Doc Code: TRACK1.REQ
Document Description: TrackOne Request

PTO/AIA/424 (04-14)

CERTIFICATION AND REQUEST FOR PRIORITIZED EXAMINATION UNDER 37 CFR 1.102(e) (Page 1 of 1)

First Named Inventor:	Angus PACALA	Nonprovisional Application Number (if known):	
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD		

APPLICANT HEREBY CERTIFIES THE FOLLOWING AND REQUESTS PRIORITIZED EXAMINATION FOR THE ABOVE-IDENTIFIED APPLICATION.

1. The processing fee set forth in 37 CFR 1.17(i)(1) and the prioritized examination fee set forth in 37 CFR 1.17(c) have been filed with the request. The publication fee requirement is met because that fee, set forth in 37 CFR 1.18(d), is currently $0. The basic filing fee, search fee, and examination fee are filed with the request or have been already been paid. I understand that any required excess claims fees or application size fee must be paid for the application.

2. I understand that the application may not contain, or be amended to contain, more than four independent claims, more than thirty total claims, or any multiple dependent claims, and that any request for an extension of time will cause an outstanding Track I request to be dismissed.

3. The applicable box is checked below:

I. ☑ Original Application (Track One) - Prioritized Examination under § 1.102(e)(1)

i. (a) The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a). This certification and request is being filed with the utility application via EFS-Web.

---OR---

(b) The application is an original nonprovisional plant application filed under 35 U.S.C. 111(a). This certification and request is being filed with the plant application in paper.

ii. An executed inventor's oath or declaration under 37 CFR 1.63 or 37 CFR 1.64 for each inventor, **or** the application data sheet meeting the conditions specified in 37 CFR 1.53(f)(3)(i) is filed with the application.

II. ☐ Request for Continued Examination - Prioritized Examination under § 1.102(e)(2)

i. A request for continued examination has been filed with, or prior to, this form.
ii. If the application is a utility application, this certification and request is being filed via EFS-Web.
iii. The application is an original nonprovisional utility application filed under 35 U.S.C. 111(a), or is a national stage entry under 35 U.S.C. 371.
iv. This certification and request is being filed prior to the mailing of a first Office action responsive to the request for continued examination.
v. No prior request for continued examination has been granted prioritized examination status under 37 CFR 1.102(e)(2).

Signature / William L. Shaffer /	Date 2021-05-18
Name (Print/Typed) William Shaffer	Practitioner Registration Number 37,234

Note: *This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. Submit multiple forms if more than one signature is required.**

☐ *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.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

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 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Angus		PACALA	

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

City	State/Province	Country of Residence
San Francisco	CA	US

Mailing Address of Inventor:

Address 1	350 Treat Avenue
Address 2	
City	San Francisco
State/Province	CA
Postal Code	94103
Country	US

Inventor 2 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Mark		FRICHTL	

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

City	State/Province	Country of Residence
San Francisco	CA	US

Mailing Address of Inventor:

Address 1	350 Treat Avenue
Address 2	
City	San Francisco
State/Province	CA
Postal Code	94103
Country	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).

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

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

Customer Number	20350		
Email Address	ipefiling@kilpatricktownsend.com	Add Email	Remove Email

Application Information:

Title of the Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD		
Attorney Docket Number	103033-P001USC5-1252977	**Small Entity Status Claimed**	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	8	**Suggested Figure for Publication (if any)**	

Filing By Reference:

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

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

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

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	20350		

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

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	15880491	2018-01-25

Prior Application Status	Patented				Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
15880491	Continuation of	15276532	2016-09-26	99924772	2018-06-05

Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
15276532	Claims benefit of provisional	62232222	2015-09-24

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

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)[i] 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).

Remove

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. Add

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

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

☐ 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.

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

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.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

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 Remove

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	Ouster, Inc.		
Mailing Address Information For Applicant:			
Address 1	350 Treat Avenue		
Address 2			
City	San Francisco	**State/Province**	CA
Country	US	Postal Code	94103
Phone Number		Fax Number	
Email Address			

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

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.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
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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.

Remove

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

Organization Name	Ouster, Inc.

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1	350 Treat Avenue		
Address 2			
City	San Francisco	**State/Province**	CA
Country i	US	Postal Code	94103
Phone Number		Fax Number	
Email Address			

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

Signature:

Remove

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	/ William L. Shaffer /			Date (YYYY-MM-DD)	2021-05-18
First Name	William L.	Last Name	Shaffer	Registration Number	37234

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

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	103033-P001USC5-1252977
	Application Number	
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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 the Freedom of Information Act requires disclosure of these records.

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 CooperationTreaty.

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 inspections 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.

ABSTRACT

An optical system for collecting distance information within a field is provided. The optical system may include lenses for collecting photons from a field and may include lenses for distributing photons to a field. The optical system may include lenses that collimate photons passed by an aperture, optical filters that reject normally incident light outside of the operating wavelength, and pixels that detect incident photons. The optical system may further include illumination sources that output photons at an operating wavelength.

CLAIMS

What is claimed is:

1. An optical system for collecting distance information, the optical system comprising:

a bulk transmitting optic;

a plurality of optical emitters arranged behind the bulk transmitting optic and configured to output electromagnetic radiation of an operating wavelength through the bulk transmitting optic into a field external to the optical system according to an illumination pattern that comprises a plurality of non-overlapping emission regions;

a bulk imaging optic disposed adjacent to the bulk transmitting optic;

a plurality of pixels arranged behind the bulk imaging optic, wherein each pixel in the plurality of pixels has a field of view coincident with an emission region of a corresponding optical emitter in the plurality of optical emitters and each pixel comprises a plurality of single photon avalanche diodes (SPADs) operable to detect photons emitted from its corresponding optical emitter and received through the bulk imaging optic after being reflected from surfaces within the field; and

an optical filter disposed in an optical path of the plurality of pixels, the optical filter configured to allow a set of wavelengths of electromagnetic radiation, including the operating wavelength, to pass through the optical filter while blocking electromagnetic radiation outside the set of wavelengths from reaching the plurality of pixels.

2. The optical system according to claim 1 wherein, the optical system is configured to collect three-dimensional distance data based on times between transmission of illuminating beams from the plurality of optical emitters and detection of photons from the illuminating beams by the plurality of pixels.

3. The optical system according to claim 1 wherein the plurality of optical emitters are arranged in a first arrangement and the plurality of pixels are arranged in a second arrangement, proportional to the first arrangement.

4. The optical system according to claim 1 wherein bulk transmitting optic and the bulk imaging optic are each image-space telecentric bulk optics.

5. The optical system according to claim 1 further comprising a rotation mechanism configured to rotate the optical system about a rotational axis.

6. The optical system according to claim 1 further comprising an aperture layer disposed between the bulk imaging optic and the plurality of pixels and comprising a plurality of apertures separated by a stop region.

7. The optical system according to claim 6 wherein the aperture layer comprises a thin opaque structure.

8. The optical system according to claim 6 wherein:

the plurality of apertures comprises a first aperture, a second aperture, a third aperture, and a fourth aperture;

the plurality of pixels comprises a first pixel, a second pixel, a third pixel and a fourth pixel; and

the optical system includes a first optical path that extends between the bulk imaging optic and the first pixel through the first aperture, a second optical path that extends between the bulk imaging optic and the second pixel through the second aperture, a third optical path that extends between the bulk imaging optic and the third pixel through the third aperture, and a fourth optical path that extends between the bulk imaging optic and the fourth pixel through the fourth aperture.

9. The optical system according to claim 6 wherein the aperture layer is arranged along a plane coincident with a focal plane of the bulk imaging optic.

10. The optical system according to claim 1 further comprising a signal processing circuit coupled to the plurality of pixels.

11. The optical system according to claim 10 wherein the signal processing circuit is configured to count incident photons within a sampling period for the plurality of pixel detectors.

12. The optical system according to claim 1 wherein the plurality of optical emitters comprises a plurality of vertical-cavity surface-emitting lasers (VCSELs) mounted on a common substrate.

13. The optical system according to claim 1 wherein each optical emitter in the plurality of optical emitters comprises a single vertical-cavity surface-emitting lasers (VCSEL).

14. An optical system for collecting distance information, the optical system comprising:

a bulk transmitting optic;

a plurality of optical emitters arranged behind the bulk transmitting optic and configured to output electromagnetic radiation of an operating wavelength into a plurality of non-overlapping emission regions, each emission region representing a spot in a field ahead of the optical system;

a bulk imaging optic;

a plurality of pixels arranged behind the bulk imaging optic and corresponding in number to the plurality of optical emitters, wherein each pixel in the plurality of pixels is paired with a different optical emitter in the plurality of optical emitters and has a field of view coincident with an emission region of its paired optical emitter and wherein each pixel comprises a plurality of single photon avalanche diodes (SPADs) operable to detect photons emitted from its paired optical emitter and received through the bulk imaging optic after being reflected from surfaces within the field; and

an optical filter disposed in an optical path of the plurality of pixels, the optical filter configured to allow a set of wavelengths of electromagnetic radiation, including the operating wavelength, to pass through the optical filter while blocking electromagnetic radiation outside the set of wavelengths from reaching the plurality of pixels;

wherein, the optical system is configured to collect distance data based on times between transmission of beams of electromagnetic radiation from the plurality of optical emitters and detection of photons from the beams by the plurality of pixels.

