESAR	
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	27	20130058535	03/07/2013	Gabriel Othmezouri	
	28	20130177168	07/11/2013	Kai Inha	
	29	20130210563	08/15/2013	Steven J. Hollinger	

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.

SyncIDS.com

INFORMATION DISCLOSURE STATEMENT BY APPLICANT	Application Number	16/713,798
	Filing Date	12/13/2019
	First Named Inventor	César Douady
	Art Unit	0000
Page 2 of 3	Matter Number	46DG-026085

U.S. PATENT/PUBLICATION DOCUMENTS					
Initials	Cite No.	Document Number	Issue/Publication Date	First Named Inventor	Relevant Pages, Columns, etc.
	30	20130250047	09/26/2013	HOLLINGER STEVEN J	
	31	20130329132	12/12/2013	TICO MARIUS	
	32	20140028876	01/30/2014	MILLS CHRISTOPHER L	
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	34	20140266773	09/18/2014	AGUILAR FRANCISCO	
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	52	20180199025	07/12/2018	HOLZER STEFAN JOHANNES JOSEF	
	53	20180220073	08/02/2018	KEAL WILLIAM KERRY	
	54	20180324358	11/08/2018	YAMADA HIDESHI	
	55	20190124267	04/25/2019	HARUNA KOHTA	

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.

SyncIDS.com

INFORMATION DISCLOSURE STATEMENT BY APPLICANT		
	Application Number	16/713,798
	Filing Date	12/13/2019
	First Named Inventor	César Douady
	Art Unit	0000
Page 3 of 3	**Matter Number**	46DG-026085

FOREIGN PATENT DOCUMENTS						
Initials	**Cite No.**	**Document Number**	**Publication Date**	**Country**	**Relevant Pages, Columns, etc.**	**T**
	56	2009047572A1	04/16/2009	WO		
	57	2014042104A1	03/20/2014	WO		
	58	2014090277A1	06/19/2014	WO		

OTHER DOCUMENTS			
Initials	**Cite No.**	**Author, Title, Date, Pages, etc.**	**T**
	59	"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>.	
	60	International Search Report and Written Opinion for Application No. PCT/US2019/020241, date of mailing June 3, 2019, 12 pages.	
	61	International Search Report and Written Opinion for Application No. PCT/US2019/031591, date of mailing June 18, 2019, 7 pages.	
	62	International Search Report and Written Opinion for Application No. PCT/US2019/048292, dated September 27, 2019, 7 pages.	
	63	International Search Report for Application No. PCT/US19/48368, date of mailing November 7, 2019, 10 pages.	
	64	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)	
	65	KOPF et al., "First-person Hyper-Lapse Videos" ACM Transactions on Graphics (Proceedings of SIGGRAPH 2014), 33(4), Article No. 78, 2014 (10 pages).	
	66	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 >	
	67	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.	
	68	PCT International Search Report and Written Opinion for PCT/US15/38913, September 29, 2015, 15 Pages	
	69	United States Office Action, U.S. Application No. 14/789,706, June 7, 2016, 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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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)

	Date of mailing *(day/month/year)* 07 NOV 2019
Applicant's or agent's file reference 46DG-026044	**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 Telephone No. PCT Helpdesk: 571-272-4300 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 4SDG-026044	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. PCT/US19/48368	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 2018/0220073 A1 (Invensense Inc.) 02 August 2018 (02.08.2018), 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 19/46368

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:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US 19/48368

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 2016/0048821 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 capture 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 [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"; 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 right. In the negative displacement region 306, 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---

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---

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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)
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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 [0058]- "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 201 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 105, 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 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");

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 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").
(continued of claim 11)
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(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 Acknowledgement Receipt

EFS ID:	38257853
Application Number:	16713798
International Application Number:	
Confirmation Number:	2783
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Cesar Douady
Customer Number:	137002
Filer:	Vadim Polonichko/Sandra Streams
Filer Authorized By:	Vadim Polonichko
Attorney Docket Number:	46DG-026085
Receipt Date:	10-JAN-2020
Filing Date:	13-DEC-2019
Time Stamp:	04:36:56
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-026085_SyncIDS-Form.pdf	66444 3ffdb8549170bd3b785e792869ffa01b19f51642	no	3

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Information:					
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Warnings:					
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Information:					
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13	Non Patent Literature	GP-46DG-026085-NPL-066.pdf	1541988 339143fe73c03c5697286e1397ebec254132b806	no	12
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Information:					
14	Non Patent Literature	GP-46DG-026085-NPL-067.pdf	226779 562594e18726392299a35942ef69b40e293eabeb	no	4
Warnings:					
Information:					
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16	Other Reference-Patent/App/Search documents	GP-46DG-026085-NPL-069-Other.pdf	2061956 e108ee7664aa8d4ae5daf2408e51df1166c6d53d	no	10

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Total Files Size (in bytes):	42251228

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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
19 June 2014 (19.06.2014)

WIPO | PCT

(10) International Publication Number
WO 2014/090277 A1

(51) International Patent Classification:
H04S 7/00 (2006.01) *H04S 3/00* (2006.01)

(21) International Application Number:
PCT/EP2012/074956

(22) International Filing Date:
10 December 2012 (10.12.2012)

(25) Filing Language: English

(26) Publication Language: English

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(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, 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, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, 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.

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

Declarations under Rule 4.17:

---- *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) Title: SPATIAL AUDIO APPARATUS

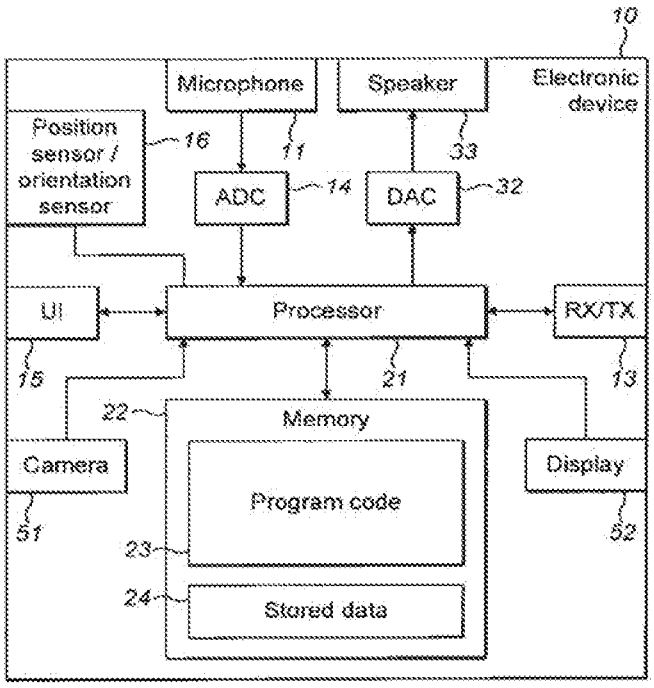


FIG. 1

(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.

WO 2014/090277 A1

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

$$\max_{\tau_b} Re\left(\sum_{n=0}^{n_{b+1}-n_b-1} (X_{1,\tau_b}^b(n)^* X_0^b(n)) \right), \tau_b \in [-D_{tot}, D_{tot}]$$

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.

$$X_{sum}^b = \begin{cases} (X_{1,\tau_b}^b + X_0^b)/2 & \tau_b \leq 0 \\ (X_1^b + X_{0,-\tau_b}^b)/2 & \tau_b > 0 \end{cases}$$

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,

$$\dot{a}_b = \pm \cos^{-1}\left(\frac{\Delta_{23}{}^2 + 2b\Delta_{23} - d^2}{2db}\right)$$

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:

$$\delta_b^+ = \sqrt{(h + b\sin(\alpha_b))^2 + (d/2 + b\cos(\alpha_b))^2}$$

$$\delta_b^- = \sqrt{(h - b\sin(\alpha_b))^2 + (d/2 + b\cos(\alpha_b))^2}$$

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

$$c_b^+ = Re\left(\sum_{n=0}^{n_{b+1}-n_b-1}(X_{sum,\tau_b^+}^b(n) \cdot X_1^b(n))\right)$$

$$c_b^- = Re\left(\sum_{n=0}^{n_{b+1}-n_b-1}(X_{sum,\tau_b^-}^b(n) \cdot X_1^b(n))\right)$$

The direction analyser can then in some embodiments then determine the direction of the dominant sound source for subband b as:

$$\alpha_b = \begin{cases} \alpha_b & c_b^L \geq c_b^R \\ -\alpha_b & c_b^L < c_b^R \end{cases}$$

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:

$$M^b = \begin{cases} (X_1^b{}_{\tau_b} + X_2^b)/2 & \tau_b \leq 0 \\ (X_2^b + X_1^b{}_{-\tau_b})/2 & \tau_b > 0 \end{cases}$$

$$S^b = \begin{cases} (X_1^b{}_{\tau_b} - X_2^b)/2 & \tau_b \leq 0 \\ (X_2^b - X_1^b{}_{-\tau_b})/2 & \tau_b > 0 \end{cases}$$

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

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.

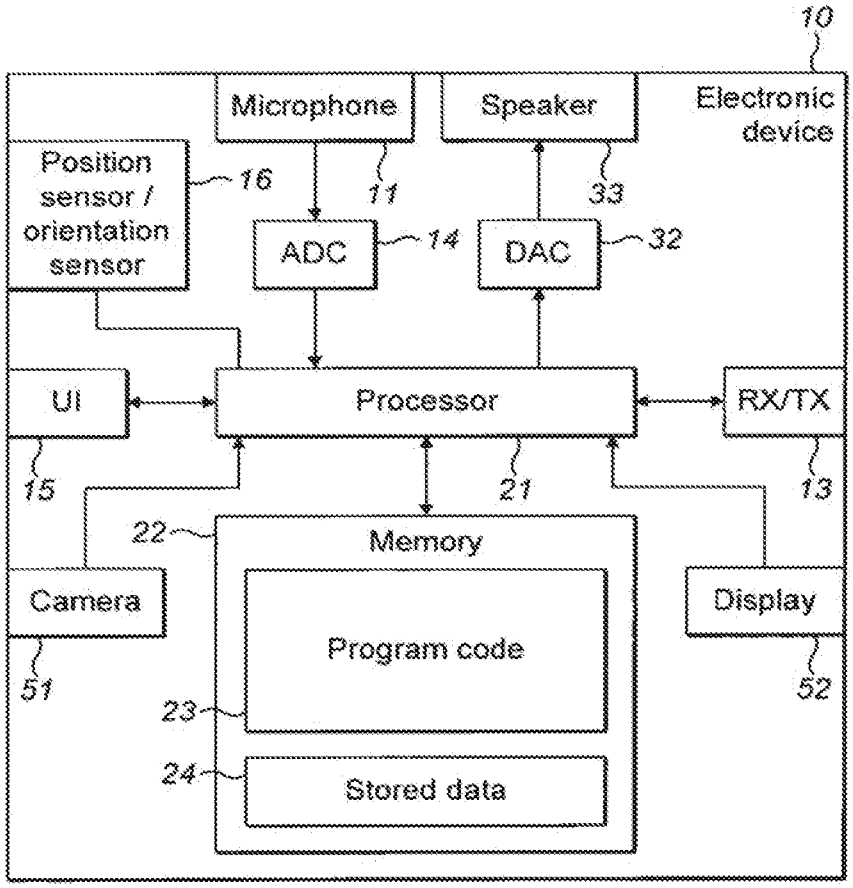


FIG. 1

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Exhibit 1002 Page 294

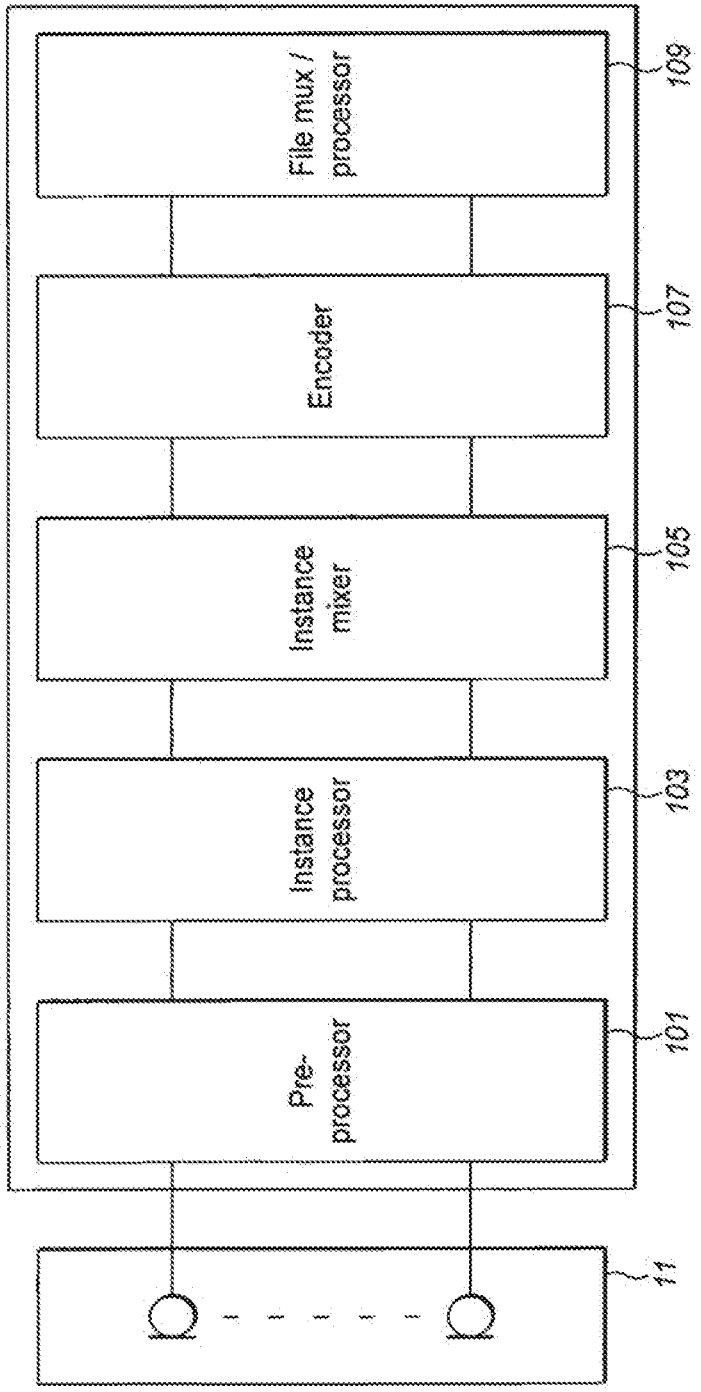


FIG. 2

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Exhibit 1002 Page 295

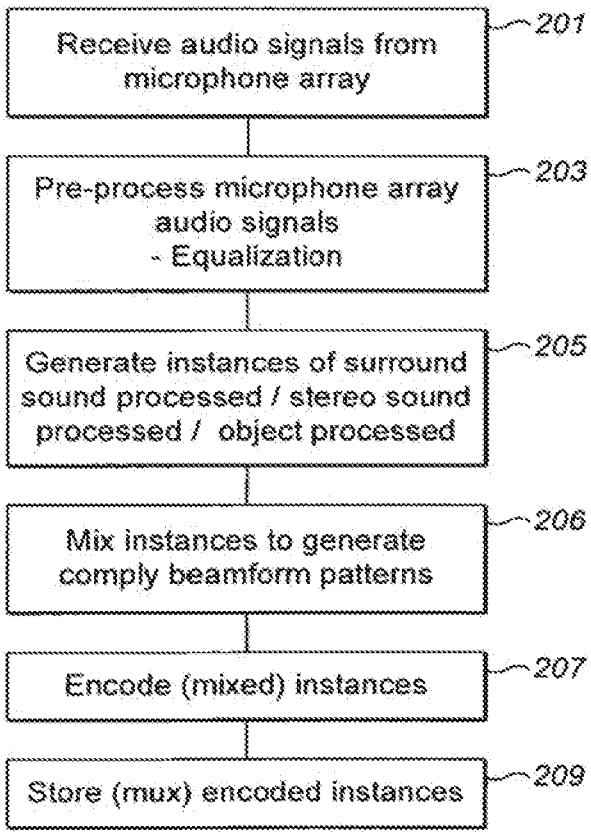


FIG. 3

Insta360
Exhibit 1002 Page 296

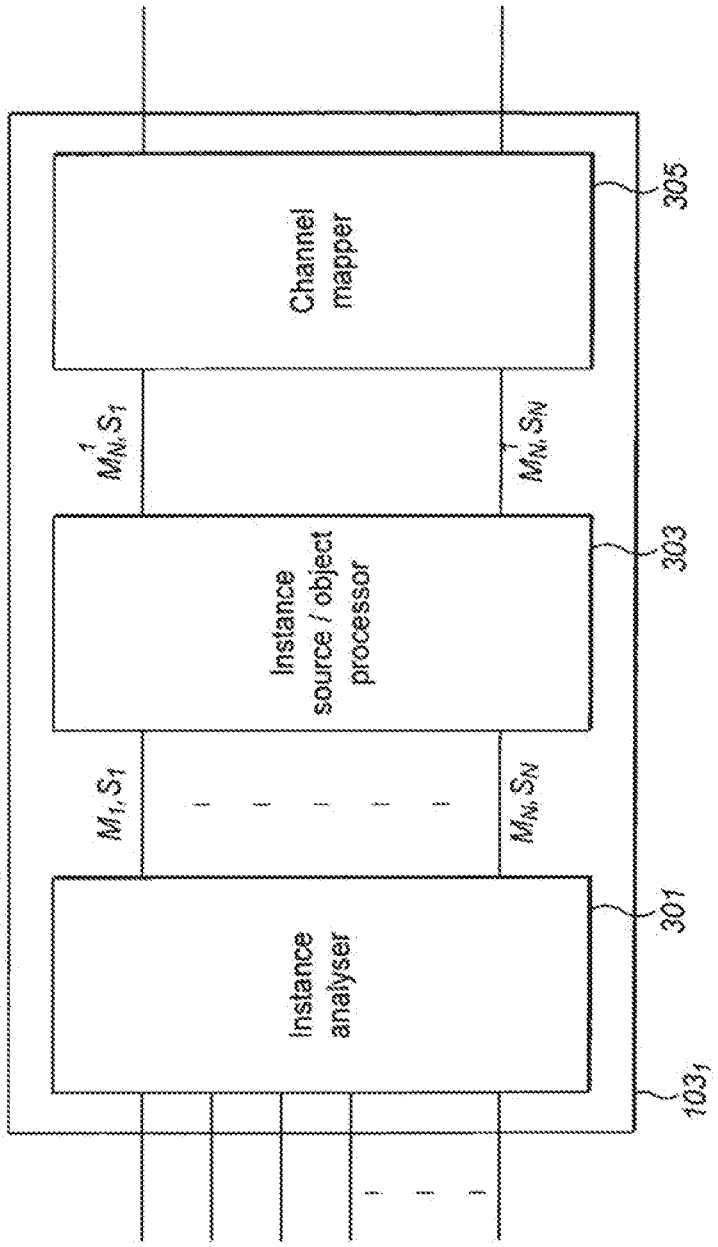


FIG. 4

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Exhibit 1002 Page 297

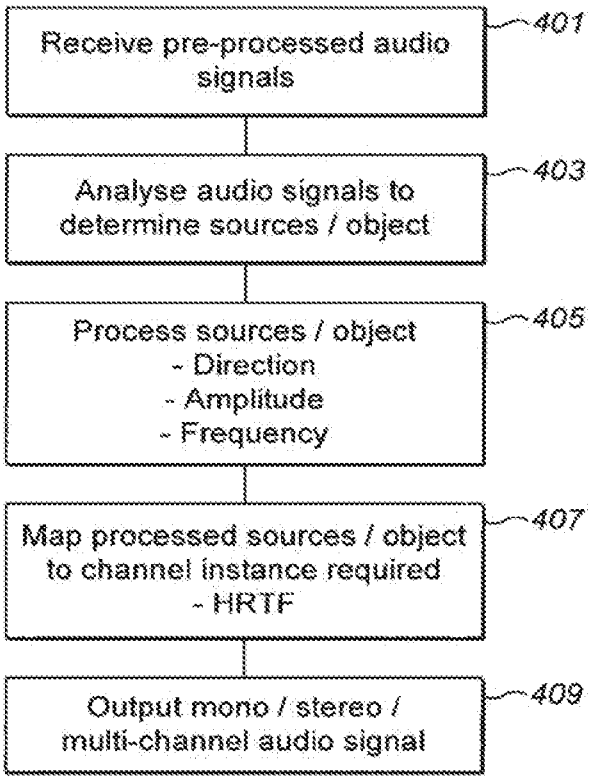


FIG. 5

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Exhibit 1002 Page 298

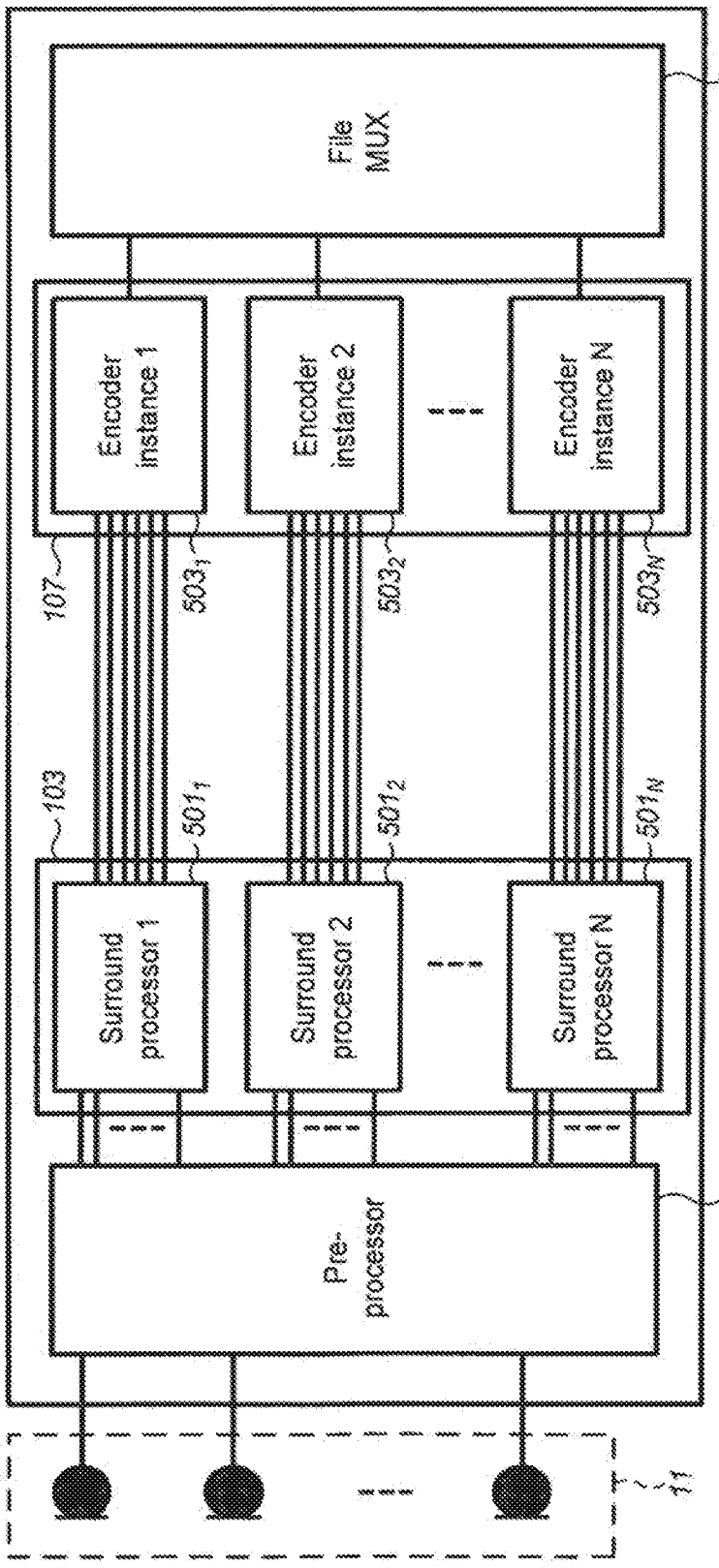

File MUX
109
Encoder instance 1
Encoder instance 2
Encoder instance N
107
503_1
503_2
503_N
103
501_1
501_2
501_N
Surround processor 1
Surround processor 2
Surround processor N
Pre-processor
101
11

FIG. 6

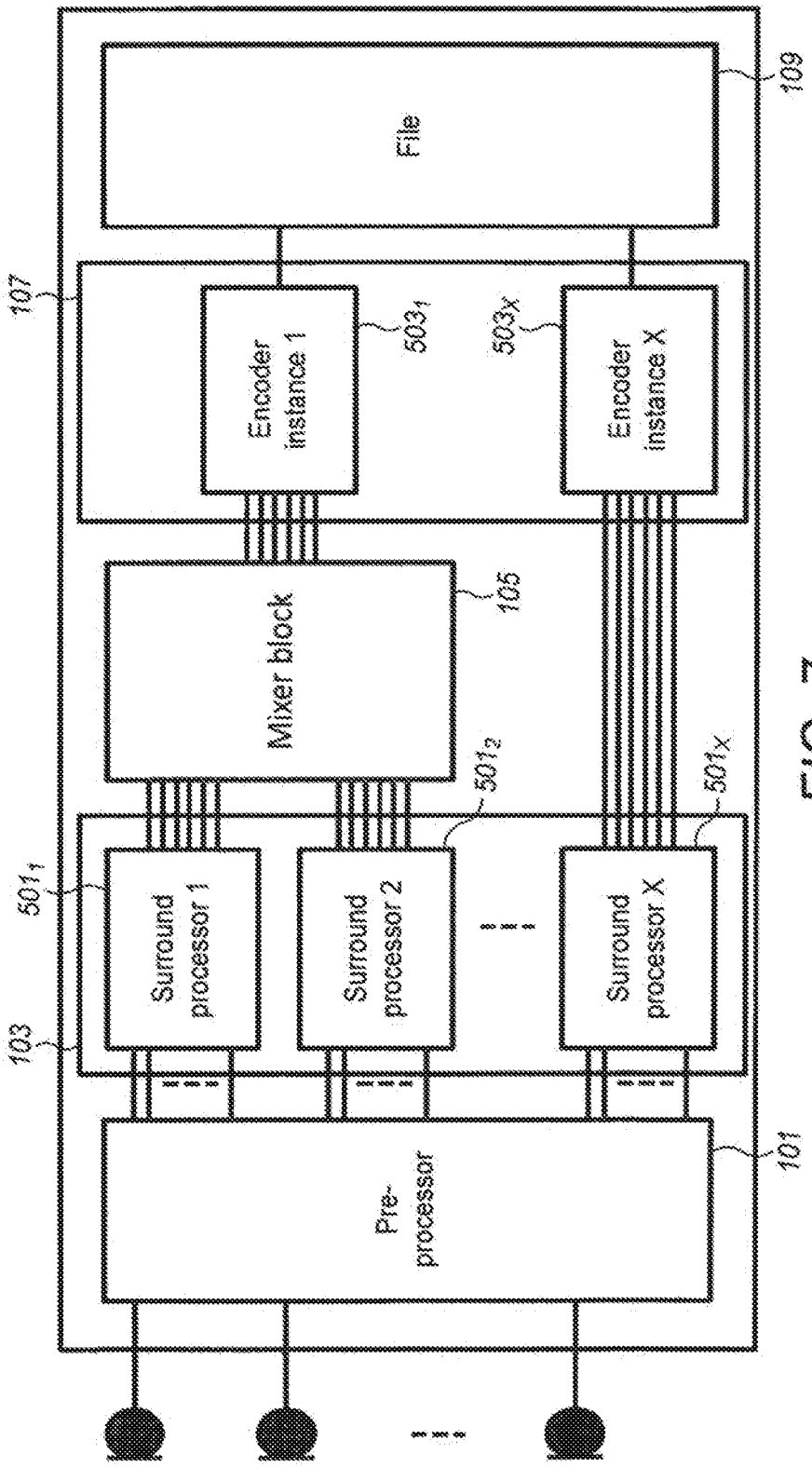


FIG. 7

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Exhibit 1002 Page 300

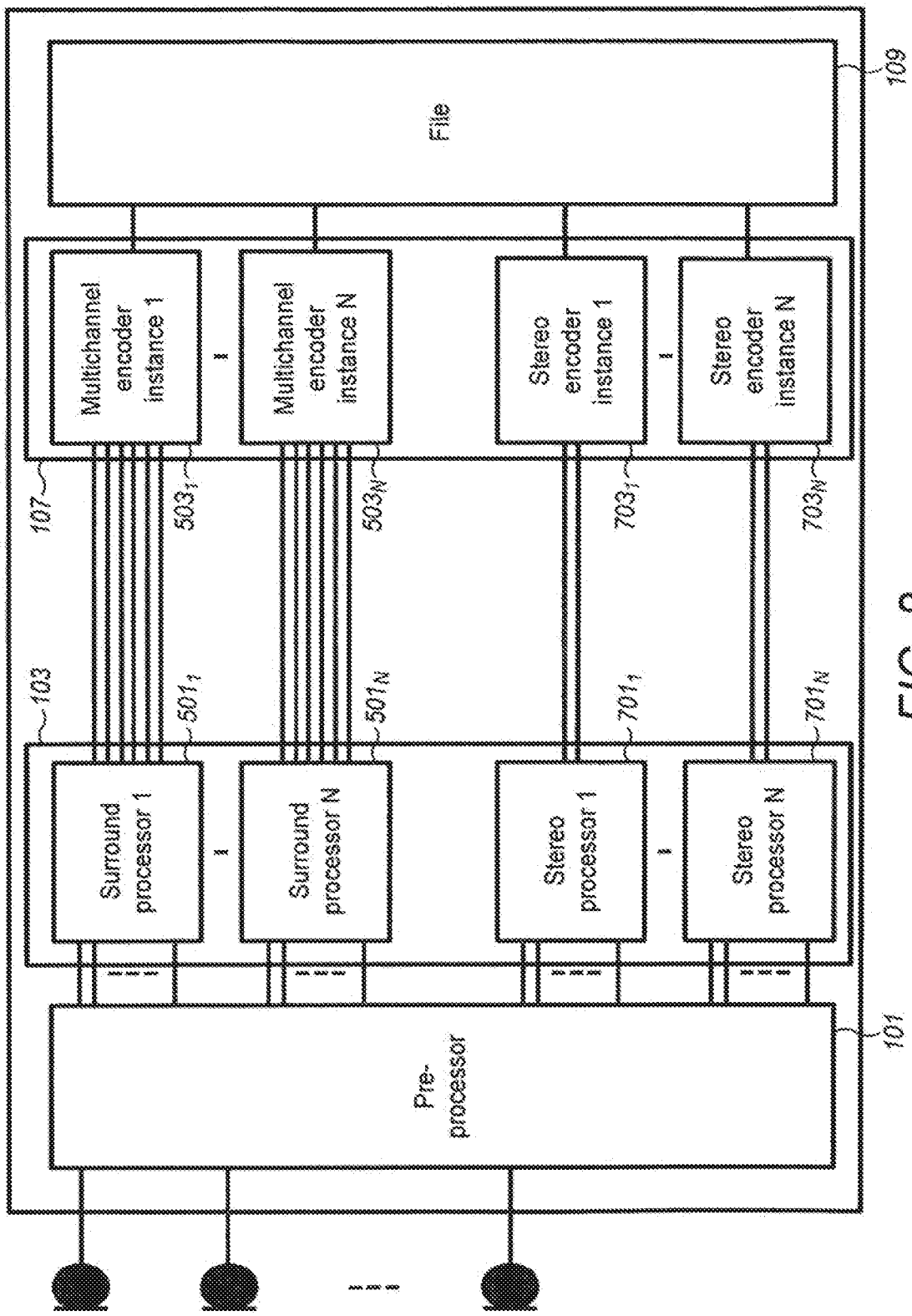


FIG. 8

Insta360
Exhibit 1002 Page 301

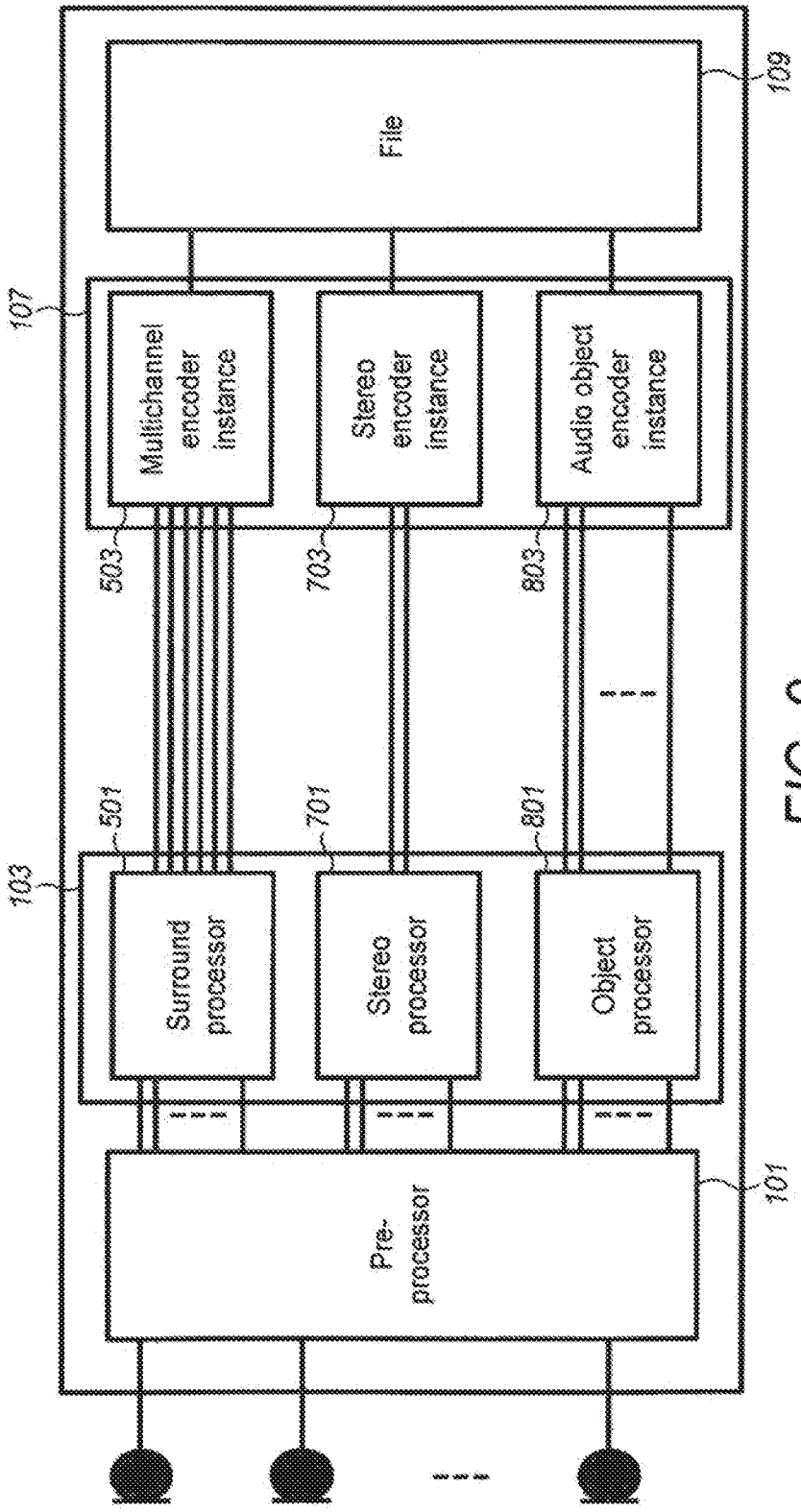


FIG. 9

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Exhibit 1002 Page 302

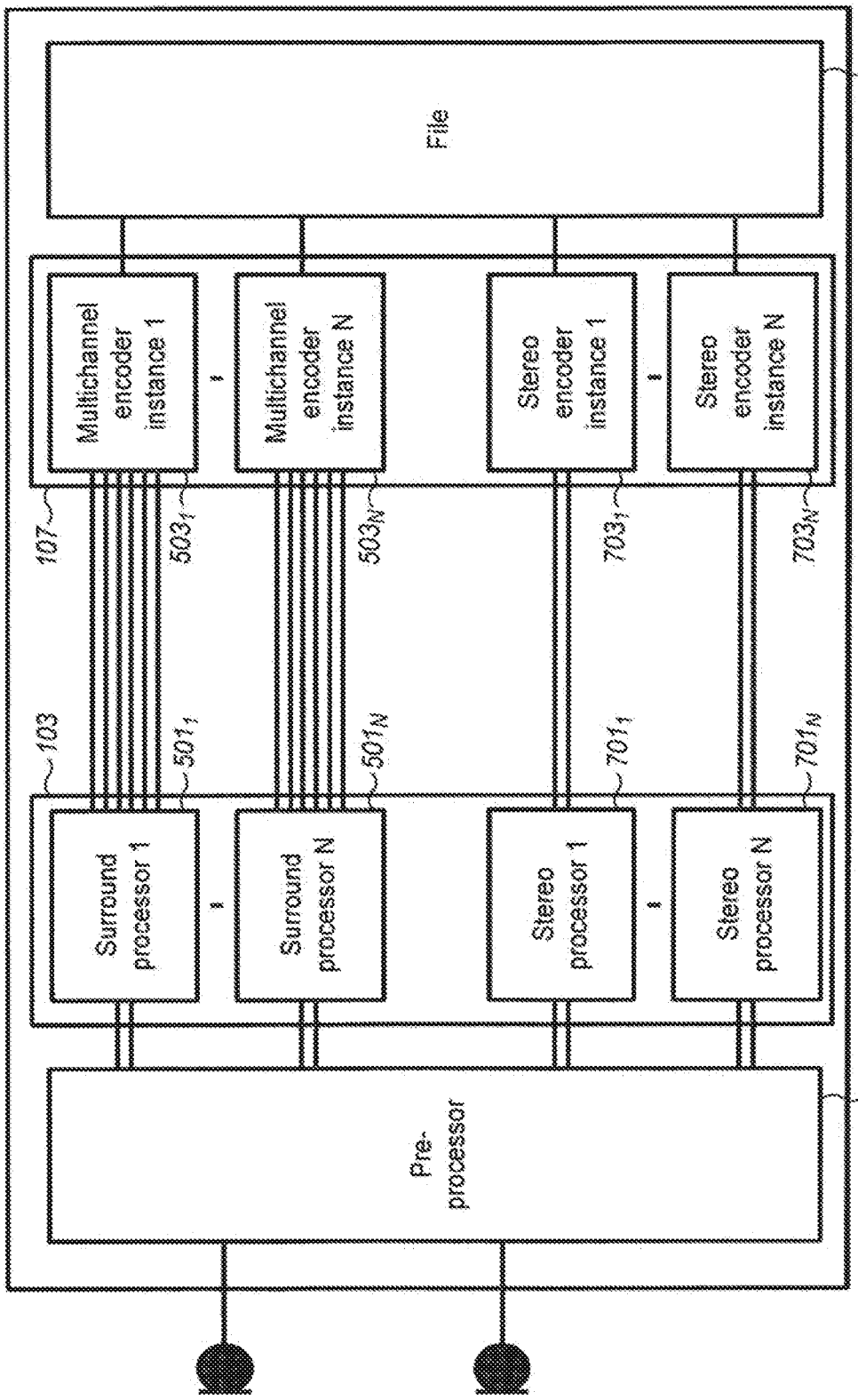

File
109
Multichannel encoder instance 1
Multichannel encoder instance N
Stereo encoder instance 1
Stereo encoder instance N
107
503_1
503_N
703_1
703_N
103
501_1
501_N
701_1
701_N
Surround processor 1
Surround processor N
Stereo processor 1
Stereo processor N
Pre-processor
101

FIG. 10

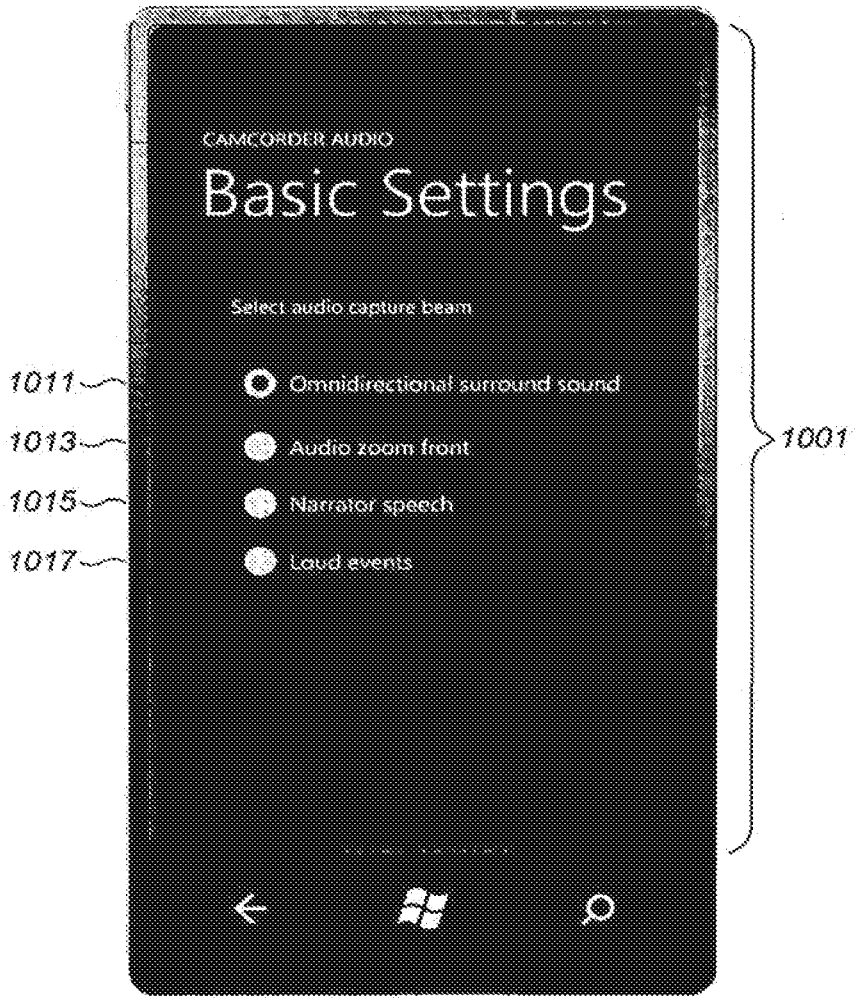

CAMCORDER AUDIO
Basic Settings
Select audio capture beam
Omnidirectional surround sound
Audio zoom front
Narrator speech
Loud events
1011
1013
1015
1017
1001