15. The optical system according to claim 14 wherein the plurality of optical emitters are configured to illuminate substantially only emission regions in the field that can be detected by the plurality of pixels in the optical system.

16. The optical system according to claim 14 wherein each pixel is operable to output a signal corresponding to a count of photons incident on the pixel within one sampling period.

17. The optical system according to claim 14 further comprising an aperture layer disposed between the bulk imaging optic and the plurality of pixels and comprising a plurality of apertures separated by a stop region.

18. The optical system according to claim 17 wherein each aperture in the plurality of apertures is axially aligned with a different pixel in the plurality of pixels and defines a field of view for its aligned pixel.

19. The optical system according to claim 14 wherein the bulk transmitting optic and the bulk imaging optic are each image-space telecentric optics.

20. A lidar system comprising:

a bulk transmitting optic;

a plurality of optical emitters arranged behind the bulk transmitting optic and configured to output illuminating beams of an operating wavelength through the bulk transmitting optic and into a field ahead of the lidar system according to an illumination pattern that comprises a plurality of non-overlapping emission regions within the field, wherein each optical emitter in the plurality of optical emitters outputs an illuminating beam into a unique one of the emission regions within the illumination pattern;

a telecentric bulk imaging optic;

a plurality of receiver channels having non-overlapping fields of view that substantially match, in size and geometry across a range of distances from the lidar system, the illumination pattern of the plurality of optical emitters, wherein each receiver channel in the plurality of receiver channels is paired with an optical emitter in the plurality of optical emitters such that a field of view for the receiver channel is coincident with the emission region of its

paired optical emitter, and wherein each receiver channel includes one pixel arranged behind the bulk imaging optic and comprising a plurality of single photon avalanche diodes (SPADs) operable to detect photons emitted its paired optical emitter and received through the bulk imaging optic after being reflected from surfaces within the field; and

an optical filter disposed in an optical path of each pixel in the plurality of receiver channels, the optical filter configured to allow a band of wavelengths of electromagnetic radiation, including the operating wavelength, to pass through the optical filter while blocking electromagnetic radiation outside the band of wavelengths from reaching the pixels;

wherein, the lidar system collects three-dimensional distance data based on times between transmission of illuminating beams from the plurality of optical emitters and detection of photons from the illuminating beans by the plurality of pixels.

21. The lidar system according to claim 20 wherein each pixel functions to output a signal corresponding to a count of photons incident on the pixel within one sampling period.

22. The lidar system according to claim 20 wherein the bulk transmitting optic and the bulk imaging optic are each image-space telecentric optics.

23. The lidar system according to claim 20 further comprising an aperture layer disposed between the bulk imaging optic and the plurality of pixels and comprising a plurality of apertures separated from each other by a non-transparent stop region.

24. The lidar system according to claim 20 wherein each optical emitter in the plurality of optical emitters comprises a single vertical-cavity surface-emitting laser (VCSEL).

25. The lidar system according to claim 20 wherein the plurality of optical emitters are configured to illuminate substantially only emission regions in the field that can be detected by the plurality of pixels in the lidar system.

PATENT APPLICATION

OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

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OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. Patent Application No. 15/880,491 ("the '491 application"), filed January 25, 2018, which is a continuation of U.S. Patent Application No. 15/276,532 ("the '532 application"), filed September 26, 2016, now U.S. Patent No. 9,992,477, issued June 5, 2018; which claims the benefit of U.S. Provisional Patent Application No. 62/232,222 ("the '222 application") filed September 24, 2015. The present application is also related to U.S. Patent Application No. 17/317,809, filed on May 11, 2021; U.S. Patent Application No. 16/584,515 filed on September 26, 2019; U.S. Patent Application No. 16/046,643, filed on July 26, 2018; and U.S. Patent Application No. 15/861,330, filed on January 3, 2018. The disclosures of each of the '491, '532 and '222 applications are each incorporated by reference herein in their entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention relates generally to the field of optical sensors and more specifically to a new and useful optical system for collecting distance information in the field of optical sensors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] FIG. 1 is a schematic representation of a system.

[0004] FIG. 2 is a schematic representation in accordance with one variation of the system.

[0005] FIG. 3 is a schematic representation in accordance with one variation of the system.

[0006] FIG. 4 is a schematic representation in accordance with one variation of the system.

[0007] FIG. 5 is a schematic representation in accordance with one variation of the system.

[0008] FIG. 6 is a schematic representation in accordance with one variation of the system.

[0009] FIG. 7 is a schematic representation in accordance with one variation of the system.

[0010] FIG. 8 is a schematic representation in accordance with one variation of the system.

[0011] FIG. 9 is a flowchart representation in accordance with one variation of the system.

[0012] FIG. 10 is a schematic representation in accordance with one variation of the system.

[0013] FIG. 11 is a schematic representation in accordance with one variation of the system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The following description of embodiments of the invention is not intended to limit the invention to these embodiments but rather to enable a person skilled in the art to make and use this invention. Variations, configurations, implementations, example implementations, and examples described herein are optional and are not exclusive to the variations, configurations, implementations, example implementations, and examples they describe. The invention described herein can include any and all permutations of these variations, configurations, implementations, example implementations, and examples.

1. One-Dimensional Optical System: Aperture Array

[0015] As shown in FIG. 1, a one-dimensional optical system 100 for collecting distance information within a field includes: a set of illumination sources 110 arranged along a first axis, each illumination source in the set of illumination sources 110 configured to output an illuminating beam of an operating wavelength toward a discrete spot in the field ahead of the illumination source; a bulk imaging optic 130 characterized by a focal plane opposite the field; an aperture layer 140 coincident the focal plane, defining a set of apertures 144 in a line array parallel to the first axis, and defining a stop region 146 around the set of apertures 144, each aperture in the set of apertures 144 defining a field of view in the field coincident a discrete spot output by a corresponding illumination source in the set of illumination sources 110, the stop region 146 absorbing light rays reflected from surfaces in the field outside of fields of view defined by the set of apertures 144 and passing through the bulk imaging optic 130 ; a set of lenses 150, each lens in the set of lenses 150 characterized by a second focal length, offset from the focal plane opposite the bulk imaging optic 130 by the second focal length, aligned with an aperture in the set of apertures 144, and configured to collimate light rays passed by the aperture; an optical filter 160 adjacent the set of lenses 150 opposite the aperture layer 140 and configured to pass light rays at the operating wavelength; a set of pixels 170 adjacent the optical filter 160 opposite the set of lenses 150, each pixel in the set of pixels 170 corresponding to a lens in the set of lenses 150 and including a set of subpixels arranged along a second axis non-parallel to the first axis; and a diffuser 180 interposed between the optical filter 160 and the set of pixels 170 and configured to spread collimated light output from each lens in the set of lenses 150 across a set of subpixels of a corresponding pixel in the set of pixels 170.

1.1 Applications

[0016] Generally, the one-dimensional optical system 100 (the "system") functions as an image sensor that, when rotated about an axis parallel to a column of apertures, collects three-dimensional distance data of a volume occupied by the system. Specifically, the one-dimensional optical system 100 can scan a volume to collect three-dimensional distance data that can then be reconstructed into a virtual three-dimensional representation of the volume, such as based on recorded times between transmission of illuminating beams from the illumination sources and detection of photons – likely originating from the illumination sources – incident on the set of pixels 170, based on phase-based measurements techniques, or based on any other suitable distance measurement technique. The system 100 includes: a column of offset apertures arranged behind a bulk imaging optic 130 and defining discrete fields of view in a field ahead of the bulk imaging optic 130 (that is non-overlapping fields of view beyond a threshold distance from the system); a set of illumination sources 110 that project discrete illuminating beams at an operating wavelength into (and substantially only into) the fields of view defined by the apertures; a column of lenses that collimate light rays passed by corresponding apertures; and an optical filter 160 that selectively passes a narrow band of wavelengths of light (i.e., electromagnetic radiation) including the operating wavelength; and a set of pixels 170 that detect incident photons (e.g., count incident photons, tracks times between consecutive incident photons). The system can therefore selectively project illuminating beams into a field ahead of the system according to an illumination pattern that substantially matches – in size and geometry across a range of distances from the system – the fields of view of the apertures. In particular, the illumination sources are configured to illuminate substantially only surfaces in the field ahead of the system that can be detected by pixels in the system such that minimal power output by the system (via the illumination sources) is wasted by illuminating surfaces in the field for which the pixels are blind. The system can therefore achieve a relatively high ratio of output signal (i.e., illuminating beam power) to input signal (i.e., photons passed to an incident on the pixel array). Furthermore, the set of lenses 150 can collimate light rays passed by adjacent apertures such that light rays incident on the optical filter 160 meet the optical filter 160 at an angle of incidence of approximately 0°, thereby maintaining a relatively narrow band of wavelengths of light passed by the optical filter 160 and achieving a relatively high signal-to-noise ratio ("SNR") for light rays reaching the set of pixels 170.