FIG. 11

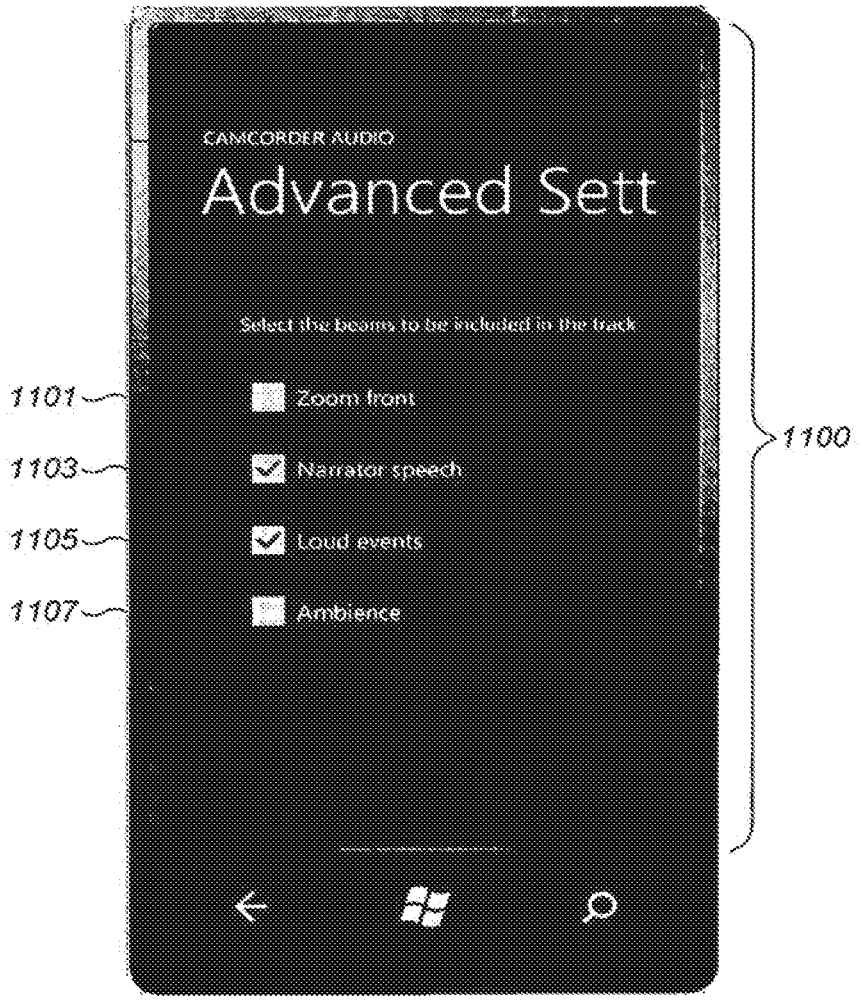

CAMCORDER AUDIO
Advanced Sett
Select the beams to be included in the track
Zoom front
Narrator speech
Loud events
Ambience
1101
1103
1105
1107
1100

FIG. 12

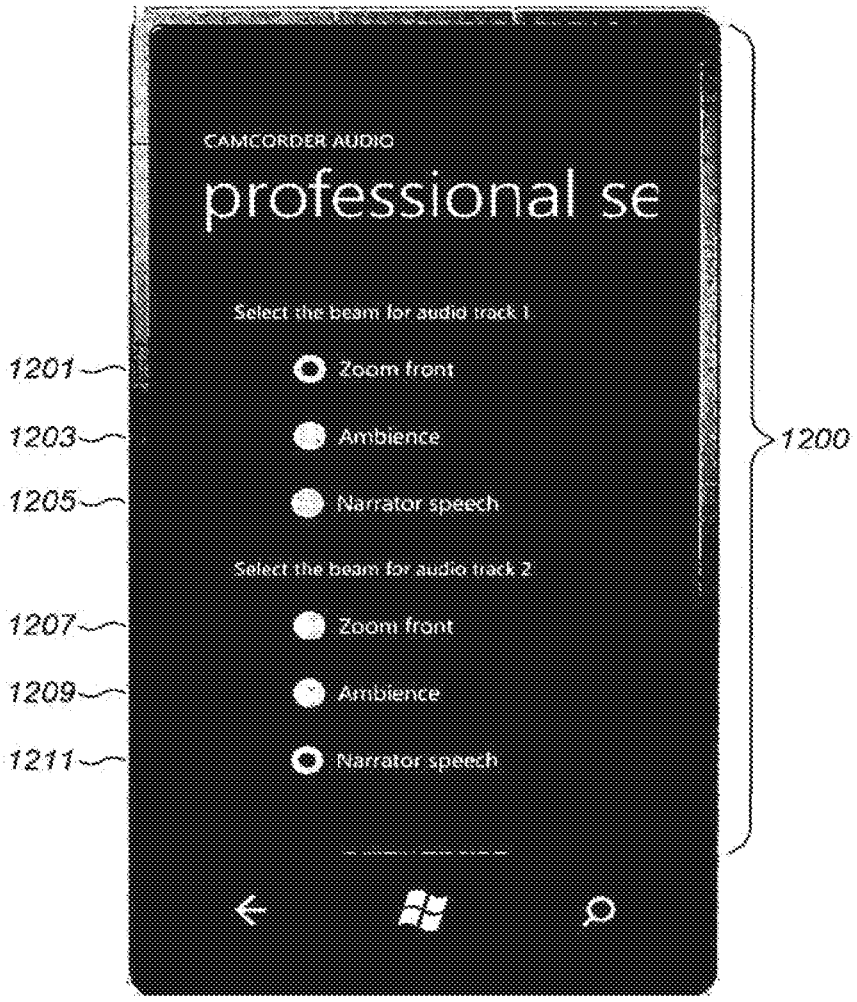


FIG. 13

Insta360
Exhibit 1002 Page 306

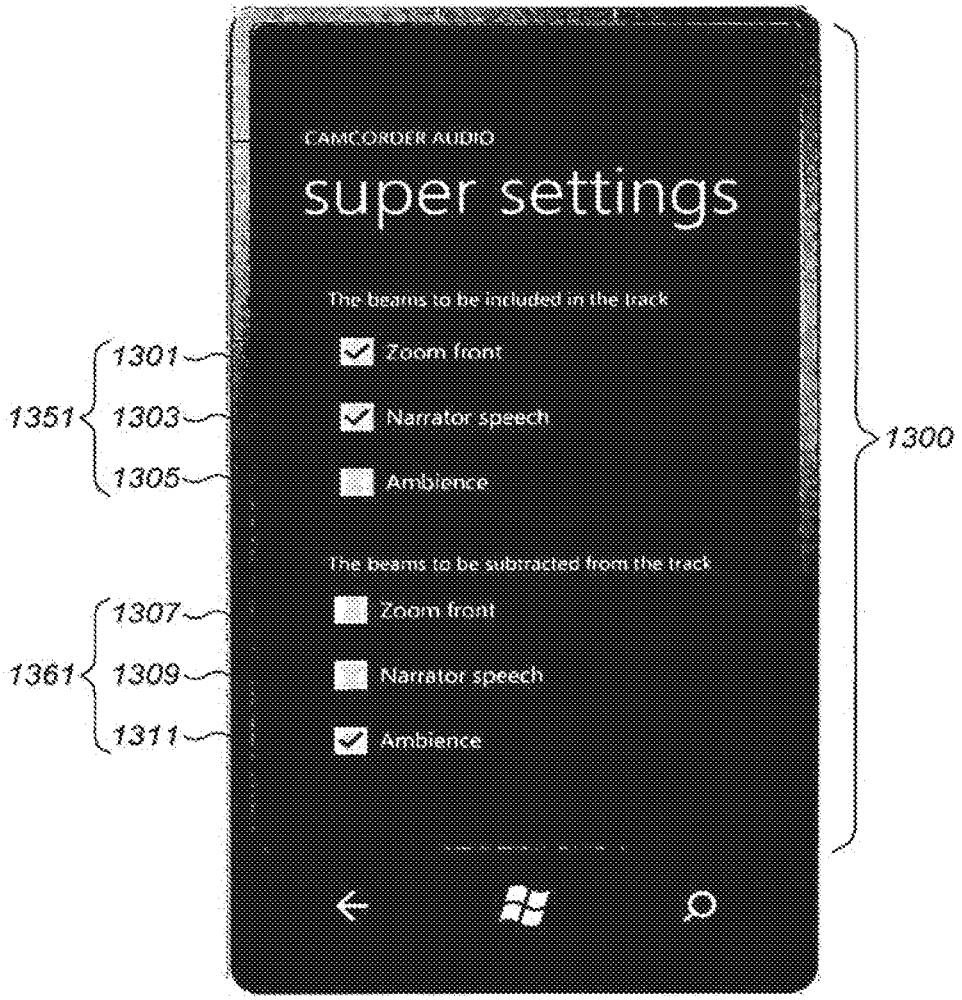


FIG. 14

Insta360
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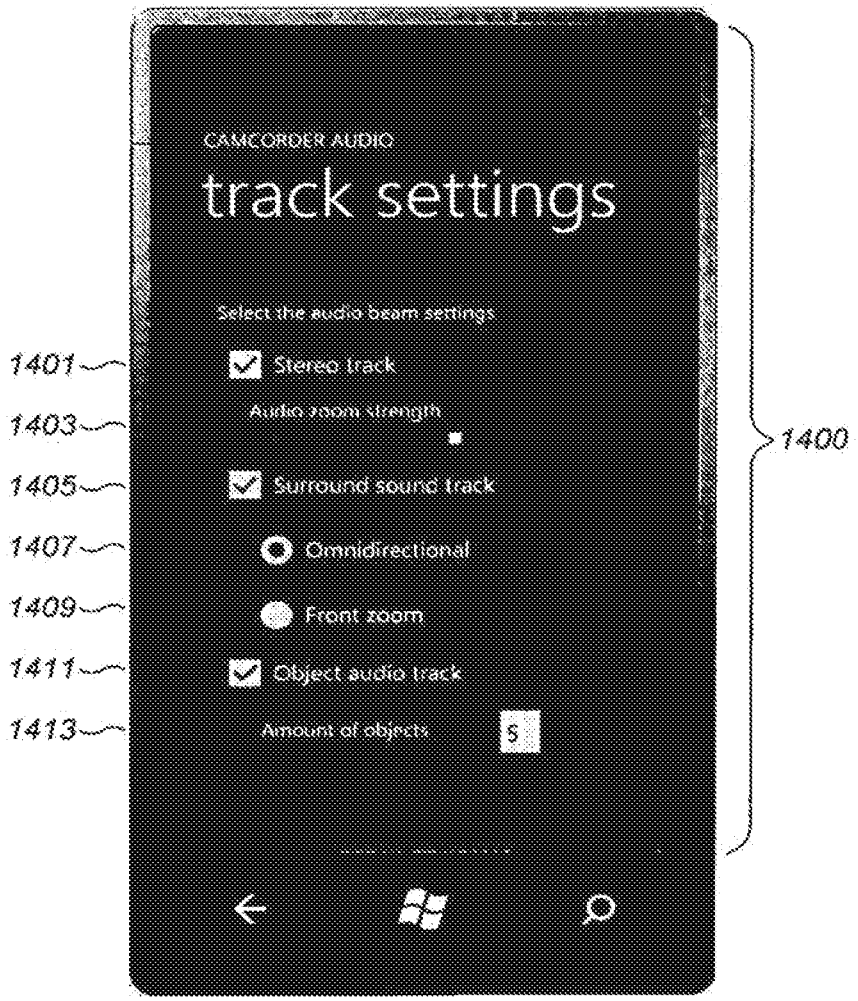


FIG. 15

Insta360
Exhibit 1002 Page 308

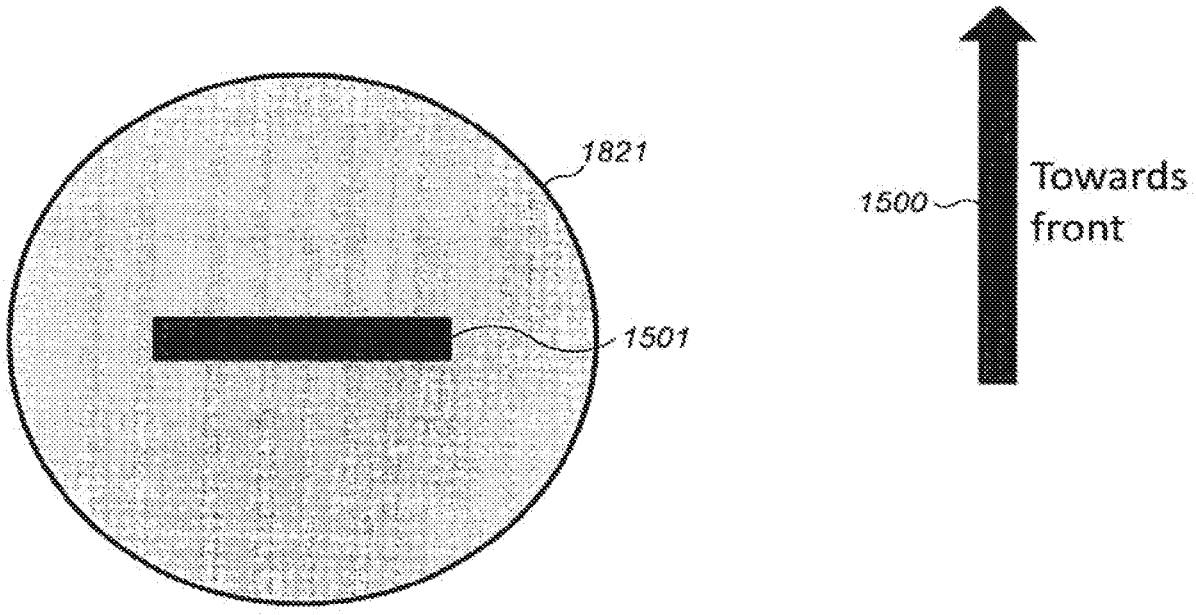


FIG. 16

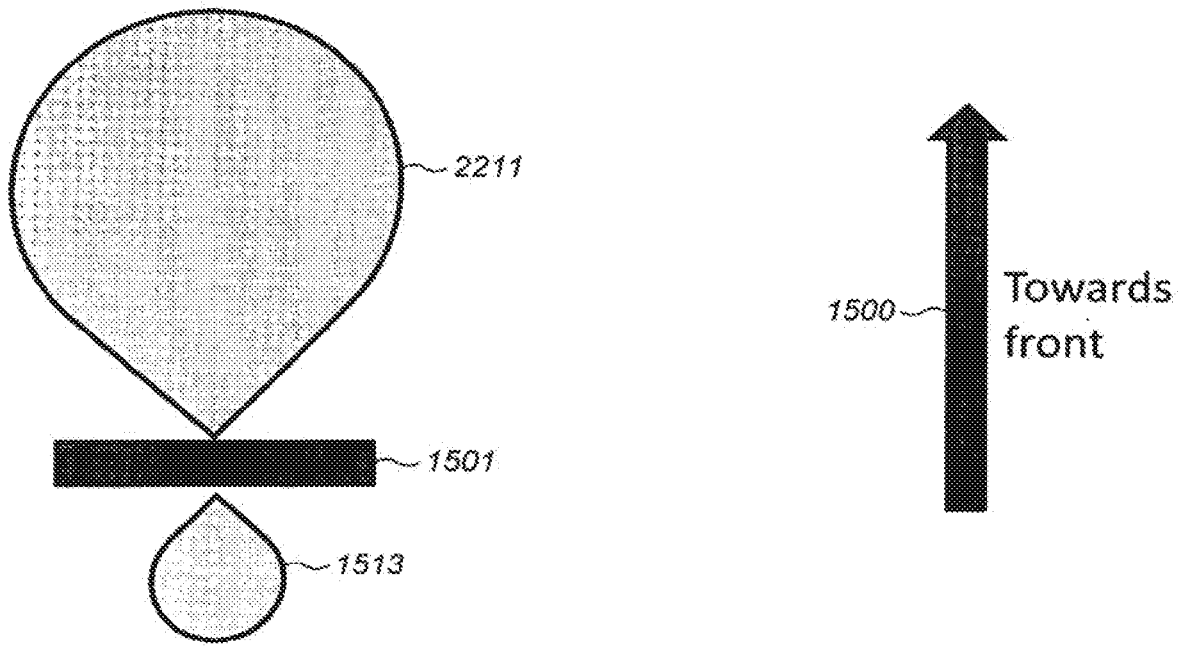


FIG. 17

Insta360
Exhibit 1002 Page 309

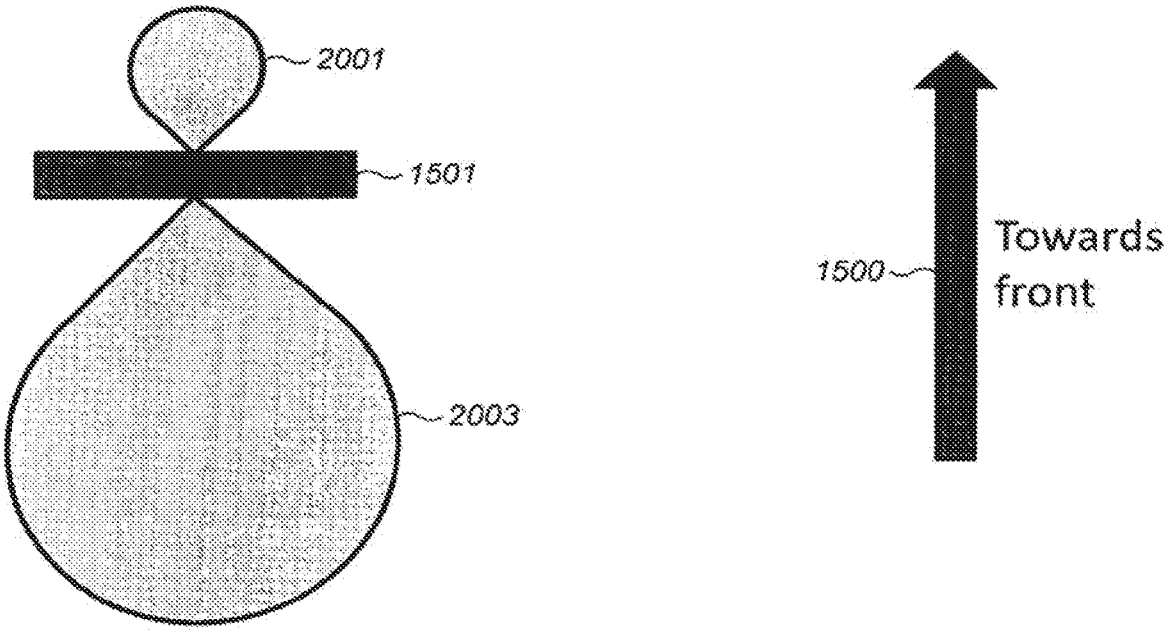


FIG. 18

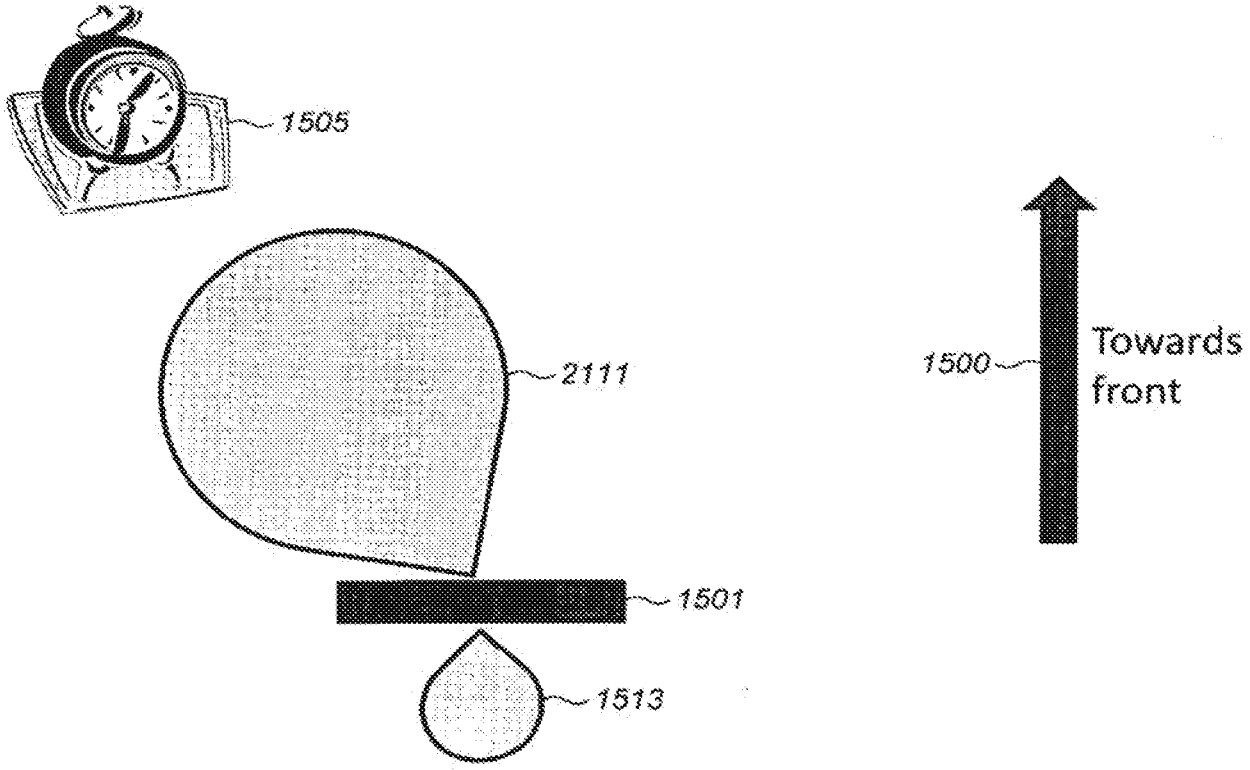


FIG. 19

Insta360
Exhibit 1002 Page 310

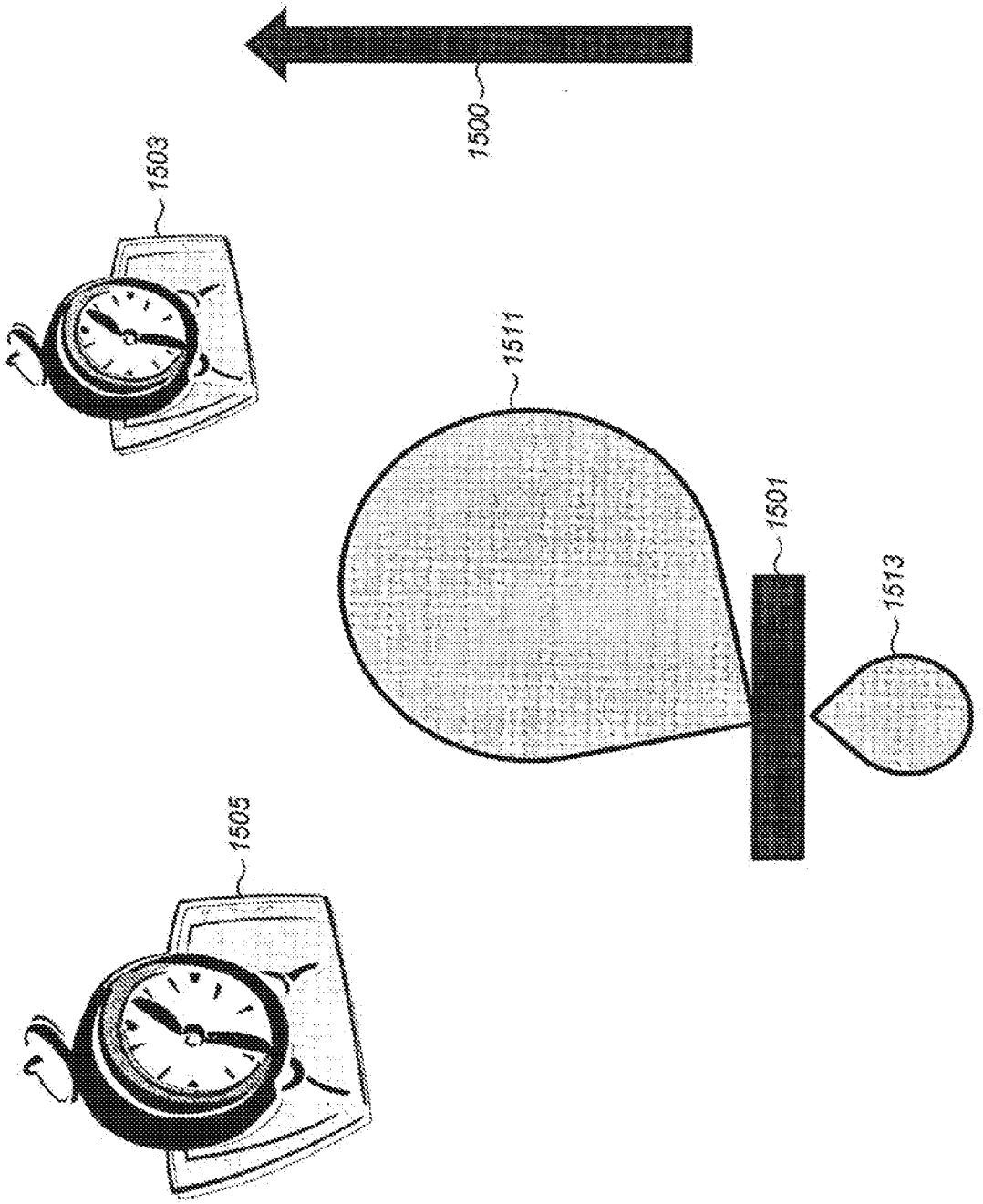


FIG. 20

Insta360
Exhibit 1002 Page 311

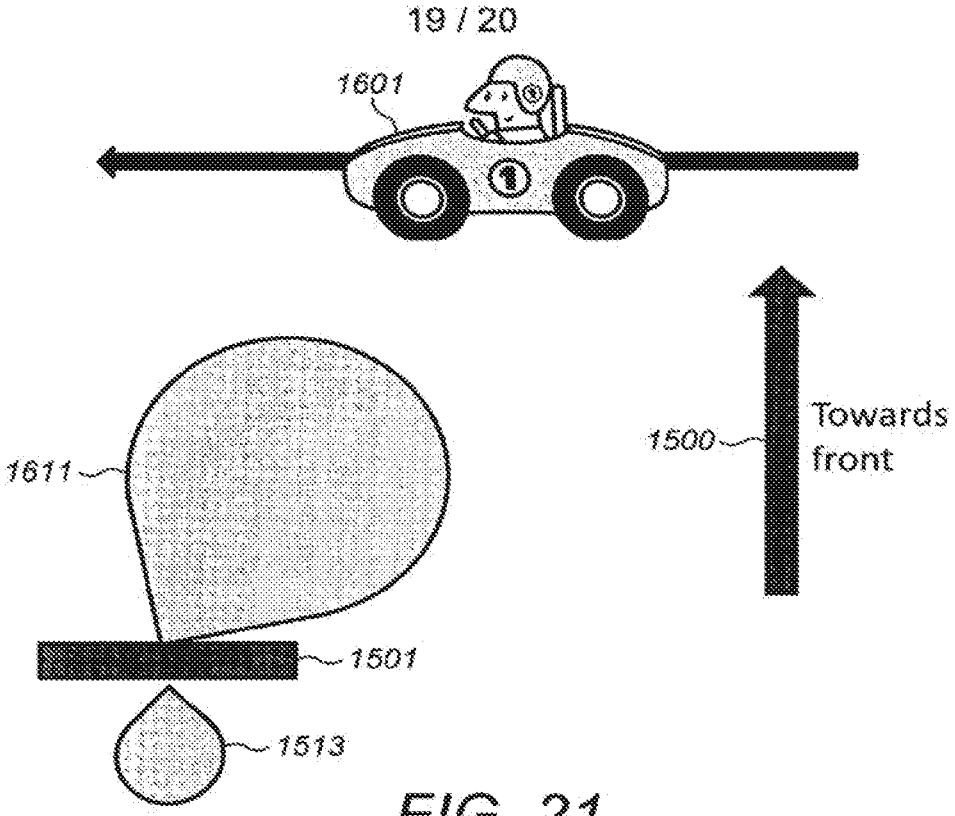


FIG. 21

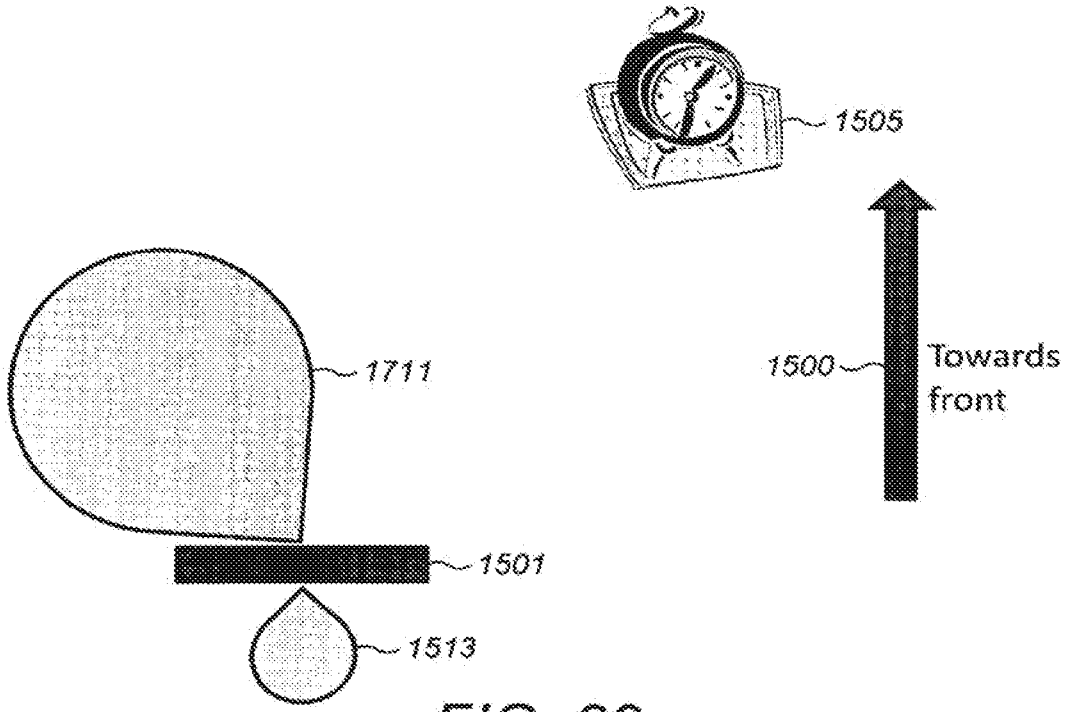


FIG. 22

Insta360
Exhibit 1002 Page 312

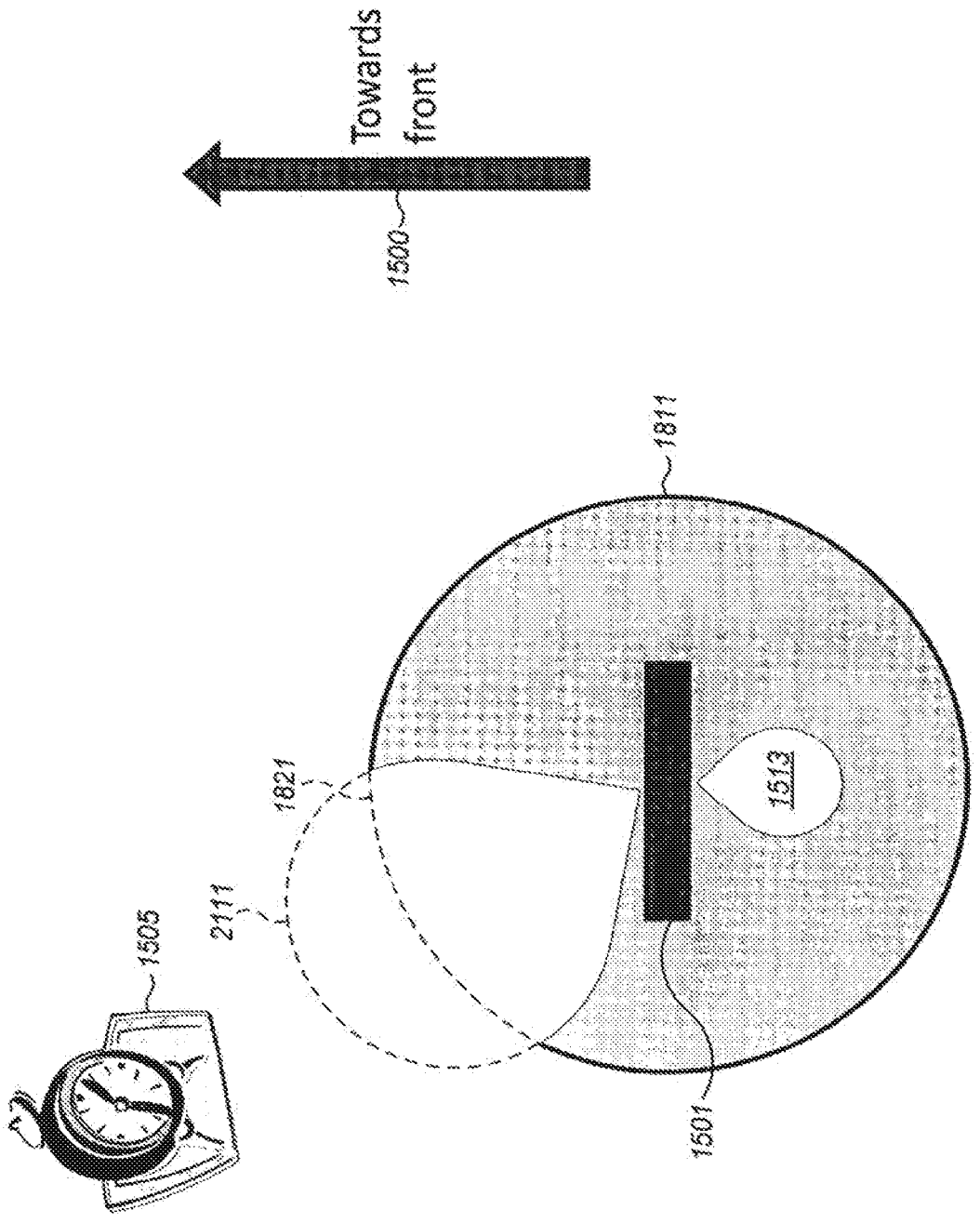


FIG. 23

Insta360
Exhibit 1002 Page 313

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

2

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

Insta360
Exhibit 1002 Page 314

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/074956

C(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)

Insta360
Exhibit 1002 Page 315

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
		JP 2008054167 A	06-03-2008
		US 2008051920 A1	28-02-2008
WO 2012031605 A1	15-03-2012	CN 103210668 A	17-07-2013
		EP 2614659 A1	17-07-2013
		JP 2013539283 A	17-10-2013
		WO 2012031605 A1	15-03-2012
EP 2146522 A1	20-01-2010	AR 072702 A1	15-09-2010
		AU 2009270526 A1	21-01-2010
		CA 2725793 A1	21-01-2010
		CN 102100088 A	15-06-2011
		CN 103354630 A	16-10-2013
		EP 2146522 A1	20-01-2010
		EP 2297978 A1	23-03-2011
		ES 2453074 T3	03-04-2014
		JP 5467105 B2	09-04-2014
		JP 2011528200 A	10-11-2011
		KR 20110037974 A	13-04-2011
		KR 20120131210 A	04-12-2012
		RU 2010150046 A	20-06-2012
		TW 201010450 A	01-03-2010
		TW 201404189 A	16-01-2014
		US 2010014692 A1	21-01-2010
		US 2012308049 A1	06-12-2012
		WO 2010006719 A1	21-01-2010
US 5477270 A	19-12-1995	CN 1112329 A	22-11-1995
		DE 4403723 A1	18-08-1994
		GB 2274958 A	10-08-1994
		JP 3495073 B2	09-02-2004
		JP H06319195 A	15-11-1994
		US 5477270 A	19-12-1995
US 2011013075 A1	20-01-2011	NONE	

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. ☒ 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.

☒ No protest accompanied the payment of additional search fees.

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.

---

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.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

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)

To:
Basile, Jr. Andrew R.
GoPro Inc.
C/o Young Basile
3001 W. Big Beaver, Suite 624
Troy MI 48084
ETATS-UNIS D'AMERIQUE

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	US 2013/329132 A1 (TICO MARIUS [US] ET AL) 12 December 2013 (2013-12-12)	1-7
A	paragraphs [0024] - [0042]; claim 9; figure 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 1002 Page 321

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

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.

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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
16/713,798	12/13/2019		1920	46DG-026085	22	2

CONFIRMATION NO. 2783

FILING RECEIPT

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

OC000000113779897

Date Mailed: 01/09/2020

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)

Cesar Douady, Les Molieres, FRANCE;
Thomas Derbanne, Paris, 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 16/587,811 09/30/2019
which is a CON of 16/548,549 08/22/2019 PAT 10536643
which is a CON of 16/392,501 04/23/2019 PAT 10432864
which claims benefit of 62/733,237 09/19/2018

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: 01/07/2020
The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 16/713,798**
Projected Publication Date: 04/16/2020
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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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 16/713,798

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))	22 minus 20 =	* 2			OR	x 100 =	200
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	1920

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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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):

[ ] United States application or PCT international application number _____ filed on _____.

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

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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: **César Douady**

Signature: DocuSigned by: César Douady DBF20CD97938400...

Date: 4/16/2019

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

Signature: DocuSigned by: Thomas Derbanne E789FFC70E624AE...

Date: 4/10/2019

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

Signature: DocuSigned by: Maxim Karpushin 0A61811B6B554D0...

Date: 4/10/2019

DocuSign Envelope ID: D897F95C-8079-484E-8BA3-E86F16341F10

ASSIGNEE hereby agrees to the foregoing terms of this assignment.

GOPRO, INC.

Date: 4/16/2019

Signature: DocuSigned by: Tyler Gee 0FB2304D7AB04F4...

By: Tyler J. Gee

Its: Associate General Counsel, Head of IP

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. Visual content having a field of view may be captured by an image capture device during a capture duration. Visual information defining the visual content, position information characterizing rotational positions of the image capture device at different moments within the capture duration, and/or other information may be obtained. A trajectory of the image capture device during the capture duration may be determined based on the position information and/or other information. The trajectory may reflect the rotational positions of the image capture device at different moments within the capture duration. The 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 smoothed trajectory of the image capture device may be determined based on a subsequent portion of the trajectory and/or other information

such that a portion of the smoothed trajectory corresponding to the first portion of the trajectory may be determined based on the second portion of the trajectory. The smoothed trajectory may have smoother changes in the rotational positions of the image capture device than the trajectory. A viewing window for the visual content may be determined based on the smoothed trajectory of the housing and/or other information. The viewing window may define one or more extents of the visual content. Stabilized visual content of a video may be generated based on the viewing window and/or other information. The stabilized visual content may include a punchout of the extent(s) of the visual content within the viewing window.

(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 visual information defining visual content, information relating to visual content, position information characterizing rotational positions of an image capture device, information relating to rotational positions of an image capture device, information relating to a trajectory of an image capture device, information relating to a smoothed trajectory of an image capture device, information relating to a field of view of an optical element, information relating to a viewing window, information relating to stabilized visual content, information relating to a punchout of visual content, and/or other information. In some implementations, the system may include one or more optical elements, 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 optical element(s), the image sensor(s), and/or the position sensor(s) of the system may be carried by the housing of

an image capture device. The housing may carry other components, such as the processor(s) and/or the electronic storage.

(06) An optical element may be configured to guide light within a field of view to an image sensor. The field of view may be larger than a size of the punchout/viewing window used to generate stabilized visual content. An image sensor may be configured to generate a visual output signal based on light that becomes incident thereon during a capture duration. The visual output signal may convey visual information that defines visual content having the field of view.

(07) 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 rotational positions of the housing at different moments within the capture duration. In some implementations, the position information may further characterize translational 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 visual information.

(08) 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 a trajectory component, a smoothed trajectory component, a viewing window component, a generation component, and/or other computer program components.

(09) The trajectory component may be configured to determine a trajectory of the housing during the capture duration based on the position information and/or other information. The trajectory may reflect rotational positions of the housing at different moments within the capture duration. In some implementations, the trajectory may further reflect translational positions of the housing at different moments within the capture duration. The 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.

(10) The smoothed trajectory component may be configured to determine a smoothed trajectory of the housing based on a subsequent portion of the trajectory and/or other information. The smoothed trajectory may be determined 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. The smoothed trajectory may have smoother changes in the rotational positions of the housing than the trajectory. In some implementations, the smoothed trajectory may have smoother changes in the translational positions of the housing than the trajectory.

(11) In some implementations, the smoothed trajectory having smoother changes in the rotational positions of the housing than the trajectory may be characterized by the smoothed trajectory having less jitters in the rotational positions of the housing than the trajectory. In some implementations, the smoothed trajectory having smoother changes in the translational positions of the housing than the trajectory may be characterized by the smoothed trajectory having less jitters in the translational positions of the housing than the trajectory.

(12) In some implementations, the smoothed trajectory having smoother changes in the rotational positions of the housing than the trajectory may include high frequency changes in the rotational positions of the housing in the trajectory being removed from the smoothed trajectory. In some implementations, the smoothed trajectory having smoother changes in the translational positions of the housing than the trajectory may include high frequency changes in the translational positions of the housing in the trajectory being removed from the smoothed trajectory.

(13) In some implementations, an extent to which the smoothed trajectory of the housing deviates from the trajectory of the housing may depend on an amount of rotational motion and/or translational motion experienced by the housing during the capture duration, an exposure time with which the visual content is captured, and/or other information.

(14) In some implementations, the determination of the smoothed trajectory of the housing based on the subsequent portion of the trajectory may include: (1) obtaining a rotational position of the housing at the first moment within the capture duration, the first moment being a point in time and corresponding to a video frame of the visual content captured at the point in time within the capture duration; (2) obtaining rotational positions of the housing at the second moment within the capture duration, the second moment being a duration of time subsequent to the point in time within the capture duration; and (3) determining a corresponding rotational position of the housing within the smoothed trajectory at the first moment based on the rotational position of the housing at the point in time, the rotational positions of the housing during the duration of time subsequent to the point in time, and/or other information. Placement of the viewing

window for the visual content with respect to the field of view of the visual content captured at the first moment may be determined based on the corresponding rotational position of the housing within the smoothed trajectory at the first moment and/or other information.

(15) In some implementations, the determination of the smoothed trajectory of the housing based on the subsequent portion of the trajectory may further include: (1) determining whether the placement of the viewing window for the visual content at the first moment results in one or more portions of the viewing window exceeding the field of view of the visual content; and (2) responsive to a determination that the portion(s) of the viewing window for the visual content at the first moment exceeds the field of view of the visual content, adjusting the corresponding rotational position of the housing within the smoothed trajectory at the first moment such that the viewing window for the visual content at the first moment does not exceed the field of view of the visual content.

(16) In some implementations, the corresponding rotational position of the housing within the smoothed trajectory at the first moment may be initially determined based on a combination of the rotational position of the housing at the first moment and an estimate of the corresponding rotational position of the housing, and/or other information. The estimate of the corresponding rotational position of the housing may be determined based on minimization of a combination of a rotational velocity of the housing and a rotational acceleration of the housing, and/or other information.

(17) The viewing window component may be configured to determine a viewing window for the visual content based on the smoothed trajectory of the housing and/or

other information. The viewing window may define one or more extents of the visual content.