[0017] The system includes pixels arranged in a column and aligned with the apertures, and each pixel can be non-square in geometry (e.g., short and wide) to extend the sensing area of the system for a fixed aperture pitch and pixel column height. The system also includes a diffuser 180 that spreads light rays passed from an aperture through the optical filter 160 across the area of a corresponding pixel such that the pixel can detect incident photons across its full width and height thereby increasing the dynamic range of the system.

[0018] The system is described herein as projecting electromagnetic radiation into a field and detecting electromagnetic radiation reflected from a surface in the field back to bulk receiver optic. Terms "illumination beam," "light," "light rays," and "photons" recited herein refer to such electromagnetic radiation. The term "channel" recited herein refers to one aperture in the aperture layer 140, a corresponding lens in the set of lenses 150, and a corresponding pixel in the set of pixels 170.

1.2 Bulk Imaging Optic

[0019] The system includes a bulk imaging optic 130 characterized by a focal plane opposite the field. Generally, the bulk imaging optic 130 functions to project incident light rays from outside the system toward the focal plane where light rays incident on a stop region 146 of the aperture layer 140 are rejected (e.g., mirrored or absorbed) and where light rays incident on apertures in the aperture layer 140 are passed into a lens characterized by a focal length and offset from the focal plane by the focal length.

[0020] In one implementation, the bulk imaging optic 130 includes a converging lens, such as a bi-convex lens (shown in FIG. 2) or a plano-convex lens, characterized by a particular focal length at the operating wavelength of the system. The bulk imaging optic 130 can also include multiple discrete lens that cooperate to project light rays toward the aperture layer 140 and that are characterized by a composite focal plane opposite the field, as shown in FIG. 11. However, the bulk imaging optic 130 can be any other suitable type of lens or combination of lenses of any other type or geometry.

1.3 Aperture Layer

[0021] As shown in FIGS. 1 and 2, the system includes an aperture layer 140 coincident the focal plane, defining a set of apertures 144 in a line array parallel to the axes of the illumination sources, and defining a stop region 146 around the set of apertures 144,

wherein each aperture in the set of apertures 144 defines a field of view in the field coincident a discrete spot output by a corresponding illumination source in the set of illumination sources 110, and wherein the stop region 146 absorbs and/or reflects light rays reflected from surfaces in the field outside of fields of view defined by the set of apertures 144 and passing through the bulk imaging optic 130. Generally, the aperture layer 140 defines an array of open regions (i.e., apertures, including one aperture per lens) and closed regions ("stop regions") between adjacent opens. Each aperture in the aperture layer 140 defines a "pinhole" that defines a field of view for its corresponding sense channel and passes light rights reflected from an external surface within its field of the view into its corresponding lens, and each stop region 146 can block light rays incident on select regions of the focal plane from passing into the lens array, as shown in FIG. 6.

[0022] The aperture layer 140 includes a relatively thin opaque structure coinciding with (e.g., arranged along) the focal plane of the bulk imaging optic 130, as shown in FIGS. 1 and 2. For example, the aperture layer 140 can include a 10 micrometer-thick copper, silver, or nickel film deposited (e.g., plated) over a photocurable transparent polymer and then selectively etched to form the array of apertures. In a similar example, a reflective metalized layer or a light-absorbing photopolymer (e.g., a photopolymer mixed with a light absorbing dye) can be deposited onto a glass wafer and selectively cured with a photomask to form the aperture layer 140 and the set of apertures 144. Alternatively, the aperture layer 140 can include a discrete metallic film that is mechanically or chemically perforated to form the array of apertures, bonded to the lens array, and then installed over the bulk imaging optic 130 along the focal plane. However, the aperture layer 140 can include any other reflective (e.g., mirrored) or light-absorbing material formed in any other way to define the array of apertures along the focal plane of the bulk imaging optic 130.

[0023] In the one-dimensional optical system 100, the aperture layer 140 can define a single column of multiple discrete circular apertures of substantially uniform diameter, wherein each aperture defines an axis substantially parallel to and aligned with one lens in the lens array, as shown in FIG. 3. Adjacent apertures are offset by an aperture pitch distance greater than the aperture diameter and substantially similar to the lens pitch distance, and the aperture layer 140 defines a stop region 146 (i.e., an opaque or reflecting region) between adjacent apertures such that the apertures define discrete, non-overlapping fields of view for their corresponding sense channels. At increasingly smaller diameters up

to a diffraction-limited diameter – which is a function of wavelength of incident light and numeric aperture of the bulk imaging lens – an aperture defines a narrower field of view (i.e., a field of view of smaller diameter) and passes a sharper but lower-intensity (attenuated) signal from the bulk imaging optic 130 into its corresponding lens. The aperture layer 140 can therefore define apertures of diameter: greater than the diffraction-limited diameter for the wavelength of light output by the illumination sources (e.g., 900 nm); substantially greater than the thickness of the aperture layer 140; and less than the aperture pitch distance, which is substantially equivalent to the lens pitch distance and the pixel pitch distance. In one example, aperture layer 140 can define apertures of diameters approaching the diffraction-limited diameter to maximize geometrical selectivity of the field of view of each sense channel. Alternatively, the apertures can be of diameter less that the diffraction-limited diameter for the wavelength of light output by the illumination sources. In one example, the aperture layer 140 can define apertures of diameters matched to a power output of illumination sources in the system and to a number and photon detection capacity of subpixel photodetectors in each pixel in the set of pixels 170 to achieve a target number of photons incident on each pixel within each sampling period. In this example, each aperture can define a particular diameter that achieves target attenuation range for pixels originating from a corresponding illumination source and incident on the bulk imaging optic 130 during a sampling period. In particular, because an aperture in the aperture layer 140 attenuates a signal passed to its corresponding lens and on to its corresponding pixel, the diameter of the aperture can be matched to the dynamic range of its corresponding pixel.

[0024] In one implementation, a first aperture 141 in the aperture layer 140 passes light rays – reflected from a discrete region of a surface in the field (the field of view of the sense channel) ahead of the bulk imaging optic 130 – into its corresponding lens; a stop region 146 interposed between the first aperture 141 and adjacent apertures in the aperture layer 140 blocks light rays – reflected from a region of the surface outside of the field of view of the first aperture 141 – from passing into the lens corresponding to the first aperture 141. In the one-dimensional optical system 100, the aperture layer 140 therefore defines a column of apertures that define multiple discrete, non-overlapping fields of view of substantially infinite depth of field, as shown in FIG. 2.

[0025] In this implementation, a first aperture 141 in the aperture layer 140 defines a field of view that is distinct and that does not intersect a field of view defined by another aperture in the aperture layer 140, as shown in FIG. 2. The set of illumination sources 110 includes a first illumination source 111 paired with the first aperture 141 and configured to project an illuminating beam substantially aligned with (i.e., overlapping) the field of view of the first aperture 141 in the field ahead of the bulk imaging optic 130. Furthermore, the first illumination source 111 and a bulk transmitting optic 120 can cooperate to project an illuminating beam of a cross-section substantially similar to (and slightly larger than) the cross section of the field of view of the first aperture 141 as various distances from the bulk imaging optic 130. Therefore light output by the first illumination source 111 – paired with the first aperture 141 – and projected into the field of view of the first aperture 141 can remain substantially outside the fields of view of other apertures in the aperture layer 140.

[0026] Generally, photons projected into the field by the first illumination source 111 illuminate a particular region of a surface (or multiple surfaces) in the field within the field of view of the first sense channel and are reflected (e.g., scattered) by the surface(s); at least some of these photons reflected by the particular region of a surface may reach the bulk imaging optic 130, which directs these photons toward the focal plane. Because these photons were reflected by a region of a surface within the field of view of the first aperture 141, the bulk imaging optic 130 may project these photons into the first aperture 141, and the first aperture 141 may pass these photons into the first lens 151 (or a subset of these photons incident at an angle relative to the axis of the first aperture 141 below a threshold angle). However, because a second aperture 142 in the aperture layer 140 is offset from the first aperture 141 and because the particular region of the surface in the field illuminated via the first illumination source 111 does not (substantially) coincide with the field of view of the second aperture 142, photons reflected by the particular region of the surface and reaching the bulk imaging optic 130 are projected into the second aperture 142 and passed to a second lens 152 behind the second aperture 142, and vice versa, as shown in FIG. 2. Furthermore, a stop region 146 between the first and second apertures 142 can block photons directed toward the focal plane between the first and second apertures 142 reflected by the bulk imaging optic 130, thereby reducing crosstalk between the first and second sense channels.