(18) The generation component may be configured to generate stabilized visual content of a video based on the viewing window and/or other information. The stabilized visual content may include a punchout of the extent(s) of the visual content within the viewing window.

(19) In some implementations, at least one of the processor(s) may be a remote processor located remotely from the housing of the image capture device. Generation of the stabilized visual content may be performed by the remote processor post capture of the visual content.

(20) 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

(21) FIG. 1 illustrates an example system that stabilizes videos.

(22) FIG. 2 illustrates an example method for stabilizing videos.

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

(24) FIG. 4 illustrates an example trajectory of rotational positions of an image capture device within a capture duration.

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

(26) FIG. 5B illustrates an example filtered trajectory.

(27) FIG. 5C illustrates an example smoothed trajectory.

(28) FIG. 6A illustrates an example orientation of a viewing window with respect to an image.

(29) FIG. 6B illustrates example orientations of a viewing window with respect to an image.

(30) FIG. 7 illustrates an example plot of smoothing values.

DETAILED DESCRIPTION

(31) 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. Visual content having a field of view may be captured by an image capture device during a capture duration. Visual information defining the visual content,

position information characterizing rotational positions of the image capture device at different moments within the capture duration, and/or other information may be obtained. Visual information, position information, and/or other information may be obtained by the processor 11. A trajectory of the image capture device during the capture duration may be determined based on the position information and/or other information. The trajectory may reflect the rotational positions of the image capture device at different moments within the capture duration. The 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 smoothed trajectory of the image capture device may be determined based on a subsequent portion of the trajectory and/or other information such that a portion of the smoothed trajectory corresponding to the first portion of the trajectory may be determined based on the second portion of the trajectory. The smoothed trajectory may have smoother changes in the rotational positions of the image capture device than the trajectory. A viewing window for the visual content may be determined based on the smoothed trajectory of the housing and/or other information. The viewing window may define one or more extents of the visual content. Stabilized visual content of a video may be generated based on the viewing window and/or other information. The stabilized visual content may include a punchout of the extent(s) of the visual content within the viewing window.

(32) 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 visual content, visual content information defining visual content, information relating to image capture device, information relating to optical element, information relating to image sensor, information relating to position sensor, position information characterizing rotational positions of the image capture device, information relating to rotational positions of the image capture device, information relating to trajectory of the image capture device, information relating to smoothed trajectory of the image capture device, information relating to field of view of an optical element, information relating to a viewing window, information relating to stabilized visual content, information relating to a punchout of visual content, and/or other information.

(33) 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 a trajectory component 102, a smoothed trajectory component 104, a viewing window component 106, a generation component 108, and/or other computer program components.

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

(35) 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. 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, the electronic storage 13, and/or one or more optical elements. References to a housing of an image capture device may refer to the image capture device, and vice versa. For example, references to position/motion of a housing of an image capture device may refer to position/motion of the image capture device, and vice versa.

(36) 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.

(37) 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 have a field of view 305. The optical element 304 may be configured to guide light within the field of view 305 to the image sensor 306. The 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 field of view 305 of the optical element 304 may refer to the extent of the observable world that is seen through the optical element 304. The field of view 305 of the optical element 304 may include one or more angles (e.g., vertical angle, horizontal angle, diagonal angle) at which light is received and passed on by the optical element 304 to the image sensor 306. In some implementations, the field of view 305 may be greater than or equal to

180-degrees. In some implementations, the field of view 305 may be smaller than or equal to 180-degrees.

(38) The field of view 305 may be larger than a size of the punchout/viewing window used to generate stabilized visual content. Portions of the visual content captured from light within the field of view 305 may be presented on a display and/or used to generate a video. The portions of the visual content presented on the display/used to generate a video may include those portions of the visual content within a viewing window. A viewing window may define extents of the visual content (e.g., of image(s)/video frame(s)) to be included within a punchout. The viewing window may be determined so that the visual content within the presentation/generated video does not appear shaky/jerky or appears less shaky/jerky. For example, the shape, size, and/or the location of the viewing window within the visual content may be determined to compensate for motion of the image capture device 302 during capture such that the video appears to have been captured from an image capture device 302 with less motion. That is, the visual content captured by the image capture device 302 may be cropped to generate stabilized visual content.

(39) 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 visual content of one or more images and/or one or more video frames of a video. For example, the image

sensor 306 may be configured to generate a visual output signal based on light that becomes incident thereon during a capture duration. The visual output signal may convey visual information that defines visual content having the field of view.

(40) The position sensor 308 may include sensor(s) that measures experienced positions and/or motions. The position sensor 308 may convert experienced positions and/or 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 and/or motions of the position sensor 308 and/or device(s) carrying the position sensor 308, such as the image capture device 302 and/or the housing 312.

(41) 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.

(42) 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 visual content/images/videos generated by the image sensor 306. Use of visual content/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.

(43) 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).

(44) 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. The processor 310 may include and/or perform one or more functionalities of the processor 11 shown in FIG. 1.

(45) For example, the processor 310 may use the position information to stabilize visual content captured through the optical element 304 and/or the image sensor 306. Visual content may be captured by the image capture device 302 during a capture duration. The trajectory (path, progression) of rotational and/or translational positions experienced by the image capture device 302 during the capture duration may be determined based on the position information and/or other information. A smoothed trajectory of the image capture device 302 may be determined based on a look-ahead of the trajectory and/or other information. A look-ahead of the trajectory may include use of a subsequent portion of the trajectory to determine a preceding portion of the smoothed trajectory. For example, a portion of the smoothed trajectory corresponding to a point or a duration within the capture duration may be determined based on a portion of the trajectory corresponding to a future point/duration ahead of the point/duration within the capture duration. For instance, a portion of the smoothed

trajectory corresponding to a point (a video frame) within the capture duration may be determined based on a portion of the trajectory corresponding to a one-second duration subsequent to/ahead of the point within the capture duration.

(46) The smoothed trajectory may be used to determine a viewing window for stabilization of the visual content. The viewing window may define the extent(s) of the visual content that is to be punched-out to stabilize the visual content. The stabilized visual content may include cropped extents of the visual content, with the viewing window defining the extents of the visual content that is cropped out. The extent to which the viewing window may be moved within the visual content may be referred to as stabilization margin. The stabilization margin may specify how much the crop may move while remaining wholly within the field of view of the visual content.

(47) Such stabilization of visual content may preserve intentional motion experienced by the image capture device 302 during the capture duration. Intentional motion may refer to the motion that was intended by the user of the image capture device 302. Intentional motion may include meaningful phenomenon related to video semantics, which may express what the user actually wanted to capture. For example, intentional motion may include a forward motion to follow an object of interest, a panning motion to shoot a wide view of a scenery, and/or other motion. Unintentional may refer to motion that was not intended by the user of the image capture device 304. Unintentional motion may result in noise within the captured visual content, such as motion of the visual content due unintended motion of the image capture device 304 (e.g., caused by shaking hands, vibrations, bumps).

(48) Intentional motion may be characterized by lower frequency motion than unintentional motion. Unintentional motion may be characterized by higher frequency motion (e.g., jitter, shake) than intentional motion. To identify intentional motion, which is characterized by low frequencies, a sufficiently long temporal horizon of experienced motion may need to be used. Thus, to stabilize visual content, a subsequent portion of the trajectory is used to determine the smoothed trajectory. Longer intervals of the temporal horizon may enable better approximation of the intentional motion while causing longer delays (longer wait to determine smoothed trajectory).

(49) The smoothed trajectory (crop trajectory) may be determined based on minimization of a value, a score, and/or a metric that expresses the amount of high frequencies. The value/score/metric may be determined based on an objective function that consists of groups of terms. For example, the objective function may include two groups of terms, where one term expresses the L2-norm of interframe angular velocity and the other term expresses the angular acceleration. One or more of the terms may be weighted by one or more constant. The constants may determine the amount of contribution of individual terms to the objective function. From signal processing perspective, the two terms may correspond to output power of two high-pass filters.

(50) The values of the smoothed trajectory over the capture duration may include values that minimize the value/score/metric expressing the amount of high frequencies while respecting a crop constraint. The crop constraint may require the viewing window for punchout of the visual content to remain within the field of view of the visual content. The viewing window (determined based on the smoothed trajectory) may not extend beyond the captured extents of the visual content.

(51) In some implementations, iterative minimization may be used to determine the smoothed trajectory. The iterative minimization may include iterations of two steps that alters the latest estimate: (1) an update step that updates the current estimate regardless of any constraint(s) in a way that the value of the objective function decreases; and (2) a projection step that applies the constraint(s)—the current estimate is tested on whether the constraint(s) are satisfied (e.g., whether the viewing window for punchout of the visual content remains within the field of view of the visual content), and the current estimate is re-projected if the constraint(s) are not satisfied (e.g., the viewing window extends beyond the field of view of the visual content).

(52) The stabilization of the visual content may include use of a trajectory retrieval algorithm and a stabilization algorithm. The input to the trajectory retrieval algorithm may include the trajectory experienced by the image capture device 302 (e.g., rotational positions when capturing video frames), a bootstrap trajectory, a fixed past, number(s) of iterations to be performed, and/or other information. The output of the trajectory retrieval algorithm may include the smoothed trajectory (e.g., virtual/actual rotational positions to be used to determine punchouts of the video frames) and/or other information.

(53) The trajectory retrieval algorithm may include one or more of the following steps. The projection may be prepared by copying the input trajectory into a projection buffer. Bootstrap may be obtained and padded if it is shorter than a given length. The bootstrap may be used as the current/initial guess of the smoothed trajectory. If there is no fixed past, the bootstrap may be extrapolated on the left using the first sample. Otherwise, the bootstrap may be extrapolated on the right using the last sample. The

trajectory may be smoothed using an iterative approach. The trajectory may be smoothed using a fine scale approach and a coarse approach. For example, the trajectory may be smoothed using a fine scale approach to smooth the trajectory on a small scale, and then the smoothed trajectory may be checked to determine whether the crop constraint is satisfied. If the crop constraint is not satisfied, projection may be performed, and the smoothing of the trajectory may be changed so that the crop constraint is satisfied. The fine scale smoothing may be iterated a number of times, and after the iterations of the fine scale smoothing, the current guess as to the smoothed trajectory may be subsampled. Then the trajectory may be smoothed using a coarse scale approach to smooth the trajectory on a larger scale. The coarse scale smoothing may be iterated a number of times, and after the iterations of the coarse scale smoothing, the subsampled current guess as to the smoothed trajectory may be upsampled. Then the trajectory may be smoothed again using a fine scale approach. The iterative smoothing of the trajectory may result in convergence of the smoothed trajectory. After a number of iterations, subsequent iterations may have smaller impact on smoothing of the trajectory. Once the iterations of the fine scale and coarse scale smoothing has been completed, the current guess may be outputted.

(54) The input to the stabilization algorithm may include visual content (video stream, video frames and their timestamps (e.g., moment when center scanline is captured)) captured by the image capture device 302, position information (e.g., gyroscope stream, packets of gyroscope samples), and/or other information. The output of the stabilization algorithm may include stabilized visual content, viewing window for the punchout of the visual content (e.g., stabilized crop orientation in time), and/or other information.

(55) The stabilization algorithm may include one or more of the following steps for individual video frames to be stabilized. Gyroscope samples may be integrated to reach the frame timestamp. The frame may be inserted into a circular buffer. When a sufficient number of frames are in the buffer (e.g., a number of frames in the buffer being same as and/or larger than a threshold number), the input trajectory may be unwrapped. The fixed past may be prepared by obtaining the crop orientation history and unwrapping it backwards with respect to the first ample of the input trajectory. If there is not history, the fixed past may be considered to be empty. The bootstrap may be prepared by taking the crop orientation history and filling the rest with input samples according to their timestamps. If there is no history, the bootstrap may be considered equal to the input trajectory. The trajectory retrieval algorithm may be invoked/performed. The smoothed trajectory outputted by the trajectory retrieval algorithm may be stored in the orientation history. The frames in the head of the buffer may be warped based on the smoothed trajectory by computing the rotation corresponding to pass from the source orientation to the stabilized orientation. The crop field of view may be sampled to take a grid of points, and the grid may be rotated. The grid may be projected onto the source camera image plane and warped. The warped image may be encoded.

(56) 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).

(57) For example, the processor 11 (or one or more components of the processor 11) may obtain visual information defining visual content having a 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 visual content and/or after acquisition of the visual content by an image capture device. For example, visual information, position information, and/or other information may be obtained while the visual content are being captured by an image capture device and/or after the visual content have been captured and stored in memory (e.g., the electronic storage 13).

(58) The trajectory component 102 may be configured to determine a 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 trajectory may be referred to as trajectory generation. The trajectory generated by the trajectory component 102 may include the trajectory of the image capture device/housing of the image capture observed by one or more positions sensors. The (observed) trajectory may refer to one or more paths and/or progression of positions

followed/experienced 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 trajectory component 102 may determine a 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.

(59) 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.

(60) FIG. 4 illustrates an example trajectory of an image capture device observed by position sensor(s). The 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 trajectory (e.g., pitch trajectory, roll trajectory, translational trajectory) are contemplated.

(61) Generating a video including visual content (e.g., of image(s), of video frame(s), of video(s)) captured along the observed yaw trajectory 400 may be undesirable. For example, generating a video by outputting 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).

(62) Stabilized visual content may be generated to provide a smoother view of the captured visual content. Stabilization may include using smaller portions/extents of the visual content to provide a punchout view of the visual content that creates a more stable view than when viewing the entirety of the visual content. Generation of stabilized visual content may include using smaller visual portions of the captured visual content (e.g., smaller visual portions of images/video frames) to provide a punchout view of the captured visual content. The stabilized visual content may provide a more stable view of the captured visual content than when the entirety of the captured visual content is presented. For example, such stabilization may be provided by creating a stabilized

(smoothed) trajectory over the capture duration and determining the punchouts from the visual content based on the stabilized trajectory. A punchout of visual content may refer to using one or more portions of the visual content for presentation, such as a cut-out of the image or a cropped portion of the image. A punchout of visual content may include one or more portions of the visual content presented on a display and/or one or more portions of the visual content used to generate video frames of video content. However, some stabilization techniques may not preserve the intent of the user that captured the images.

(63) 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 punchout 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 punchout 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.

(64) 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 punchout of the images using "past" position/motion information may result in a predicted trajectory as shown in FIG. 5A.

(65) 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 punchout location/shape.

(66) As another example, videos may be stabilized by filtering 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 remove abrupt rotational and/or translational changes in the positions/motions of the image capture device.

(67) For example, as shown in FIG. 5B, by applying a low-pass filter to the observed yaw trajectory 400, a filtered yaw trajectory 516 may be determined. The filtered yaw trajectory 516 may have smoother changes in the positions/motions of the image capture device than the observed yaw trajectory. However, such filtering 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 filtered 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).

(68) The smoothed trajectory component 104 may be configured to determine a smoothed trajectory of the image capture device/housing of the image capture device based on one or more subsequent portions of the trajectory and/or other information. The determination of the smoothed trajectory may be referred to as smoothed trajectory generation. The smoothed trajectory may refer to one or more paths and/or progression of positions (e.g., rotational positions, translational position) to be used in determining which portions of the visual content (punchouts) may be used to generate a video. The smoothed trajectory may be used to determine the viewing window from which punchouts of the visual content are generated. The placement of the viewing window within the visual content (e.g., the orientation of the viewing window with respect to the field of view of the visual content, the shape of the viewing window, the size of the viewing window) may be determined based on the smoothed trajectory.

(69) The smoothed 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.

(70) The smoothed trajectory may have smoother changes in the positions (rotational positions, translational positions) of the image capture device/housing of the image

capture device than the (observed) trajectory of the image capture device/housing of the image capture device. That is, the smoothed trajectory may have less jitters (slight irregular movement/variation), less abrupt changes, and/or less discontinuous changes in the positions (rotational positions, translational positions) of the image capture device/housing of the image capture device than the (observed) trajectory image capture device/housing of the image capture device. The smoothed trajectory having smoother changes in positions of the image capture device/housing of the image capture device than the trajectory may include high frequency changes in the positions (rotational positions, translational positions) of the image capture device/housing of the image capture device in the trajectory being removed from the smoothed trajectory. That is, the smoothed trajectory may not include and/or may have fewer high frequencies changes in rotational and/or translational positions of the housing than the (observed) trajectory.

(71) Determining a smoothed trajectory (smoothed trajectory generation) based on a subsequent portion of an (observed trajectory) may include determining a portion of the smoothed 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 (future moment(s) of the given moment) within the capture duration. That is, the smoothed trajectory component 104 may “look ahead” in time (look ahead of the given moment) 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 smoothed trajectory. Such generation of smoothed 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 smoothed trajectory component 104 to determine a smoothed 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.

(72) To determine the smoothed trajectory based on a look ahead of the (observed) trajectory, a subsequent portion of the (observed) trajectory may be used to determine a preceding portion of the smoothed trajectory such that a portion of the smoothed trajectory corresponding to a portion of the (observed) trajectory, which corresponds to a moment within the capture duration, is determined based on a later portion of the (observed) trajectory, which corresponds to a later moment within the capture duration.

(73) 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 smoothed 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, corresponding to next second of capture) may be analyzed to determine whether the position/motion of the image capture device at the moment was intended or not.

(74) For example, to determine the smoothed trajectory based on the subsequent portion of the (observed) trajectory, a rotational position of the image capture device/housing at a given moment within the capture duration may be obtained. The given moment may be a point in time within the capture duration and may correspond to a video frame of the visual content captured at the point in time within the capture duration. Rotational positions of the image capture device/housing at a later moment within the capture duration may be obtained. The later moment may be a duration of time subsequent to the point in time within the capture duration. A corresponding rotational position of the image capture device/housing within the smoothed trajectory at the given moment may be determined based on the rotational position of the image capture device/housing at the point in time, the rotational positions of the image capture device/housing during the duration of time subsequent to the point in time, and/or other information. Placement of the viewing window for the visual content with respect to the field of view of the visual content captured at the given moment may be determined based on the corresponding rotational position of the image capture device/housing within the smoothed trajectory at the given moment and/or other information.

(75) In some implementations, the determination of the smoothed trajectory of based on the subsequent portion of the (observed) trajectory may further include a check on whether the determined smoothed trajectory results in the corresponding viewing window for the punchout of the visual content remaining within the field of view of the visual content or extending beyond the field of view of the visual content (whether the placement of the viewing window satisfies or violates a margin constraint). For example, it may be determined whether the placement of the viewing window for the

visual content at the given moment results in one or more portions of the viewing window exceeding the field of view of the visual content. Responsive to a determination that the portion(s) of the viewing window for the visual content at the given moment exceeds the field of view of the visual content, the corresponding rotational position of the image capture device/housing within the smoothed trajectory at the given moment may be adjusted. That is, the smoothed trajectory may be adjusted so that the viewing window for the visual content at the given moment does not exceed the field of view of the visual content (the placement of the viewing window satisfies the margin constraint).

(76) In some implementations, the corresponding position (e.g., rotational position, translational position) of the image capture device/housing within the smoothed trajectory at the given moment may be initially determined based on a combination of the position of the image capture device/housing at the given moment and an estimate of the corresponding position of the image capture device/housing, and/or other information. Such initial determination of the positions within the smoothed trajectory may be referred to as bootstrapping.

(77) For example, an optimal estimate of the rotational position of the image capture device/housing within the smoothed trajectory at the given moment may be determined based on minimization of a combination of a rotational velocity of the image capture device/housing and a rotational acceleration of the image capture device/housing, and/or other information. The optimal estimate of the rotational position that minimizes motion (combination of velocity and acceleration) may result in placement of the viewing window for the punchout of the visual content that does not satisfy the margin constraint. Thus, the initial rotational position at the given moment within the smoothed

trajectory may be determined by combining the rotational position of the image capture device/housing at the given moment and the optimal estimate of the rotational position within the smoothed trajectory. Combination of the rotational position with the optical estimate of the rotational position may include an average of the two rotational positions. The average of the two rotational positions may weigh the two rotational positions equally or differently.

(78) In some implementations, the smoothed trajectory component 104 may determine a smoothed 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. The past position/motion of the image capture may be weighted less than the future position/motion of the image capture device in determining the smoothed trajectory. The prior portion(s) of the (observed) trajectory may have less impact on the determination of the smoothed trajectory than the future portion(s) of the (observed) trajectory. The amount of the prior portions of the (observed) trajectory used to determine the smoothed trajectory may be smaller than the amount of the future portion(s) of the (observed) trajectory. For example, when determining the smoothed trajectory for a moment (e.g., corresponding to the 1000th video frame) within the capture duration, the amount of the duration subsequent to the moment (e.g., corresponding to the next 30 video frames, corresponding to next second of capture) used may be larger than the amount of the duration preceding the moment (e.g., corresponding to the previous 15 video frames, corresponding to previous 0.5 second of capture).

(79) FIG. 5C illustrates an example smoothed trajectory determined by the smoothed trajectory component 104. The smoothed trajectory may include a smoothed yaw trajectory 532. The smoothed 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 (punchouts) may be used to generate a video. For example, the smoothed 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 smoothed trajectory (e.g., smoothed pitch trajectory, smoothed roll trajectory, smoothed translational trajectory) are contemplated.

(80) The smoothed yaw trajectory 532 may be determined such that a portion of the smoothed 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 smoothed 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 smoothed yaw trajectory 532 for portion(s) of the duration A 522 may differ from the observed yaw trajectory 400. The smoothed yaw trajectory 532 may be determined based on subsequent portion(s) of the observed yaw trajectory 400 such that the smoothed 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 yaw trajectory 400, the smoothed 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 smoothed yaw trajectory 532 to be directed to the front during durations 522, 524. Based on the subsequent portion(s) (look ahead) of the observed yaw trajectory 400, the smoothed 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 smoothed yaw trajectory 532 to include continuous rotation to the right during durations 528, 530. Other determinations of smoothed trajectory are contemplated.