[0027] For a first aperture 141 in the aperture layer 140 paired with a first illumination source 111 in the set of illumination sources 110, the first aperture 141 in the aperture layer 140 defines a first field of view and passes – into the first lens 151 – incident light rays originating at or reflected from a surface in the field coinciding with the first field of view. Because the first illumination source 111 projects an illuminating beam that is substantially coincident (and substantially the same size as or minimally larger than) the field of view defined by the first aperture 141 (as shown in FIG. 4), a signal passed into the first lens 151 by the first aperture 141 in the aperture layer 140 can exhibit a relatively high ratio of light rays originating from the first illumination source 111 to light rays originating from other illumination sources in the system. Generally, because various illumination sources in the system may output illuminating beams at different frequencies, duty cycles, and/or power levels, etc. at a particular time during operation, light rays passed from the bulk imaging optic 130 into a first pixel 171 in the set of pixels 170 but originating from an illumination source other than the first illumination source 111 paired with the first pixel 171 constitute noise at the first pixel 171. Though the relatively small diameters of apertures in the aperture layer 140 may attenuate a total light signal passed from the bulk imaging optic 130 into the set of lenses 150, each aperture in the aperture layer 140 may pass a relatively high proportion of photons originating from its corresponding illumination source than from other illumination sources in the system; that is, due to the geometry of a particular aperture and its corresponding illumination source, a particular aperture may pass a signal exhibiting a relatively high SNR to its corresponding lens and thus into its corresponding pixel. Furthermore, at smaller aperture diameters in the aperture layer 140 – and therefore smaller fields of view of corresponding channels – the system can pass less noise from solar radiation or other ambient light sources to the set of pixels 170.

[0028] In one variation, the system includes a second aperture layer interposed between the lens array and the optical filter 160, wherein the second aperture layer defines a second set of apertures 144, each aligned with a corresponding lens in the set of lenses 150, as described above. In this variation, an aperture in the second aperture layer 140 can absorb or reflect errant light rays passed by a corresponding lens, as described above, to further reduce crosstalk between channels, thereby improving SNR within the system. Similarly, the system can additionally or alternatively include a third aperture layer interposed between the optical filter 160 and the diffuser(s) 180, wherein the third aperture layer

defines a third set of apertures 144, each aligned with a corresponding lens in the set of lenses 150, as described above. In this variation, an aperture in the third aperture layer can absorb or reflect errant light rays passed by the light filter, as described above, to again reduce crosstalk between channels, thereby improving SNR within the system.

1.4 Lens Array

[0029] The system includes a set of lenses 150, wherein each lens in the set of lenses 150 is characterized by a second focal length, is offset from the focal plane opposite the bulk imaging optic 130 by the second focal length, is aligned with a corresponding aperture in the set of apertures 144, and is configured to collimate light rays passed by the corresponding aperture. Generally, a lens in the set of lenses 150 functions to collimate lights rays passed by its corresponding aperture and to pass these collimated light rays into the optical filter 160.

[0030] In the one-dimensional optical system 100, the lenses are arranged in a single column, and adjacent lenses are offset by a uniform lens pitch distance (i.e., a center-to-center-distance between adjacent pixels), as shown in FIG. 3. The set of lenses 150 is interposed between the aperture layer and the optical filter 160. In particular, each lens can include a converging lens characterized by a second focal length and can be offset from the focal plane of the bulk imaging optic 130 – opposite the bulk imaging optic 130 – by the second focal length to preserve the aperture of the bulk imaging optic 130 and to collimate light incident on the bulk imaging optic 130 and passed by a corresponding aperture. Each lens in the set of lens can be characterized by a relatively short focal length (i.e., less than a focal length of the bulk imaging optic 130) and a relatively large marginal ray angle (e.g., a relatively high numeric aperture lens) such that the lens can capture highly-angled light rays projected toward the lens by the extent of the bulk imaging optic 130. That is, each lens in the set of lens can be characterized by a ray cone substantially matched to a ray cone of the bulk imaging optic 130.

[0031] Lenses in the set of lenses 150 can be substantially similar. A lens in the set of lenses 150 is configured to collimate light rays focused into its corresponding aperture by the bulk imaging optic 130. For example, a lens in the set of lenses 150 can include a bi-convex or plano-convex lens characterized by a focal length selected based on the size (e.g., diameter) of its corresponding aperture and the operating wavelength of the system. In this

example, the focal length (f) of a lens in the set of lenses 150 can be calculated according to the formula:

$$f = \frac{d^2}{2\lambda}$$

where d is the diameter of the corresponding aperture in the aperture layer and λ is the operating wavelength of light output by the illumination source (e.g., 900 nm). The geometry of a lens in the set of lenses 150 can therefore be matched to the geometry of a corresponding aperture in the aperture layer such that the lens passes a substantially sharp image of light rays – at or near the operating wavelength – into the optical filter 160 and thus on to the pixel array.

[0032] However, the set of lenses 150 can include lenses of any other geometry and arranged in any other way adjacent the aperture layer.

1.5 Optical Filter

[0033] As shown in FIG. 3, the system includes an optical filter 160 adjacent the set of lenses 150 opposite the aperture layer and configured to pass light rays at the operating wavelength. Generally, the optical filter 160 receives electromagnetic radiation across a spectrum from the set of lenses 150, passes a relatively narrow band of electromagnetic radiation – including radiation at the operating wavelength – to the pixel array, and blocks electromagnetic radiation outside of the band. In particular, electromagnetic radiation other than electromagnetic radiation output by the illumination source – such as ambient light – incident on a pixel in the set of pixels 170 constitutes noise in the system. The optical filter 160 therefore functions to reject electromagnetic radiation outside of the operating wavelength or, more pragmatically, outside of a narrow wavelength band, thereby reducing noise in the system and increasing SNR.

[0034] In one implementation, the optical filter 160 includes an optical bandpass filter that passes a narrow band of electromagnetic radiation substantially centered at the operating wavelength of the system. In one example, the illumination sources output light (predominantly) at an operating wavelength of 900 nm, and the optical filter 160 is configured to pass light between 899.95 nm and 900.05 nm and to block light outside of this band.

[0035] The optical filter 160 may selectively pass and reject wavelengths of light as a function of angle of incidence on the optical filter 160. Generally, optical bandpass filters may pass wavelengths of light inversely proportional to their angle of incidence on the light optical bandpass filter. For example, for an optical filter 160 including a 0.5 nm-wide optical bandpass filter, the optical filter 160 may pass over 95% of electromagnetic radiation over a sharp band from 899.75 nm to 900.25 nm and reject approximately 100% of electromagnetic radiation below 899.70 nm and above 900.30 nm for light rays incident on the optical filter 160 at an angle of incidence of approximately 0°. However, in this example, the optical filter 160 may pass over 95% of electromagnetic radiation over a narrow band from 899.5 nm to 900.00 nm and reject approximately 100% of electromagnetic radiation over a much wider band below 899.50 nm and above 900.30 nm for light rays incident on the optical filter 160 at an angle of incidence of approximately 15°. Therefore, the incidence plane of the optical filter 160 can be substantially normal to the axes of the lenses, and the set of lenses 150 can collimate light rays received through a corresponding aperture and output these light rays substantially normal to the incidence plane of the optical filter 160 (i.e., at an angle of incidence of approximately 0° on the optical filter). Specifically, the set of lenses 150 can output light rays toward the optical filter 160 at angles of incidence approximating 0° such that substantially all electromagnetic radiation passed by the optical filter 160 is at or very near the operating wavelength of the system.

[0036] In the one-dimensional optical system 100, the system can include a single optical filter 160 that spans the column of lens in the set of lenses 150. Alternatively, the system can include multiple optical filters 160, each adjacent a single lens or a subset of lenses in the set of lenses 150. However, the optical filter 160 can define any other geometry and can function in any other way to pass only a limited band of wavelengths of light.

1.6 Pixel Array and Diffuser

[0037] The system includes a set of pixels 170 adjacent the optical filter 160 opposite the set of lenses 150, each pixel in the set of pixels 170 corresponding to a lens in the set of lenses 150 and including a set of subpixels arranged along a second axis non-parallel to the first axis. Generally, the set of pixels 170 are offset from the optical filter 160 opposite the set of lenses 150, and each pixel in the set of pixels 170 functions to output a single signal or stream of signals corresponding to the count of photons incident on the pixel within one

or more sampling periods, wherein each sampling period may be picoseconds, nanoseconds, microseconds, or milliseconds in duration.

[0038] The system also includes a diffuser 180 interposed between the optical filter 160 and the set of pixels 170 and configured to spread collimated light output from each lens in the set of lenses 150 across a set of subpixels of a single corresponding pixel in the set of pixels 170. Generally, for each lens in the set of lenses 150, the diffuser 180 functions to spread light rays – previously collimated by the lens and passed by the optical filter 160 – across the width and height of a sensing area within a corresponding pixel. The diffuser 180 can define a single optic element spanning the set of lenses 150, or the diffuser 180 can include multiple discrete optical elements, such as including one optical diffuser element aligned with each channel in the system.

[0039] In one implementation, a first pixel 171 in the set of pixels 170 includes an array of single-photon avalanche diode detectors (hereinafter "SPADs"), and the diffuser 180 spreads lights rays – previously passed by a corresponding first aperture 141, collimated by a corresponding first lens 151, and passed by the optical filter 160 – across the area of the first pixel 171, as shown in FIGS. 3, 5, and 6. Generally, adjacent apertures can be aligned and offset vertically by an aperture pitch distance, adjacent lenses can be aligned and offset vertically by a lens pitch distance substantially identical to the aperture pitch distance, and adjacent pixels can be aligned and offset vertically by a pixel pitch distance substantially identical to the lens and aperture pitch distances. However, the pixel pitch distance may accommodate only a relatively small number of (e.g., two) vertically-stacked SPADs. Each pixel in the set of pixels 170 can therefore define an aspect ratio greater than 1:1, and the diffuser 180 can spread light rays passed by the optical filter 160 according to the geometry of a corresponding pixel in order to accommodate a larger sensing area per pixel.

[0040] In one example, each pixel in the set of pixels 170 is arranged on an image sensor, and a first pixel 171 in the set of pixels 170 includes a single row of 16 SPADs spaced along a lateral axis perpendicular to a vertical axis bisecting the column of apertures and lenses. In this example, the height of a single SPAD in the first pixel 171 can be less than the height (e.g., diameter) of the first lens 151, but the total length of the 16 SPADs can be greater than the width (e.g., diameter) of the first lens 151; the diffuser 180 can therefore converge light rays output from the first lens 151 to a height corresponding to the height of a SPAD at the plane of the first pixel 171 and can diverge light rays output from the first

lens 151 to a width corresponding to the width of the 16 SPADs at the plane of the first pixel 171. In this example, the remaining pixels in the set of pixels 170 can include similar rows of SPADs, and the diffuser 180 can similarly converge and diverge light rays passed by corresponding apertures onto corresponding pixels.

[0041] In the foregoing example, the aperture layer can include a column of 16 like apertures, the set of lenses 150 can include a column of 16 like lenses arranged behind the aperture layer, and the set of pixels 170 can include a set of 16 like pixels – each including a similar array of SPADs – arranged behind the set of lenses 150. For a 6.4 mm-wide, 6.4 mm-tall image sensor, each pixel can include a single row of 16 SPADs, wherein each SPAD is electrically coupled to a remote analog front-end processing electronics/digital processing electronics circuit 240. Each SPAD can be arranged in a 400 μm-wide, 400 μm-tall SPAD area and can define an active sensing area approaching 400 μm in diameter. Adjacent SPADs can be offset by a SPAD pitch distance of 400 μm. In this example, the aperture pitch distance along the vertical column of apertures, the lens pitch distance along the vertical column of lenses, and the pixel pitch distance along the vertical column of pixels can each be approximately 400 μm accordingly. For the first sense channel in the system (i.e., the first aperture 141, the first lens 151, and the first pixel 171, etc.), a first diffuser 180 can diverge a cylindrical column of light rays passed from the first lens 151 through the optical filter 160 – such as a column of light approximately 100 μm in diameter for an aperture layer aspect ratio of 1:4 – to a height of approximately 400 μm aligned vertically with the row of SPADs in the first pixel 171. The first diffuser can similarly diverge the cylindrical column of light rays passed from the first lens 151 through the optical filter 160 to a width of approximately 6.4 μm centered horizontally across the row of SPADs in the first pixel 171. Other diffusers 180 in the system can similarly diverge (or converge) collimated light passed by corresponding lenses across corresponding pixels in the set of pixels 170. Therefore, in this example, by connecting each SPAD (or each pixel) to a remote analog front-end processing electronics/digital processing electronics circuit 240 and by incorporating diffusers 180 that spread light passed by the optical filter 160 across the breadths and heights of corresponding pixels, the system can achieve a relatively high sensing area fill factor across the imaging sensor.

[0042] Therefore, in the one-dimensional optical system 100, pixels in the set of pixels 170 can include an array of multiple SPADS arranged in aspect ratio exceeding 1:1, and the

diffuser 180 can spread light rays across corresponding non-square pixels that enables a relatively large numbers of SPADs to be tiled across a single pixel to achieve a greater dynamic range across the image sensor than an image sensor with a single SPAD per pixel, as shown in FIG. 3. In particular, by incorporating multiple SPADs per pixel (i.e., per sense channel), a first sense channel in the system can detect multiple incident photons – originating from a surface in the field bound by a field of view defined by the first aperture 141 – within the span of the dead time characteristic of the SPADs. The first sense channel can therefore detect a "brighter" surface in its field of view. Additionally or alternatively, the first pixel 171 in the first sense channel can be sampled faster than the dead time characteristic of SPADs in the first pixel 171 because, though a first subset of SPADs in the first pixel 171 may be down (or "dead") during a first sampling period due to collection of incident photons during the first sampling period, other SPADs in the first pixel 171 remain on (or "alive") and can therefore collect incident photons during a subsequent sampling period. Furthermore, by incorporating pixels characterized by relatively high aspect ratios of photodetectors, the image sensor can include pixels offset by a relatively small pixel pitch, but the system 100 can still achieve a relatively high dynamic range pixel.

[0043] However, pixels in the set of pixels 170 can include any other number of SPADs arranged in any other arrays, such as in a 64-by-1 grid array (as described above), in a 32-by-2 grid array, or in a 16-by-4 grid array, and the diffuser 180 can converge and/or diverge collimated light rays onto corresponding pixels accordingly in any other suitable way. Furthermore, rather than (or in addition to) SPADs, each pixel in the set of pixels 170 can include one or more linear avalanche photodiodes, Geiger mode avalanche photodiodes, photomultipliers, resonant cavity photodiodes, QUANTUM DOT detectors, or other types of photodetectors arranged as described above, and the diffuser(s) 180 can similarly converge and diverge signals passed by the optical filter(s) 160 across corresponding pixels, as described herein.

1.7 Illumination Sources

[0044] The system includes a set of illumination sources 110 arranged along a first axis, each illumination source in the set of illumination sources 110 configured to output an illuminating beam of an operating wavelength toward a discrete spot in a field ahead of the illumination source. Generally, each illumination source functions to output an illuminating

beam coincident a field of view defined by a corresponding aperture in the set of apertures 144, as shown in FIGS. 1 and 2.

[0045] In one implementation, the set of illumination sources 110 includes a bulk transmitter optic and one discrete emitter per sense channel. For example, the set of illumination sources 110 can include a monolithic VCSEL arrays including a set of discrete emitters. In this implementation, the bulk transmitter optic can be substantially identical to the bulk imaging optic 130 in material, geometry (e.g., focal length), thermal isolation, etc., and the bulk transmitter optic is adjacent and offset laterally and/or vertically from the bulk imaging optic 130. In a first example, set of illumination sources 110 includes a laser array including discrete emitters arranged in a column with adjacent emitters offset by an emitter pitch distance substantially identical to the aperture pitch distance. In this first example, each emitter outputs an illuminating beam of diameter substantially identical to or slightly greater than the diameter of a corresponding aperture in the apertures layer, and the column of emitters is arranged along the focal plane of the bulk transmitter optic such that each illuminating beam projected from the bulk transmitter optic into the field intersects and is of substantially the same size and geometry as the field of view of the corresponding sense channel, as shown in FIG. 4. Therefore, substantially all power output by each emitter in the set of illumination sources 110 can be projected into the field of view of its corresponding sense channel with relatively minimal power wasted illuminating surfaces in the field outside of the fields of view of the sense channels.