(81) In some implementations, the smoothed 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 smoothed 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:

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

(83) 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.

(84) In some implementations, information on high frequencies (jitters) of image capture may be used to improve visual characteristics of generated video content/stabilized visual 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.

(85) 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 smoothed trajectory is smooth for inter-frame phases while corresponding to the original motion for intra-frame phases. That is, the smoothed 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.

(86) In some implementations, an extent to which the smoothed trajectory of the image capture device/housing deviates from the (observed) trajectory of the image capture device/housing may depend on an amount of rotational motion and/or translational motion experienced by the image capture device/housing during the capture duration, an exposure time with which the visual content is captured, and/or other information. That is, the amount of smoothing performed may take into account the amount of rotational and/or translational motion experienced by the image capture device during capture of the visual content and/or the exposure time used by the image capture device to capture the visual content. For example, visual content captured during larger amount of image capture device emotion may result in motion blur within the visual content, and smoothing the trajectory may result in the motion blur becoming more evident (e.g., motion blur becoming bigger, longer) within the stabilized visual content.

(87) The amount of smoothing/stabilization performed/allowed may depend on motion of the image capture device, the exposure time of the image capture device, and/or other information. FIG. 7 illustrates a plot 700 showing different values of smoothing as a function of motion of the image capture device (e.g., values characterizing frequency

of motion) and the exposure time with which the image capture device captures visual content. Smoothing values (S1, S2, S3, S4) may refer to the amount of smoothing performed to generate the smoothed trajectory. Smoothing values may impact, characterize, and/or set the power/strength of smoothing/stabilization performed. For example, the smoothing values may range between 0 and 1, with the value of 0 corresponding to no smoothing (deactivating smoothing) and the value of 1 corresponding to regular smoothing (smoothing as described herein). Values between 0 and 1 may correspond to reduced smoothing. For example, a value of 0.5 may correspond to decreasing the smoothing impact by half (e.g., smoothing operating at 50%).

(88) Use of different smoothing values may enable use of different smoothing powers (stabilization strengths) for different capture situations. For example, the smoothing value of S1 may correspond to the amount of smoothing to be used when the exposure time is short (shorter than T1, short exposure time threshold) and image capture device motion is high (e.g., higher than and/or same as high motion threshold). The smoothing value of S2 may correspond to the amount of smoothing to be used when the exposure time is long (longer than T2, long exposure time threshold) and image capture device motion is high. The smoothing value of S3 may correspond to the amount of smoothing to be used when the exposure time is short (shorter than T1) and image capture device motion is low (e.g., lower than and/or same as low motion threshold). The smoothing value of S4 may correspond to the amount of smoothing to be used when the exposure time is long (longer than T2) and image capture device motion is low. Thus, exposure time and image capture device motion may determine the extent of stabilization to be

performed on the visual content captured by the image capture device. In some implementations, the exposure time of the image capture device may be automatically adjusted based on light conditions, motion of the image capture device, and/or other information. For example, longer exposure time may be used with low light conditions and shorter exposure time may be used with high light conditions. For instance, referring to FIG. 7, exposure time of less than T1 may be used in high light conditions, exposure time between T1 and T2 may be used in mid light conditions, and exposure time greater than T2 may be used in low light conditions. Higher exposure time may result in greater amount of motion blur within the captured visual content.

(89) One or more of the smoothing values (S1, S2, S3, S4) may be tunable. For example, the values of the smoothing values may be set as follows: S1 = 1, S2 = 1, S3 = 1, and S4 = 1. Such setting of smoothing values may result in full stabilization of the captured visual content regardless of the image capture device motion and/or exposure time. As another example, the values of the smoothing values may be set as follows: S1 = 1, S2 = 0, S3 = 1, and S4 = 0. Such setting of smoothing values may result in full stabilization of the captured visual content when the exposure time is shorter than T1 and deactivation of the stabilization of the captured visual content when the exposure time is longer than T2. The smoothing value may change linearly between 0 and 1 as the exposure time increases from T1 to T2. As yet another example, the values of the smoothing values may be set as follows: S1 = 0.6, S2 = 0, S3 = 1, and S4 = 0.5. Such setting of smoothing values may result in full stabilization of the captured visual content when the exposure time is shorter than T1 and the image capture device motion is low, and deactivation of the stabilization of the captured visual content when the exposure

time is longer than T2 and the image capture device motion is high. The stabilization may operate at 60% when the exposure time is shorter than T1 and the image capture device motion is high, and the stabilization may operate at 50% when the exposure time is longer than T2 and the image capture device motion is low. Other values of smoothing values are contemplated. The smoothing values when image capture device motion is between the high motion threshold and the low motion threshold, and the smoothing values when exposure time is between the short exposure time threshold and the long exposure time threshold may be determined as an interpolation of S1, S2, S3, and/or S4.

(90) In some implementations, a set of constraints (including one or more constraints) may be applied in generating the smoothed trajectory. The set of constraints for generating the smoothed trajectory may include one or more constraints that provide limitations/restrictions/rules on how the smooth path/smoothed trajectory 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/smoothed trajectory may be generated. The margin constraint may be determined based on a difference between the size of the viewing window for generating a punchout of the visual content and the field of view of the visual content, and/or other information. The field of view of the visual content may refer to the field of view of a scene captured within the visual content. That is, the field of view of the visual content may refer to the spatial extent/angle of the scene captured within the visual content. The size of the viewing window may refer to the field of view of the punchout for generating a video based on visual content. That is, a video may be generated based

on visual content of the images within the viewing window. The viewing window may be defined in terms of shape and/or size.

(91) For example, FIG. 6A illustrates an example orientation of a viewing window 604 with respect to an image A 600. The image A 600 may have a field of view 602. The viewing window 604 may have a punchout field of view 606. The image A 600 may include capture of a scene within an angle defined by the field of view 602. The viewing window 604 may provide a punchout of the image A 600 to be used for video generation. The punchout field of view 606 of the viewing window 604 604 may be smaller than the field of view 602. The amount and/or direction from which the smooth path/smoothed trajectory may deviate from the (observed) trajectory may depend on the difference between the field of view 602 and the punchout field of view 606. The difference between the field of view 602 and the punchout field of view 606 (e.g., 10%) may define a margin 608 within which the viewing window 604 may move with respect to the image A 600/field of view 602. The margin 608 may be a stabilization margin, which specifies how much the viewing window may move while remaining inside the field of view of the visual content)

(92) For example, referring to FIG. 6B, a viewing window 614 may be rotated with respect to a field of view 612 of an image B 610 while not going beyond the pixels captured within the image B 610. A viewing window 624 may be laterally moved with respect to a field of view 622 of an image C 620 while not going beyond the pixels captured within the image C 620.

(93) Referring back to FIG. 6A, larger difference between the field of view 602 and the viewing window 604/punchout field of view 606 may enable larger movement of the

viewing window 604 with respect to the field of view 602 of the image A 600 while smaller difference between the field of view 602 and the viewing window 604/punchout field of view 606 may enable smaller movement of the viewing window 604 with respect to the field of view 602 of the image A 600. However, larger margin 608 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).

(94) 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/smoothed trajectory 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.

(95) 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/smoothed trajectory 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/smoothed trajectory so that the target is within one or more of the punchouts of the visual content. Other constraints are contemplated.

(96) In some implementations, a set of parameters (including one or more parameters) may control the generation of the smoothed trajectory. The set of parameters for generating the smoothed trajectory may include one or more parameters that influence and/or direct how the smooth path/smoothed trajectory is generated. For example, the set of parameters may include a weight-balance parameter, a low-light high-pass parameter, a stickiness parameter, and/or other parameters.

(97) A weight-balance parameter may refer to a parameter that controls the types of motion that are minimized in generation of the smoothed trajectory. For example, types of motion that may be minimized to generate the smoothed trajectory/smooth path may include rotational velocity, rotational acceleration, translational velocity, translational acceleration and/or other motions. For instance, a weight-balance parameter (value of the weight-balance parameter) may control to what extent a combination of rotational velocity and rotational acceleration is minimized when determining the smoothed trajectory. The weight-balance parameter may range between 0 and 1, with 0 corresponding to minimization of angular velocity and 1 corresponding to minimization of angular acceleration. A value between 0 and 1 may correspond to minimization of both angular velocity and angular acceleration, with minimization of different types of motion weighed according to the value. Other values of the weight-balance parameter are contemplated.

(98) Sole minimization of angular velocity may result in a smoothed trajectory that prefers to keep a steady position when possible and may result in piecewise-linear sharp-corners in the smoothed trajectory. Sole minimization of angular velocity may minimize apparent motion between video frames, but the resulting motion may appear unnatural. Sole minimization of angular acceleration may result in a smoothed trajectory with no/reduced number of corner points. Sole minimization of angular acceleration may result a constant velocity and may produce more motion than Sole minimization of angular velocity. Minimization of a combination of angular velocity and angular acceleration may provide for an in-between generation of smoothed trajectory (with different minimization weighted according to the value of the weight-balance parameter).

(99) A low-light high-pass parameter may refer to a parameter that controls the amount/strength of smoothing performed to generate the smoothed trajectory. For trajectory smoothing/visual content stabilization, motion of the image capture device may be categorized into (1) inter-frame motion, and (2) intra-frame motion. Inter-frame motion may refer to motion between frame exposure periods. Inter-frame motion may be attenuated based on the margin constraint. Intra-frame motion may refer to motion of the image capture device during an exposure period of individual video frames. The motion may be encrusted in the video frames through the motion blur, and attenuation of the intra-frame motion may result in motion blur pulsations that create poor visual impression. Such visual defect may be reduced by having the smoothed trajectory follow the (observed) trajectory during the exposure periods.

(100) A low-light high-pass parameter may range between 0 and 1, with 0 corresponding to no motion blur compensation and 1 corresponding to full motion blur compensation. The low-light high-pass parameter of 0 may result in the observed motion being fully attenuated and no image capture device motion during the exposure periods being taken into account. The low-light high-pass parameter of 1 may result in the smoothed trajectory being same as the (observed) trajectory during the exposure periods. That is, the output motion may include high frequencies that mask motion blur within the visual content. A value between 0 and 1 may change the amount/strength of the smoothing performed to generate the smoothed trajectory. Other values of the low-light high-pass parameter are contemplated.

(101) A stickiness parameter may refer to a parameter that control the extent by which preceding portion(s) of the (observed) trajectory impacts determination of the smoothed trajectory. A stickiness parameter may range between 0 and 1. The stickiness parameter of 1 may result in a "lazy" stabilizer that maximizes the impact of the preceding motion/position, unless the future motion/position indicate that the lazily determined smoothed trajectory will result in the violation of the margin constraint. The stickiness parameter of 0 may result in the smoothed trajectory being generated without taking the preceding portion(s) of the (observed) trajectory into account. A value between 0 and 1 may change the extent by which preceding portion(s) of the (observed) trajectory impacts determination of the smoothed trajectory. The value of the stickiness parameter may impact bootstrapping—the value of the stickiness parameter may determine how the positions of an image capture device/housing and the optimal

estimates of the positions are weighed to form initial estimates of the smoothed trajectory. Other values of the stickiness parameter are contemplated.

(102) The viewing window component 106 may be configured to determine one or more viewing windows for the visual content based on the smoothed trajectory of the image capture device/housing and/or other information. Placement of a viewing window for the visual content with respect to the field of view of the visual content captured at a moment may be determined based on the corresponding position (rotational position, translational position) of the image capture device/housing within the smoothed trajectory at the moment and/or other information.

(103) A viewing window may define one or more extents of the visual content. A viewing window may define extent(s) of the visual content to be included within a punchout of the visual content as the function of progress through the progress length of the visual content. The progress length of the visual content may be the same as or determined based on the capture duration of the visual content. A viewing window may define extent(s) of the visual content included within a video generated from the visual content. For example, a viewing window may define which spatial portions of the visual content captured by the image capture device during the capture duration is presented on display(s) and/or included within stabilized visual content.

(104) A viewing window may be characterized by viewing directions, viewing sizes (e.g., viewing zoom, viewing magnification), viewing rotations, and/or other information. A viewing direction may define a direction of view for visual content. A viewing direction may define the angle/visual portion of the visual content at which the viewing window may be directed. A viewing direction may be defined based on rotation about an axis

that defines lateral movement of the viewing window (e.g., yaw). A viewing direction may be defined based on rotation about an axis that defines vertical movement of the viewing window (e.g., pitch). The yaw and pitch values of the viewing direction may determine the location of the viewing window within captured images/video frames.

(105) A viewing size may define a size of the viewing window. A viewing size may define a size (e.g., size, magnification, viewing angle) of viewable extents of visual content. A viewing size may define the dimensions of the viewing window. In some implementations, a viewing size may define different shapes of the viewing window/viewable extents. For example, a viewing window may be shaped as a rectangle, a triangle, a circle, and/or other shapes. A viewing rotation may define a rotation of the viewing window. A viewing rotation may define one or more rotations of the viewing window about one or more axis. For example, a viewing rotation may be defined based on rotation about an axis corresponding to a viewing direction (e.g., roll).

(106) The viewing window(s) may be determined as the function of progress through the capture duration. That is, one or more of viewing direction, viewing rotation, and/or viewing size may be determined for different parts of the capture duration. For example, different placement (determined based on viewing direction, viewing rotation, and/or viewing size) of the viewing window may be determined for different parts of the capture duration. The viewing window(s) may be determined for different time points and/or different time durations within the capture duration. The viewing window(s) may be determined for different images/video frames and/or different groups of images/video frames captured during the capture duration.

(107) A viewing window may be used to provide a punchout of the visual content. A punchout of the visual content may refer to an output of one or more portions of the visual content for presentation (e.g., current presentation, future presentation based on video generated using the punchout). A punchout of the visual content may refer to extents of the visual content that is obtained for viewing and/or extraction. The extents of the visual content viewable/extracted within the viewing window may be used to provide views of different spatial portions of the visual content.

(108) For example, the visual content may include a field of view, and the punchout of the visual content may include the entire extent of the visual content (the visual content within the entire field of view) or one or more extents of the visual content (the visual content within one or more portions of the field of view). A viewing window may define extents of the visual content to be included within a punchout of the visual content as the function of progress through the progress length/capture duration of the visual content. A viewing window may correspond to the entire duration of the progress length/capture duration or for one or more portions (e.g., portions including moments of interest) of the progress length/capture duration. The punchout of the visual content may be presented on one or more displays, included in one or more videos, and/or otherwise used for presenting the visual content.

(109) Determining a viewing window for visual content based on the smoothed trajectory may include determining one or more of viewing direction, viewing rotation, and/or viewing size of the viewing window based on the smoothed trajectory. That is, determining a viewing window for visual content may include determining orientations of the viewing window with respect to the field of view of the visual content based on the

smoothed trajectory. Placement (viewing direction, viewing rotation, and/or viewing size) of the viewing window at different moments may be determined based on corresponding positions/values of the smoothed trajectory. The orientations of the viewing window with respect to the field of view of the visual content may determine which portions of the visual content (punchouts) may be used to generate a video. That is, the viewing window component 106 may determine how the punchouts for the visual content may be oriented with respect to the field of view of the visual content.

(110) The viewing window component 106 may be configured to determine how the viewing window should be oriented with respect to the field of view of the visual content (images, video frames) based on the smoothed trajectory. The viewing window component 106 may determine how the punchouts for the visual content may be laterally and/or vertically positioned with respect to the field of view of the visual content based on the smoothed trajectory. The viewing window component 106 may determine how the punchouts for the visual content may be rotated with respect to the field of view of the visual content based on the smoothed trajectory.

(111) The viewing window may be oriented with respect to the field of view of the visual content to provide a punchout of the visual content that is stable with respect to prior and/or next punchout of the visual content. For example, the viewing window may be oriented with respect to the field of view of images/video frames captured by the image capture device to provide a punchout of the images/video frames such that the presented content appears to have been captured with a stable/more stable image capture device (e.g., a punchout of a video frame being stable/more stable with a punchout of the preceding video frame and/or a subsequent video frame).

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

(113) The generation component 108 may be configured to generate stabilize visual content of one or more videos based on the viewing window(s) and/or other information. The stabilized visual content may include a punchout of the extent(s) of the visual content within the viewing window(s). Stabilized visual content may be generated as video frames including extent(s) of the visual content within the viewing window(s). Stabilized visual content may be generated as outputs of portions of the visual captured by the image capture device, with the outputted portions including extent(s) of the visual content within the viewing window(s). Inclusion of the extent(s) of the visual content within the viewing windows in video may effectuate stabilization of the visual content via selective cropping. The portions of the visual content that is cropped for stabilization

may depend on the smoothed trajectory and/or other information. The portions of the visual content that is cropped for stabilization may depend on one or more of the weight-balance parameter, the low-light high-pass parameter, the stickiness parameter, and/or other parameters.

(114) 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.

(115) The video frames of the video content may be determined based on visual content of the visual content within the viewing window and/or other information. The video frames of the video content may be determined based on a punchout of the visual content in accordance with the smoothed trajectory, the viewing window, 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 viewing window 604, the visual content of the image B 610 within the viewing window 614, the visual content of the image C 620 within the viewing window 624, and/or other

information. Such determination of extents of visual content for inclusion in video content may effectuate stabilization of the video content.

(116) 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.

(117) In some implementations, visual content (e.g., images, video frames) and/or one or more of the portions of visual content used to generate video content may be stored in one or more buffers (e.g., 1s buffer, circular buffer). The buffer(s) may be used to store visual content/portions of visual content that may be used (e.g., included in a punchout, warped) to generate stabilized visual content. The buffer(s) may be used to store other information, such as visual information, position information, and/or other information for look ahead and/or trajectory generation. For example, the buffer(s) may be used to store images/video frames for which trajectory generation is being performed using look ahead. After corresponding portion of the smoothed trajectory is generated, the relevant portions of the images (visual content of the images within the viewing window) in the buffer(s) may be used to generate the video content.

(118) 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/video frames, 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 visual content (images, video frames) should be included within the presentation of the video content. The director track may include information on the location, size, shape, and/or rotation of the punchout of images/video frames to be used to as a function progress through the video content to provide a stabilized view of the images/video frames. A video player may use the director track to retrieve the relevant visual portions of the images/video frames when the video content is opened and/or is to be presented.

(119) 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.

(120) In some implementations, the processor 11 may represent multiple processors, and at least one of the processors may be a remote processor located remotely from the housing of the image capture device (e.g., the image capture device 302). One or more of the functionalities of the components 102, 104, 106, 108 may be performed by the image capture device 302 (e.g., by the processor 310) and/or by a remote processor. For example, one or more of trajectory determination (functionalities of the trajectory component 102), smoothed trajectory determination (functionalities of the smoothed trajectory component 104), viewing window determination (functionalities of the viewing window component 106), and/or stabilized visual content generation (functionality of the generation component 108) may be performed by the remote processor post capture of the visual content by the image capture device.

(121) The image capture device may capture the position information and the visual content but may not stabilize the visual content in real time. For example, the image capture device may not have sufficient resource to apply the stabilization technique described herein in real-time and/or may be devoting its resources to other tasks. The stabilization of the visual content may be performed by the image capture device once sufficient resource becomes available. The stabilization of the visual content may be performed by the remote processor. For example, the remote processor may be one or more processors of a remote computing device (e.g., mobile device, desktop, server), and the remote processor may receive visual information and the position information captured/generated by the image capture device. The remote computing device

(software running on the remote computing device) may apply the stabilization technique described herein post capture of the visual content by the image capture device. The post-capture stabilization of the visual content may be performed by the remote processor responsive to reception of the visual information and position information, responsive to user/system command to stabilize the visual content, responsive to the visual content being opened for playback, and/or responsive to other conditions.

(122) 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.

(123) 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 (non-transitory) machine-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.

(124) 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.

(125) 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.

(126) 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.

(127) 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. While computer program components are described as performing or being configured to perform operations, computer program components may comprise instructions which may program processor 11 and/or system 10 to perform the operation.

(128) 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

(129) 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.

(130) 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.

(131) 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.

(132) 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 operations of method 200.

(133) Referring to FIG. 2 and method 200, at operation 201, a visual output signal may be generated. The visual output signal may convey visual information that defines visual content having a 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).

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

(135) At operation 203, a 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 trajectory component 102 (Shown in FIG. 1 and described herein).

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

(137) At operation 205, a viewing window for the visual content may be determined based on the smoothed trajectory. The viewing window may define one or more extents of the visual content. In some implementation, operation 205 may be performed by a processor component the same as or similar to the viewing window component 106 (Shown in FIG. 1 and described herein).

(138) At operation 206, stabilized visual content may be generated based on the viewing window. The stabilized visual content may include a punchout of the extent(s) of the visual content within the viewing window. 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).

(139) 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.

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ABSTRACT

Visual content is captured by an image capture device during a capture duration. The image capture devices experiences change in position during the capture duration. The trajectory of the image capture device is smoothed based on a look ahead of the trajectory. A punchout of the visual content is determined based on the smoothed trajectory. The punchout of the visual content is used to generate stabilized visual content.

What is claimed is:

1. An image capture system that stabilizes videos, the image capture system comprising:

a housing of an image capture device;

an optical element carried by the housing and configured to guide light within a field of view to an image sensor;

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, the field of view being larger than a size of a viewing window for generating stabilized visual content;

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 a trajectory of the housing during the capture duration based on the position information, the trajectory reflecting the rotational positions of the housing at the different moments within the capture duration, the 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 smoothed trajectory of the housing based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter, the look-ahead of the trajectory including use of a subsequent portion of the trajectory to determine a preceding portion of the smoothed 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, the smoothed trajectory having smoother changes in the rotational positions of the housing than the trajectory;

determine placement of the viewing window for the visual content with respect to the field of view of the visual content based on the smoothed trajectory of the housing, the viewing window defining one or more extents of the visual content to be included within a punchout of the visual content; and

generate the stabilized visual content of a video based on the viewing window, the stabilized visual content including the punchout of the one or more extents of the visual content within the viewing window, wherein inclusion in the stabilized visual content of the one or more extents of the visual content within the viewing window effectuates stabilization of the visual content via selective cropping.

2. The image capture system of claim 1, wherein the position information further characterizes translational positions of the housing at the different moments within the capture duration, the trajectory further reflects the translational positions of the housing

at the different moments within the capture duration, and the smoothed trajectory has smoother changes in the translational positions of the housing than the trajectory.

3. The image capture system of claim 1, wherein the smoothed trajectory is determined further based on a trajectory retrieval algorithm, input to the trajectory retrieval algorithm including the trajectory of the housing and a bootstrap trajectory, the bootstrap trajectory including a current or an initial guess of the smoothed trajectory.

4. The image capture system of claim 3, wherein the smoothed trajectory is determined further based on iterations of smoothing including a fine scale approach to smooth on a small scale and a coarse approach to smooth on a large scale, the iterations of smoothing resulting in convergence of the smoothed trajectory.

5. The image capture system of claim 1, wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes use of a temporal horizon of motion experienced by the image capture device, the temporal horizon enabling approximation of intentional motion of the image capture device while causing a delay in the determination of the smoothed trajectory.

6. The image capture system of claim 5, wherein a longer interval of the temporal horizon enables better approximation of the intentional motion of the image capture device while causing a longer delay in the determination of the smoothed trajectory.

7. The image capture system of claim 5, wherein the smoothed trajectory is determined further based on minimization of a value, a score, or a metric that expresses an amount of high frequencies while respecting a crop constraint.

8. The image capture system of claim 7, wherein the smoothed trajectory is determined further based on iterative minimization, the iterative minimization including iterations of steps that alter latest estimate, the steps including an update step that updates a current estimate to decrease a value of an objective function and a projection step that applies one or more constraints, the current estimate being re-projected based on the one or more constraints not being satisfied.

9. The image capture system of claim 1, wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes weighing past positions of the housing less than future positions of the housing.

10. The image capture system of claim 1, wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes a prior portion of the trajectory having less impact on the determination of the smoothed trajectory than a future portion of the trajectory.

11. The image capture system of claim 1, wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes using a first amount of a

prior portion of the trajectory and a second amount of a future portion of the trajectory, the first amount being smaller than the second amount.

12. The image capture system of claim 1, wherein the visual content are stored in a buffer during smoothed trajectory generation such that the visual content corresponding to the portion of the smoothed trajectory are stored in the buffer during the determination of the portion of the smoothed trajectory using the lookahead of the trajectory, and the visual content stored in the buffer are used after the determination of the portion of the capture trajectory to generate the stabilized visual content.

13. The image capture system of claim 12, wherein the buffer includes a circular buffer, and the visual content are stored in the circular buffer as video frames to be stabilized.

14. The image capture system of claim 1, wherein the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration.

15. The image capture system of claim 1, wherein the low-light high-pass parameter controls amount or strength of smoothing performed in smoothed trajectory generation and an extent of motion blur compensation applied in determination of the smoothed trajectory.

16. The image capture system of claim 1, wherein the stickiness parameter controls an extent by which a preceding portion of the trajectory impacts determination of the smoothed trajectory.

17. A method for stabling videos, the method performed by an image capture system including one or more processors, an optical element, an image sensor, and a position sensor, the optical element carried by an image capture device and configured to guide light within a field of view to the image sensor, 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, the field of view being larger than a size of a viewing window for generating stabilized visual content;

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

determining, by the one or more processors, a trajectory of the image capture device during the capture duration based on the position information, the trajectory reflecting the rotational positions of the image capture device at the different moments within the capture duration, the 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 smoothed trajectory of the image capture device based on a look-ahead of the trajectory and one or more of a weight-balance parameter, a low-light high-pass parameter, and/or a stickiness parameter, the look-ahead of the trajectory including use of a subsequent portion of the trajectory to determine a preceding portion of the smoothed 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, the smoothed trajectory having smoother changes in the rotational positions of the image capture device than the trajectory;

determining, by the one or more processors, placement of the viewing window for the visual content with respect to the field of view of the visual content based on the smoothed trajectory of the image capture device, the viewing window defining one or more extents of the visual content to be included within a punchout of the visual content; and

generating, by the one or more processors, the stabilized visual content of a video based on the viewing window, the stabilized visual content including the punchout of the one or more extents of the visual content within the viewing window, wherein inclusion in the stabilized visual content of the one or more extents of the visual content within the viewing window effectuates stabilization of the visual content via selective cropping.

18. The method of claim 17, wherein:

the weight-balance parameter controls types of motion that are minimized in smoothed trajectory generation, the types of motion including rotational velocity and rotational acceleration;

the low-light high-pass parameter controls amount or strength of smoothing performed in smoothed trajectory generation and an extent of motion blur compensation applied in determination of the smoothed trajectory; and

the stickiness parameter controls an extent by which a preceding portion of the trajectory impacts determination of the smoothed trajectory.

19. The method of claim 17, wherein the smoothed trajectory is determined further based on a trajectory retrieval algorithm, input to the trajectory retrieval algorithm including the trajectory of the image capture device and a bootstrap trajectory, the bootstrap trajectory including a current or an initial guess of the smoothed trajectory.

20. The method of claim 17, wherein the determination of the smoothed trajectory based on the look-ahead of the trajectory includes:

weighing past positions of the image capture device less than future positions of the image capture device;

a prior portion of the trajectory having less impact on the determination of the smoothed trajectory than a future portion of the trajectory; or

using a first amount of the prior portion of the trajectory and a second amount of the future portion of the trajectory, the first amount being smaller than the second amount.

21. The method of claim 17, wherein the smoothed trajectory is determined further based on iterations of smoothing including a fine scale approach to smooth on a small scale and a coarse approach to smooth on a large scale, the iterations of smoothing resulting in convergence of the smoothed trajectory.

22. The method of claim 17, wherein the smoothed trajectory is determined further based on iterative minimization, the iterative minimization including iterations of steps that alter latest estimate, the steps including an update step that updates a current estimate to decrease a value of an objective function and a projection step that applies one or more constraints, the current estimate being re-projected based on the one or more constraints not being satisfied.

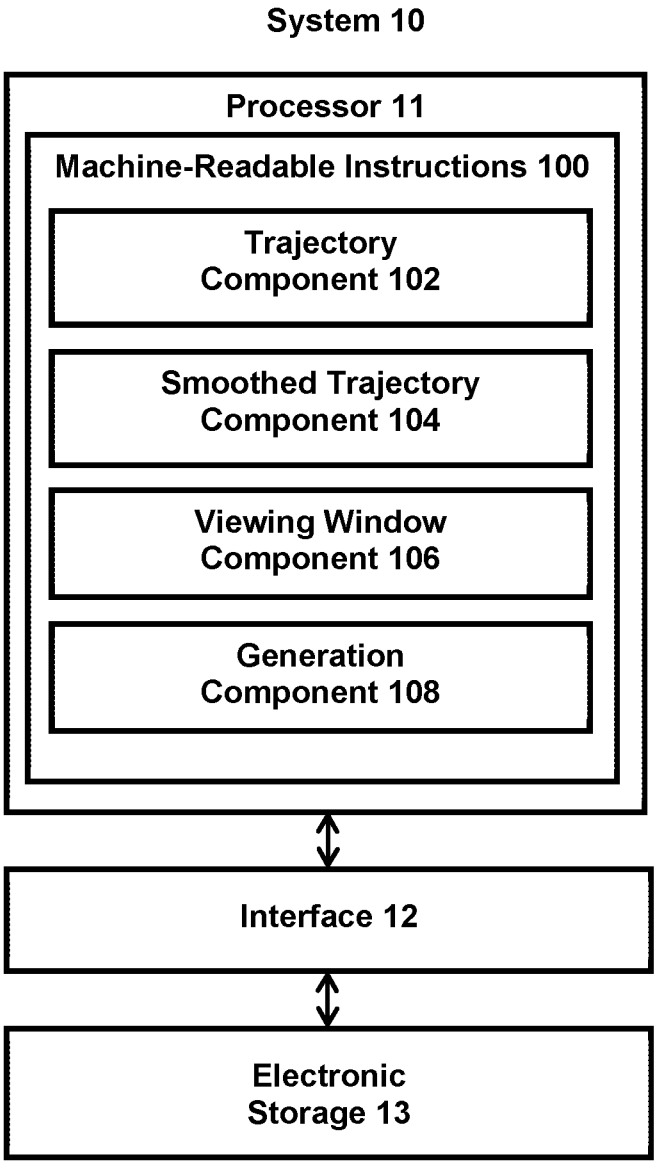

System 10
Processor 11
Machine-Readable Instructions 100
Trajectory Component 102
Smoothed Trajectory Component 104
Viewing Window Component 106
Generation Component 108
Interface 12
Electronic Storage 13

FIG. 1

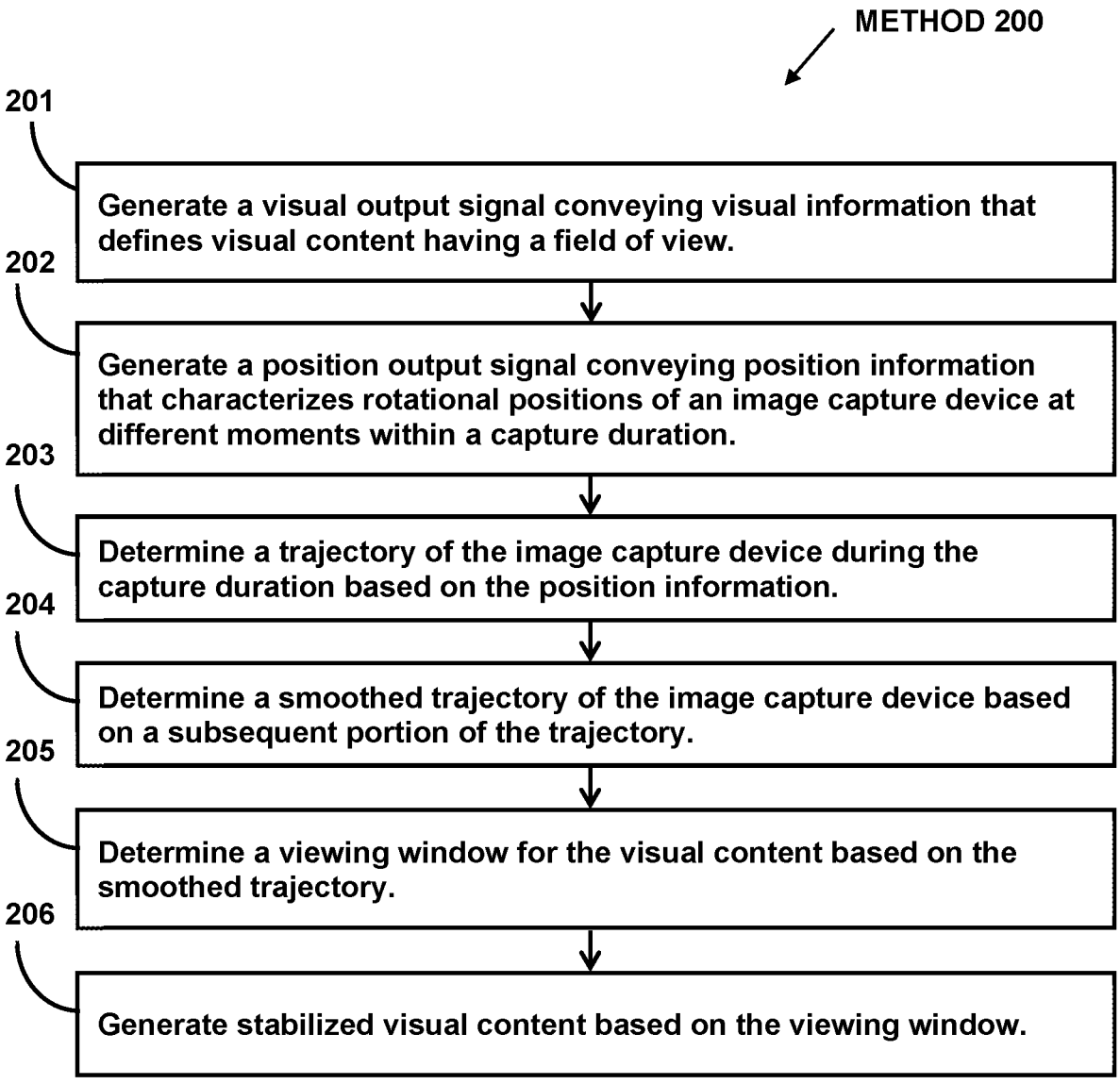

METHOD 200
201
Generate a visual output signal conveying visual information that defines visual content having a field of view.
202
Generate a position output signal conveying position information that characterizes rotational positions of an image capture device at different moments within a capture duration.
203
Determine a trajectory of the image capture device during the capture duration based on the position information.
204
Determine a smoothed trajectory of the image capture device based on a subsequent portion of the trajectory.
205
Determine a viewing window for the visual content based on the smoothed trajectory.
206
Generate stabilized visual content based on the viewing window.

FIG. 2

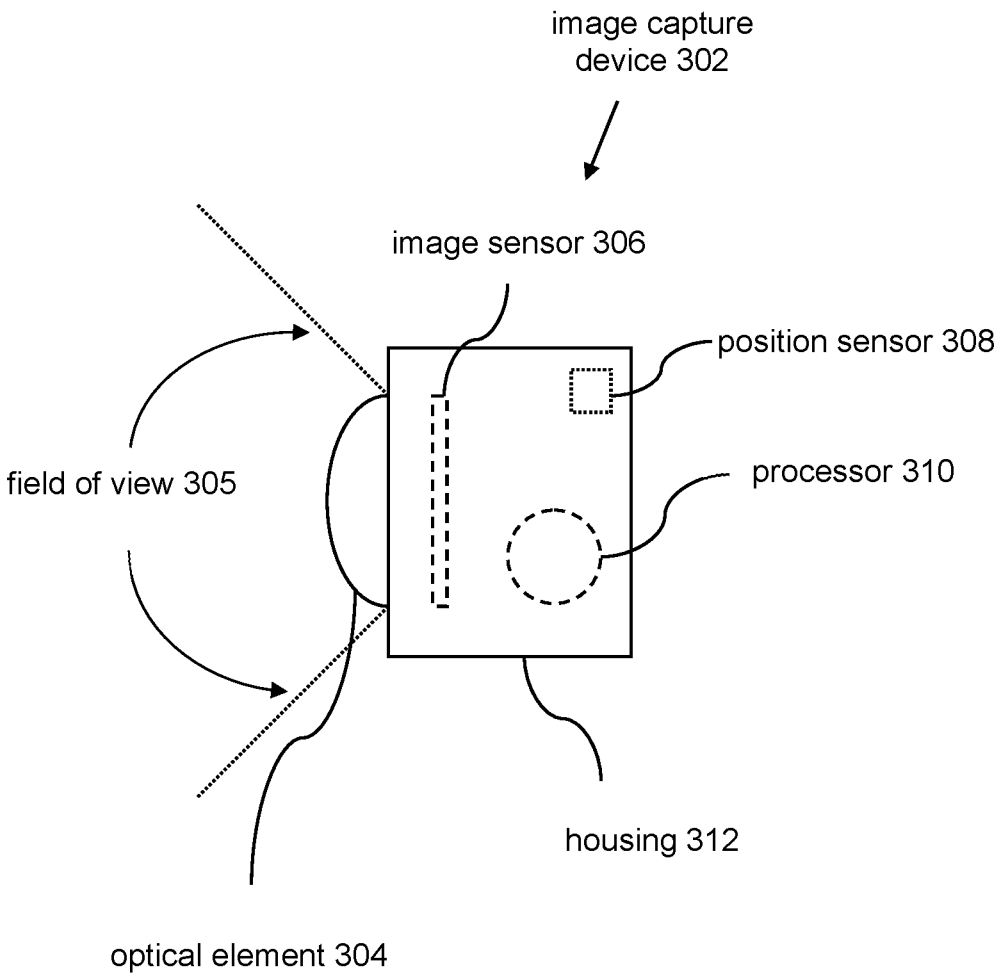

image capture
device 302
image sensor 306
position sensor 308
processor 310
field of view 305
housing 312
optical element 304

FIG. 3

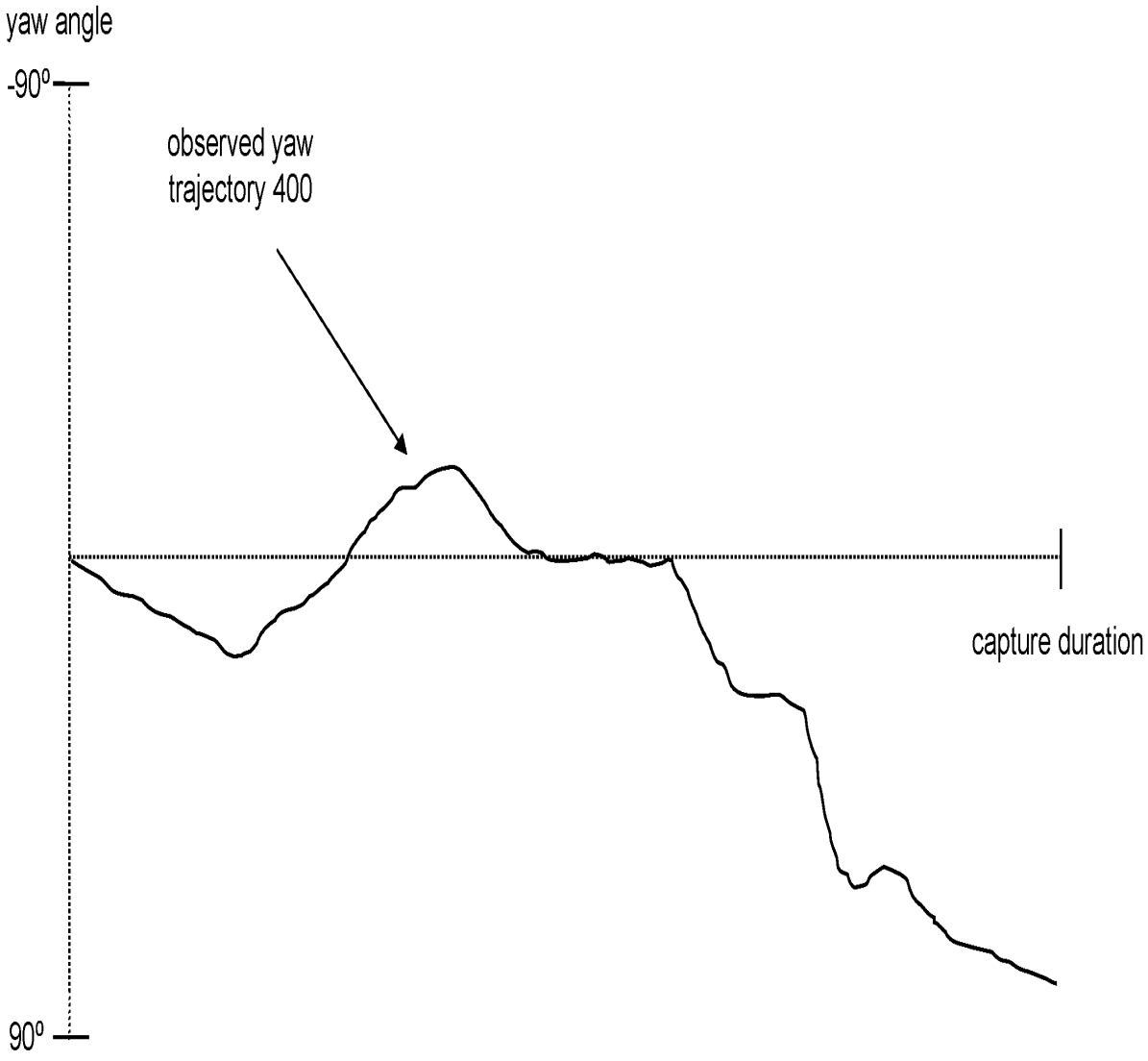

yaw angle
-90°
observed yaw
trajectory 400
capture duration
90°

FIG. 4

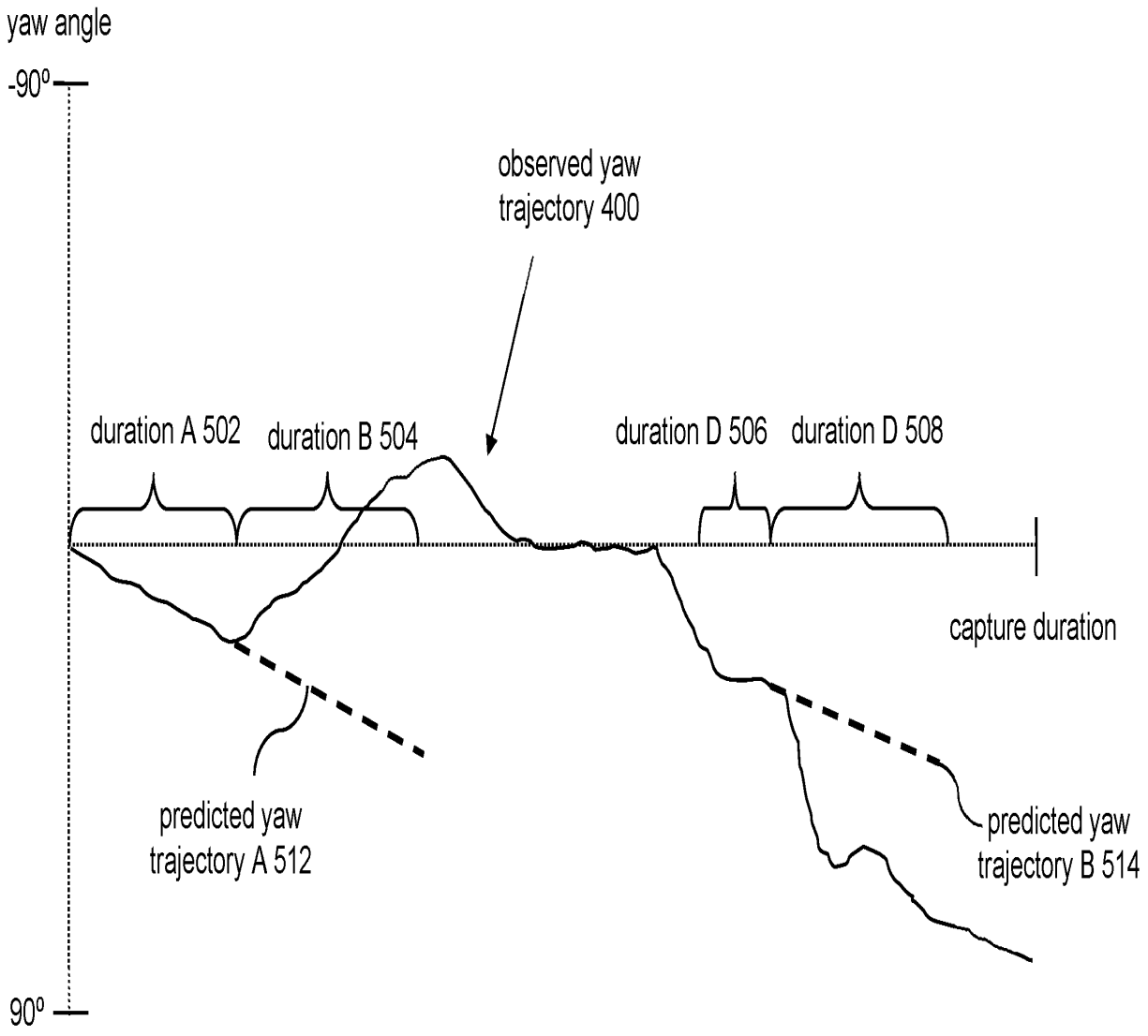

yaw angle
-90°
observed yaw
trajectory 400
duration A 502
duration B 504
duration D 506
duration D 508
capture duration
predicted yaw
trajectory A 512
predicted yaw
trajectory B 514
90°