[0046] In a second example, the discrete emitters are similarly arranged in a column with adjacent emitters offset by an emitter pitch distance twice the aperture pitch distance, as shown in FIG. 2. In this second example, each emitter is characterized by an illuminating active area (or aperture) of diameter approximately (or slightly greater than) twice the diameter of a corresponding aperture in the apertures layer, and the column of emitters is offset behind the bulk transmitter optic by twice the focal length of the bulk transmitter optic such that each illuminating beam projected from the bulk transmitter optic into the field intersects and is of substantially the same size and geometry as the field of view of the corresponding sense channel, as described above. Furthermore, for the same illumination beam power density, an illuminating beam output by an emitter in this second example may contain four times the power of an illuminating beam output by an emitter in the first example described above. The system can therefore include a set of emitter arranged

according to an emitter pitch distance, configured to output illuminating beams of diameter, and offset behind the bulk transmitter optic by an offset distance as a function of a scale factor (e.g., 2.0 or 3.0) and 1) the aperture pitch distance in the aperture layer, 2) the diameter of apertures in the aperture layer, and 3) the focal length of bulk transmitter optic, respectively. The system can therefore include an illuminating subsystem that is proportionally larger than a corresponding receiver subsystem to achieve greater total output illumination power within the same beam angles and fields of view of corresponding channels in the receiver subsystem.

[0047] The system can also include multiple discrete sets of illumination sources, each set of illumination sources 110 paired with a discrete bulk transmitter optic adjacent the bulk imaging optic 130. For example, the system can include a first bulk transmitter optic, a second bulk transmitter optic, and a third bulk transmitter optic patterned radially about the bulk imaging optic 130 at a uniform radial distance from the center of the bulk imaging optic 130 and spaced apart by an angular distance of 120°. In this example, the system can include a laser array with one emitter – as described above – behind each of the first, second, and third bulk transmitter optics. Each discrete laser array and its corresponding bulk transmitter optic can thus project a set of illuminating beams into the fields of view of defined by corresponding in the apertures in the aperture layer. Therefore, in this example, the three discrete laser arrays and the three corresponding bulk transmitter optics can cooperate to project three times the power onto the fields of view of the sense channels in the system, as compared to a single laser array and one bulk transmitter optic. Additionally or alternatively, the system can include multiple discrete layer arrays and bulk transmitter optics to both: 1) achieve a target illumination power output into the field of view of each sensing channel in the receiver subsystem with multiple lower-power emitters per sensing channel; and 2) distribute optical energy over a larger area in the near-field to achieve an optical energy density less than a threshold allowable optical energy density for the human eye.

[0048] However, the system can include any other number and configuration of illumination source sets and bulk transmitter optics configured to illuminate fields of view defined by the sense channels. The set of illumination sources 110 can also include any other suitable type of optical transmitter, such as a 1x16 optical splitter powered by a single

laser diode, a side-emitting laser diode array, an LED array, or a quantum dot LED array, etc.

1.8 Fabrication

[0049] In one implementation, the bulk receiver lens, the aperture layer, the set of lenses 150, the optical filter 160, and the diffuser 180 are fabricated and then aligned with and mounted onto an image sensor. For example, the optical filter 160 can be fabricated by coating a fused silica substrate. Photoactive optical polymer can then be deposited over the optical filter 160, and a lens mold can be placed over the photoactive optical polymer and a UV light source activated to cure the photoactive optical polymer in the form of lenses patterned across the optical filter 160. Standoffs can be similarly molded or formed across the optical filter 160 via photolithography techniques, and an aperture layer defined by a selectively-cured, metallized glass wafer can then be bonded or otherwise mounted to the standoffs to form the aperture layer. The assembly can then be inverted, and a set of discrete diffusers and standoffs can be similarly fabricated across the opposite side of the optical filter 160. A discrete image sensor can then be aligned with and bonded to the standoffs, and a bulk imaging optic 130 can be similarly mounted over the aperture layer.

[0050] Alternatively, photolithography and wafer level bonding techniques can be implemented to fabricate the bulk imaging optics, the aperture layer, the set of lenses 150, the optical filter 160, and the diffuser 180 directly on to the un-diced semiconductor wafer containing the detector chips in order to simplify manufacturing, reduce cost, and reduce optical stack height for decreased pixel crosstalk.

2. One-Dimensional Optical System: Lens Tube

[0051] One variation of the system includes: a set of illumination sources 110 arranged along a first axis, each illumination source in the set of illumination sources 110 configured to output an illuminating beam of an operating wavelength toward a discrete spot in a field ahead of the illumination source; a bulk imaging optic 130 characterized by a focal plane opposite the field; a set of lens tubes 210 arranged in a line array parallel to the first axis, each lens tube in the set of lens tubes 210 including: a lens characterized by a focal length, offset from the focal plane by the focal length, and configured to collimate light rays reflected into the bulk imaging optic 130 from a discrete spot in the field illuminated by a corresponding illumination source in the set of optics into the bulk imaging optic 130; and a

cylindrical wall 218 extending from the lens opposite the focal plane, defining a long axis substantially perpendicular to the first axis, and configured to absorb incident light rays reflected into the bulk imaging optic 130 from a region in the field outside the discrete spot illuminated by the corresponding illumination source. In this variation, the system also includes: an optical filter 160 adjacent the set of lens tubes 210 opposite the focal plane and configured to pass light rays at the operating wavelength; a set of pixels 170 adjacent the optical filter 160 opposite the set of lenses 150, each pixel in the set of pixels 170 corresponding to a lens in the set of lenses 150 and including a set of subpixels aligned along a third axis perpendicular to the first axis; and a diffuser 180 interposed between the optical filter 160 and the set of pixels 170 and configured to spread collimated light output from each lens in the set of lenses 150 across a set of subpixels of a corresponding pixel in the set of pixels 170.

[0052] Generally, in this variation, the system includes a lens tube in replacement of (or in addition to) each aperture and lens pair described above. In this variation, each lens tube can be characterized by a second (short) focal length and can be offset from the focal plane of the bulk imaging optic 130 by the second focal length to preserve the aperture of the bulk imaging optic 130 and to collimate incident light received from the bulk imaging optic 130, as described above and as shown in FIGS. 5 and 7.

[0053] Each lens tube also defines an opaque cylindrical wall 218 defining an axis normal to the incidence plane of the adjacent optical filter 160 and configured to absorb incident light rays, as shown in FIG. 5. Generally, at greater axial lengths, the cylindrical wall 218 of a lens tube may absorb light rays passing through the lens tube at shallower angles to the axis of the lens tube, thereby reducing the field of view of the lens tube (which may be similar to decreasing the diameter of an aperture in the aperture layer up to the diffraction-limited diameter, as described above) and yielding an output signal of collimated light rays nearer to perpendicular to the incidence plane of the optical filter 160. Each lens tube can therefore define an elongated cylindrical wall 218 of length sufficient to achieve a target field of view and to pass collimated light rays at maximum angles to the axis of the lens tube less than a threshold angle. In this variation, a lens tube can thus function as an aperture-sense pair described above to define a narrow field of view and to output substantially collimated light to the adjacent optical filter 160.

[0054] The cylindrical wall 218 of a lens tube can define a coarse or patterned opaque interface about a transparent (or translucent) lens material, as shown in FIG. 5, to increase absorption and decrease reflection of light rays incident on the cylindrical wall 218. Each lens tube (and each lens described above) can also be coated with an anti-reflective coating.

[0055] As shown in FIG. 9, in this variation, the set of lens tubes 210 can be fabricated by implementing photolithography techniques to pattern a photoactive optical polymer (e.g., SU8) onto the optical filter 160 (e.g., on a silicon wafer defining the optical filter). A light-absorbing polymer can then be poured between the lens tubes and cured. A set of lenses 150 can then be fabricated (e.g., molded) separately and then bonded over the lens tubes. Alternatively, lenses can be fabricated directly onto the lens tubes by photolithography techniques. Yet alternatively, a mold for lenses can be cast directly onto the lens tubes by injecting polymer into a mold arranged over the lens tubes. A singular diffuser 180 or multiple discrete diffusers 180 can be similarly fabricated and/or assembled on the optical filter 160 opposite the lens tubes. Standoffs extending from the optical filter 160 can be similarly fabricated or installed around the diffuser(s) 180, and the image sensor can be aligned with and bonded to the standoffs opposite the optical filter 160. Other optical elements within the system (e.g., the bulk imaging lens, the bulk transmitting lens, etc.) can be fabricated according to similar techniques and with similar materials.

3. Two-Dimensional Optical System

[0056] Another variation of the system includes: a set of illumination sources 110 arranged in a first rectilinear grid array, each illumination source in the set of illumination sources 110 configured to output an illuminating beam of an operating wavelength toward a discrete spot in a field ahead of the illumination source; a bulk imaging optic 130 characterized by a focal plane opposite the field; an aperture layer coincident the focal plane, defining a set of apertures 144 in a second rectilinear grid array proportional to the first rectilinear grid array, and defining a stop region 146 around the set of apertures 144, each aperture in the set of apertures 144 defining a field of view in the field coincident a discrete spot output by a corresponding illumination source in the set of illumination sources 110, the stop region 146 absorbing light rays reflected from surfaces in the field outside of fields of view defined by the set of apertures 144 and passing through the bulk imaging optic 130; a set of lenses 150, each lens in the set of lenses 150 characterized by a second focal length, offset from the focal plane opposite the bulk imaging optic 130 by the

second focal length, aligned with an aperture in the set of apertures 144, and configured to collimate light rays passed by the aperture; an optical filter 160 adjacent the set of lenses 150 opposite the aperture layer and configured to pass light rays at the operating wavelength; a set of pixels 170 adjacent the optical filter 160 opposite the set of lenses 150, each pixel in the set of pixels 170 aligned with a subset of lenses in the set of lenses 150; and a diffuser 180 interposed between the optical filter 160 and the set of pixels 170 and configured to spread collimated light output from each lens in the set of lenses 150 across a corresponding pixel in the set of pixels 170.

[0057] Generally, in this variation, the system includes a two-dimensional grid array of channels (i.e., aperture, lens, and pixel sets or lens tube and pixel sets) and is configured to image a volume occupied by the system in two dimensions. The system can collect one-dimensional distance data – such as counts of incident photons within a sampling period and/or times between consecutive photons incident on pixels of known position corresponding to known fields of view in the field – across a two-dimensional field. The one-dimensional distance data can then be merged with known positions of the fields of view for each channel in the system to reconstruct a virtual three-dimensional representation of the field ahead of the system.

[0058] In this variation, the aperture layer can define a grid array of apertures, the set of lenses 150 can be arranged in a similar grid array with one lens aligned with one aperture in the aperture layer, and the set of pixels 170 can include one pixel per aperture and lens pair, as described above. For example, the aperture layer can define a 24-by-24 grid array of 200-µm-diameter apertures offset vertically and laterally by an aperture pitch distance of 300 µm, and the set of lenses 150 can similarly define a 24-by-24 grid array of lenses offset vertically and laterally by a lens pitch distance of 300 µm. In this example, the set of pixels 170 can include a 24-by-24 grid array of 300-µm-square pixels, wherein each pixel includes a 3x3 square array of nine 100-µm-square SPADs.

[0059] Alternatively, in this variation, the set of pixels 170 can include one pixel per group of multiple aperture and lens pairs. In the foregoing example, the set of pixels 170 can alternatively include a 12-by-12 grid array of 600-µm-square pixels, wherein each pixel includes a 6x6 square array of 36 100-µm-square SPADs and wherein each pixel is aligned with a group of four adjacent lenses in a square grid. In this example, for each group of four adjacent lenses, the diffuser 180: can bias collimated light rays output from a lens in the

(1,1) position in the square grid upward and to the right to spread light rays passing through the (1,1) lens across the full breadth and width of the corresponding pixel; can bias collimated light rays output from a lens in the (2,1) position in the square grid upward and to the left to spread light rays passing through the (2,1) lens across the full breadth and width of the corresponding pixel; can bias collimated light rays output from a lens in the (1,2) position in the square grid downward and to the right to spread light rays passing through the (1,2) lens across the full breadth and width of the corresponding pixel; and can bias collimated light rays output from a lens in the (2,2) position in the square grid downward and to the left to spread light rays passing through the (2,2) lens across the full breadth and width of the corresponding pixel, as shown in FIG. 8.

[0060] In the foregoing example, for each group of four illumination sources in a square grid and corresponding to one group of four lenses in a square grid, the system can actuate one illumination source in the group of four illumination sources at any given instance in time. In particular, for each group of four illumination sources in a square grid corresponding to one pixel in the set of pixels 170, the system can actuate a first illumination source 111 in a (1,1) position during a first sampling period to illuminate a field of view defined by a first aperture 141 corresponding to a lens in the (1,1) position in the corresponding group of four lenses, and the system can sample all 36 SPADs in the corresponding pixel during the first sampling period. The system can then shut down the first illumination source 111 and actuate a second illumination source 112 in a (1,2) position during a subsequent second sampling period to illuminate a field of view defined by a second aperture 142 corresponding to a lens in the (1,2) position in the corresponding group of four lenses, and the system can sample all 36 SPADs in the corresponding pixel during the second sampling period. Subsequently, the system can then shut down the first and second illumination sources 112 and actuate a third illumination source in a (2,1) position during a subsequent third sampling period to illuminate a field of view defined by a third aperture corresponding to a lens in the (2,1) position in the corresponding group of four lenses, and the system can sample all 36 SPADs in the corresponding pixel during the third sampling period. Finally, the system can shut down the first, second, and third illumination sources and actuate a fourth illumination source in a (2,2) position during a fourth sampling period to illuminate a field of view defined by a fourth aperture corresponding to a lens in the (2,2) position in the corresponding group of four lenses, and the system can sample all

36 SPADs in the corresponding pixel during the fourth sampling period. The system can repeat this process throughout its operation.

[0061] Therefore, in the foregoing example, the system can include a set of pixels 170 arranged across an image sensor 7.2 mm in width and 7.2 mm in length and can implement a scanning schema such that each channel in the system can access (can project light rays onto) a number of SPADs otherwise necessitating a substantially larger image sensor (e.g., a 14.4 mm by 14.4 mm image sensor). In particular, the system can implement a serial scanning schema per group of illumination sources to achieve an exponential increase in the dynamic range of each channel in the system. In particular, in this variation, the system can implement the foregoing imaging techniques to increase imaging resolution of the system.

[0062] In the foregoing implementation, the system can also include a shutter 182 between each channel and the image sensor, and the system can selectively open and close each shutter 182 when the illumination source for the corresponding channel is actuated and deactivated, respectively. For example, the system can include one independently-operable electrochromic shutter 182 interposed between each lens, and the system can open the electrochromic shutter 182 over the (1,1) lens in the square-gridded group of four lenses and close electrochromic shutters 182 over the (1,2), (2,1), and (2,2) lens when the (1,1) illumination source is activated, thereby rejecting noise passing through the (1,2), (2,1), and (2,2) lens from reaching the corresponding pixel on the image sensor. The system can therefore selectively open and close shutters 182 between each channel and the image sensor to increase SNR per channel during operation. Alternatively, the system can include one independently-operable electrochromic shutter 182 arranged over select regions of each pixel, as shown in FIG. 8, wherein each electrochromic shutter 182 is aligned with a single channel (i.e., with a single lens in the set of lenses). The system can alternatively include MEMS mechanical shutters or any other suitable type of shutter interposed between the set of lenses 150 and the image sensor.

[0063] In this variation, the system can define two-dimension grid arrays of apertures, lenses, diffusers, and/or pixels characterized by a first pitch distance along a first (e.g., X) axis and a second pitch distance – different from the first pitch distance – along a second (e.g., Y) axis. For example, the image sensor can include pixels offset by a 25μm horizontal pitch and a 300μm vertical pitch, wherein each pixel includes a single row of twelve subpixels.

[0064] However, in this variation, the two-dimensional optical system can include an array of any other number and pattern of channels (e.g., apertures, lenses (or lens tubes), and diffusers) and pixels and can execute any other suitable scanning schema to achieve higher spatial resolutions per channel than the raw pixel resolution of the image sensor. The system can additionally or alternatively include a converging optic, a diverging optic, and/or any other suitable type of optical element to spread light rights passed from a channel across the breadth of a corresponding pixel.

[0065] As a person skilled in the art will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the embodiments of the invention without departing from the scope of this invention as defined in the following claims.