FIG. 5A

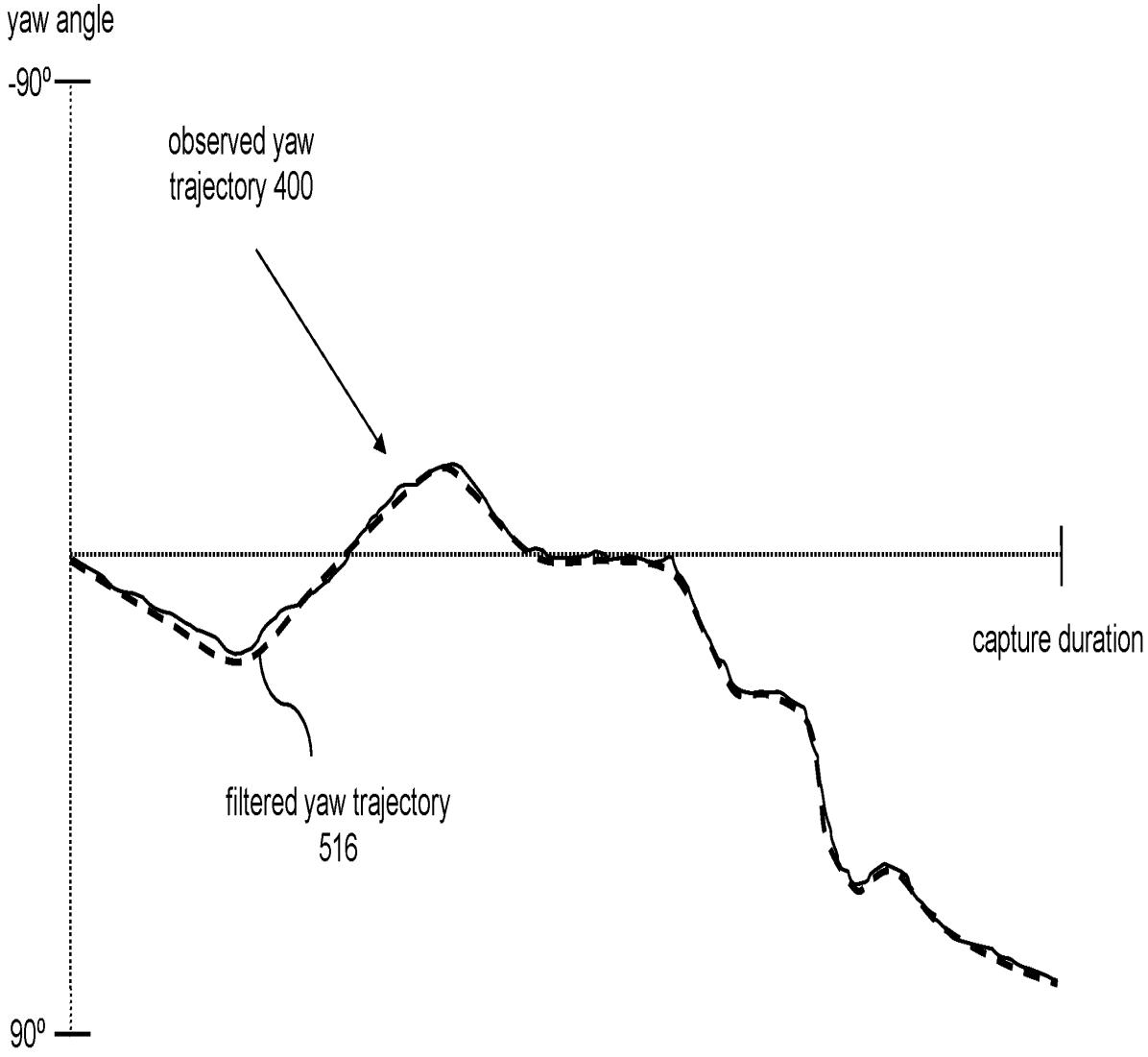

yaw angle
-90°
observed yaw
trajectory 400
capture duration
filtered yaw trajectory
516
90°

FIG. 5B

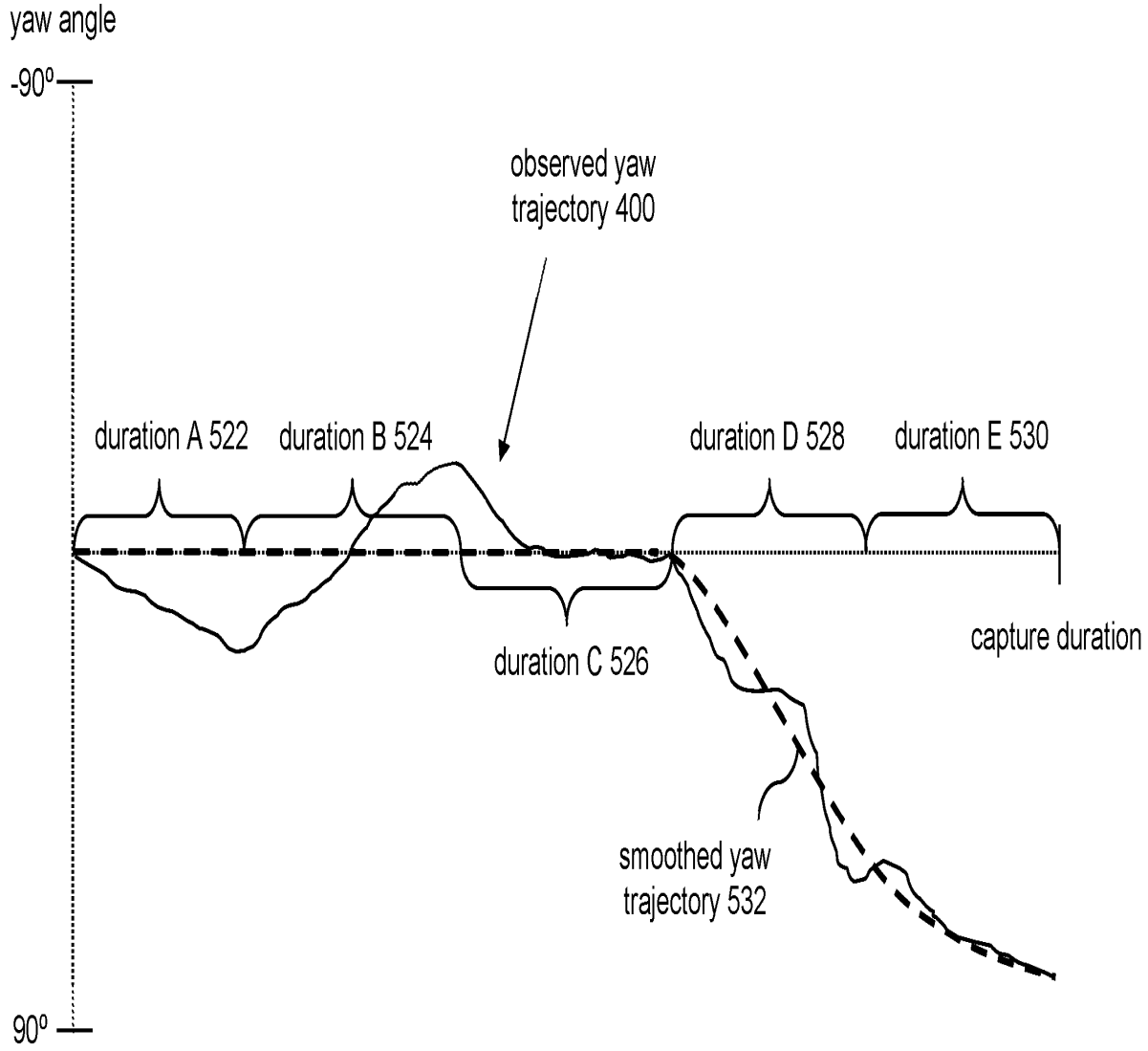

yaw angle
-90°
observed yaw
trajectory 400
duration A 522
duration B 524
duration D 528
duration E 530
capture duration
duration C 526
smoothed yaw
trajectory 532
90°

FIG. 5C

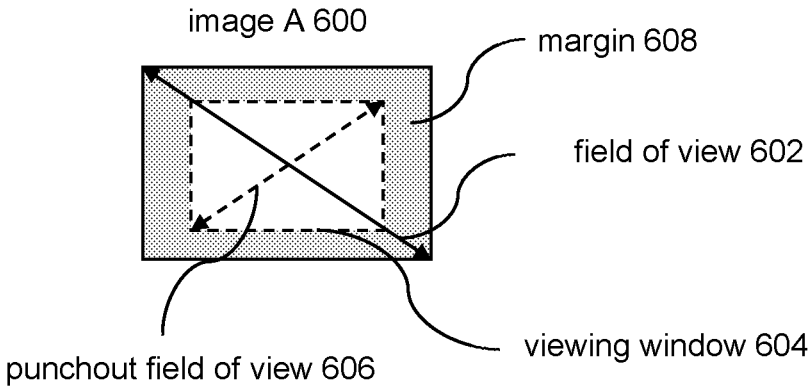

image A 600
margin 608
field of view 602
viewing window 604
punchout field of view 606

FIG. 6A

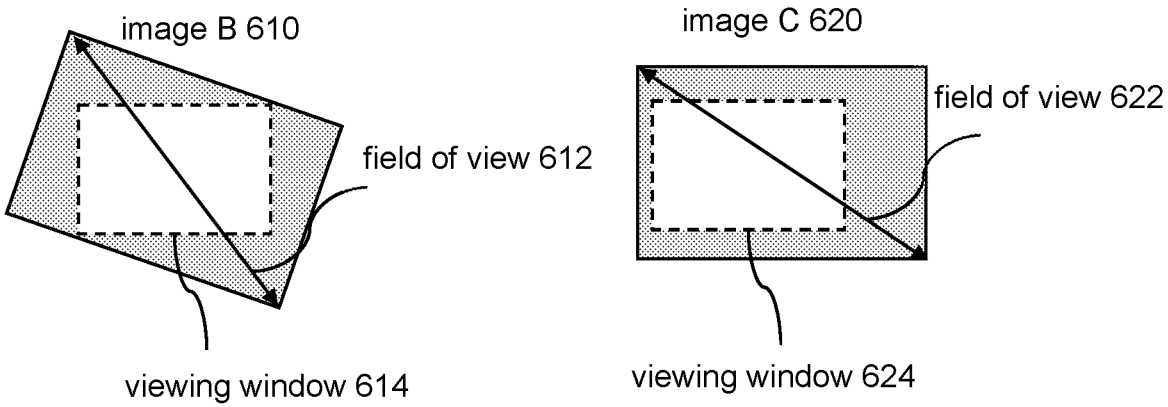

image B 610
field of view 612
viewing window 614
image C 620
field of view 622
viewing window 624

FIG. 6B

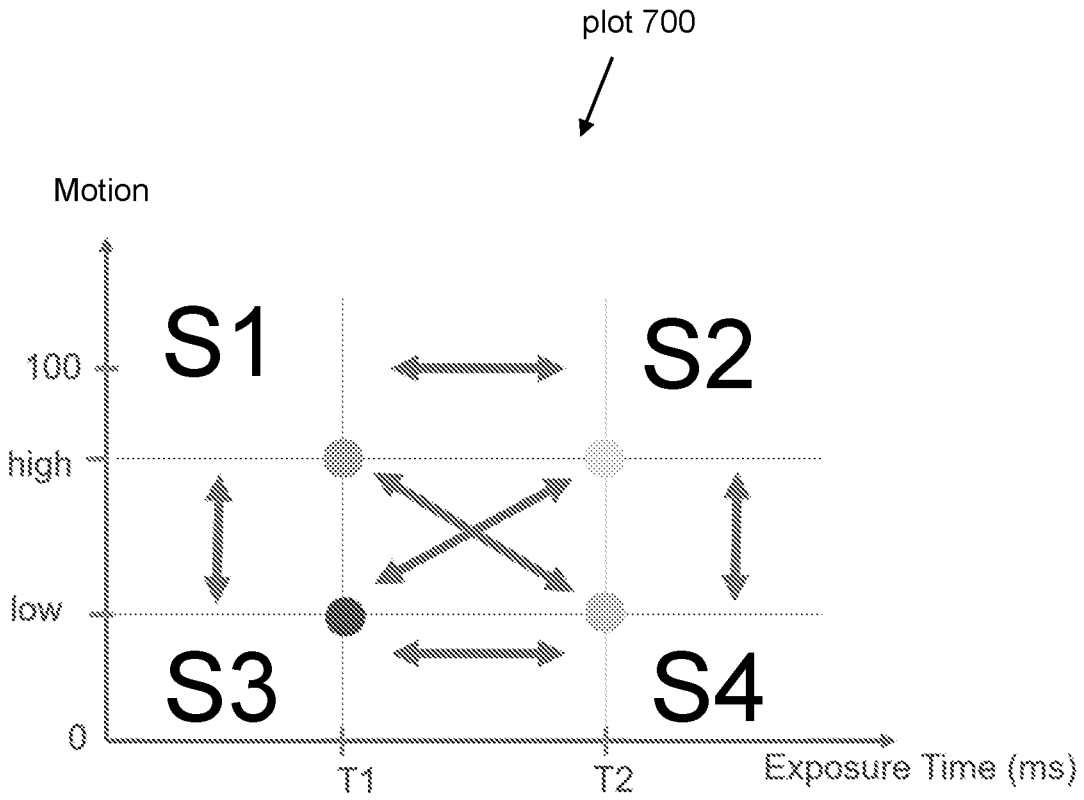

plot 700
Motion
100
high
low
0
S1
S2
S3
S4
T1
T2
Exposure Time (ms)

FIG. 7

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Cesar Douady
Filer:	D. Benjamin Esplin/Chelsea Pearsall
Attorney Docket Number:	46DG-026085

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:				
CLAIMS IN EXCESS OF 20	1202	2	100	200
Miscellaneous-Filing:				
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1920**

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	Cesar Douady
	Art Unit	
	Examiner Name	
	Practitioner Docket No.	46DG-026085

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

December 13, 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 Acknowledgement Receipt

EFS ID:	38012213
Application Number:	16713798
International Application Number:	
Confirmation Number:	2783
Title of Invention:	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
First Named Inventor/Applicant Name:	Cesar Douady
Customer Number:	137002
Filer:	D. Benjamin Esplin/Chelsea Pearsall
Filer Authorized By:	D. Benjamin Esplin
Attorney Docket Number:	46DG-026085
Receipt Date:	13-DEC-2019
Filing Date:	
Time Stamp:	15:11:45
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$1920
RAM confirmation Number	E2019BCF12121811
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	144565 40248a201e0587dc59a8e5ad79079186b5e2d3e0	no	8
Warnings:					
Information:					
2	Drawings-only black and white line drawings	46DG-026085_Drawings.pdf	226888 d052e73205e7d40676a4d8397327c4e43de3b43c	no	9
Warnings:					
Information:					
3	Oath or Declaration filed	46DG-026085_Declaration-Assignment.pdf	109343 e8902203743869302 76bc1b40d046e88e40329b7	no	3
Warnings:					
Information:					
4	Power of Attorney	46DG-026085_POA.pdf	313218 77221fc1cc0e6354aacfadeaac53ff1b62344157	no	2
Warnings:					
Information:					
5	Internet Communications Authorized	46DG-026085_Email_Authorization.pdf	73619 aa9ef937202327130b8ed4c9752ff24623ddb431	no	2
Warnings:					
Information:					
6	Fee Worksheet (SB06)	fee-info.pdf	36975 452433c644c2094898b18f6df5a2e15549282c04	no	2
Warnings:					
Information:					

7	Specification	28daf58d-d1cb-4c19-85b2-0f04c683f47d.docx	58058 38d993afc748670ea22866d185b807946dd2df625d9f1082ffa7e8d5067d1e2bc0161a387cb69a270aa48bb05e8652609e0b482ac058670d35153fa508fc5197	no	60
Warnings:					
Information:					
8	Specification	5a2cb063-4e03-4f16-bf03-e05b352ee074.pdf	442419 f4d428058db957ec593f19db54490a62e64ec157	no	60
Warnings:					
Information:					
9	Abstract	da3baf7c-1725-46df-a9c8-0e3f2f29f0d8.docx	19891 ac656f4240e1fd462ab49b7c7d9f822ddfb2c5871d0b5ad45d78e1528c237b864a7c608f76aa97c4a74d9355b64adce9ec69b9ccc11a006f0523f4232257ee2d	no	1
Warnings:					
Information:					
10	Abstract	a195c06a-a052-432e-9736-8daf093e6d83.pdf	5529 026b0bd271353b51ae61fa15f6d077b2f4d022eb	no	1
Warnings:					
Information:					
11	Claims	7dfebab3-f34d-4265-9d31-10992a153eca.docx	23172 86a33a39ff177e394f3c2a95878432359cf40a08b6856172ca9f369d97821035be6575e385ca95c807e966472660f61a316c004c9ff17bec02b96322bea2a6fe	no	9
Warnings:					
Information:					
12	Claims	2071ae7d-f665-41a6-a2aa-d71301a6507c.pdf	118117 178cccad7dca19e9cf94c8e87acd13b22a7b5ce6	no	9
Warnings:					
Information:					
		Total Files Size (in bytes):	1571794		

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-026085
	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
	Cesar		Douady	

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

City	Les Molieres	Country of Residence ⓘ	FR

Mailing Address of Inventor:

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

Inventor 2

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 ⓘ	FR

Mailing Address of Inventor:

Address 1	3000 Clearview Way		
Address 2			
City	San Mateo	State/Province	CA
Postal Code	94402	Country ⓘ	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-026085
	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-026085	**Small Entity Status Claimed**	☐
Application Type			
Subject Matter			
Total Number of Drawing Sheets (if any)	9	**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)
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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-026085
	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	16/587,811	2019-09-30

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026085
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
16/587,811	Continuation of	16/548,549	2019-08-22

Prior Application Status	Patented				Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
16548549	Continuation of	16392501	2019-04-23	10432864	2019-10-01

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
16392501	Claims benefit of provisional	62733237	2018-09-19

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[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (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-026085
	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)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

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-026085
	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. ☒

Organization Name	GoPro, Inc.

Mailing Address Information For Applicant:

Address 1	3000 Clearview Way		
Address 2			
City	San Mateo	**State/Province**	CA
Country[i]	US	Postal Code	94402
Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button.

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-026085
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Assignee Information including Non-Applicant Assignee 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.

Assignee 1

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.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

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

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

PTO/AIA/14 (08-15)
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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	46DG-026085
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR STABILIZING VIDEOS	

Signature:

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). **However, if this Application Data Sheet is submitted with the INITIAL filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).**

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e. g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

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

Additional Signature may be generated within this form by selecting the Add button.

Doc Code: PA..
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PTO/AIA/82A (07-13)
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Application Number	
Filing Date	Herewith
First Named Inventor	Cesar Douady
Title	SYSTEMS AND METHODS FOR STABILIZING VIDEOS
Art Unit	
Examiner Name	
Attorney Docket Number	46DG-026085

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.

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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

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☑ 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.)

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OR

Firm or Individual Name					
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City		State		Zip	
Country					
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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.

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