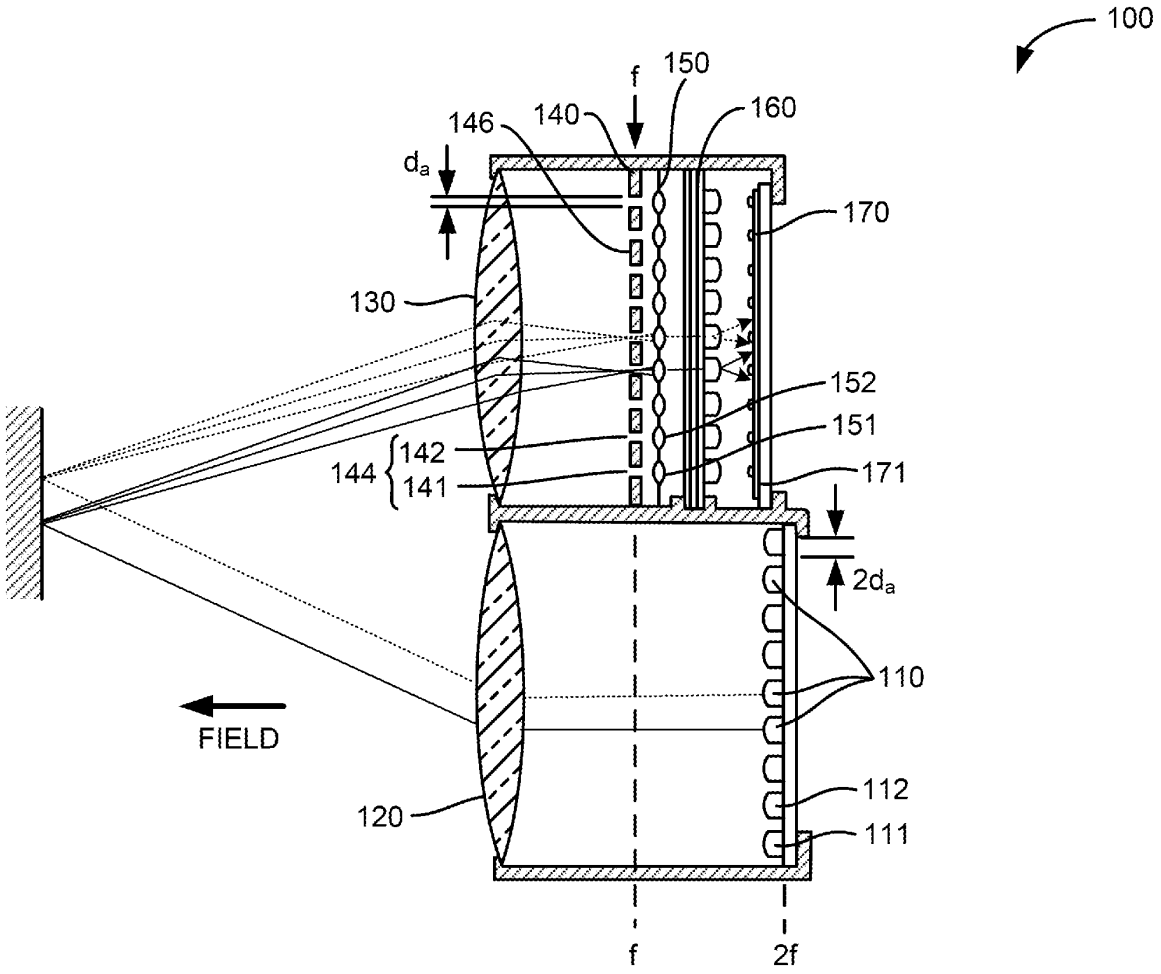

100
f
150
146
140
160
d_a
170
130
152
151
144
142
141
171
$2d_a$
110
FIELD
120
112
111
f
2f

FIG. 1

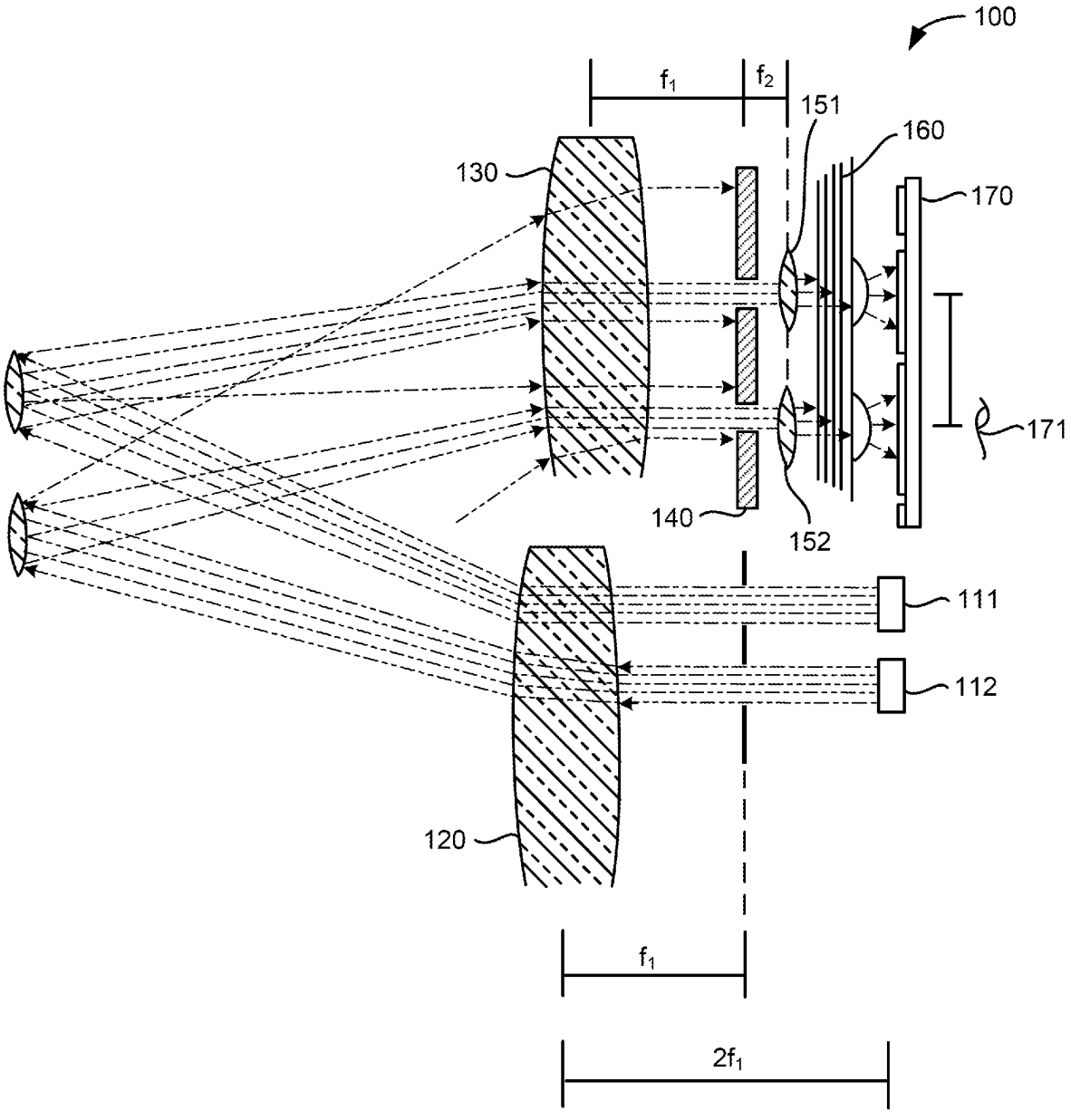


FIG. 2

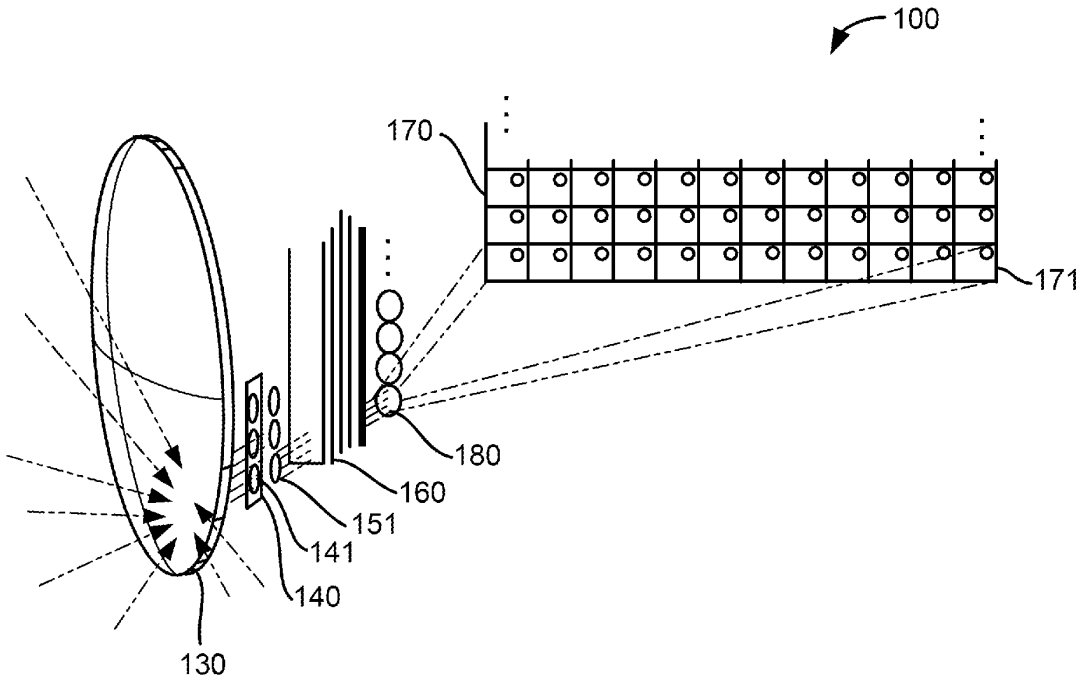


FIG. 3

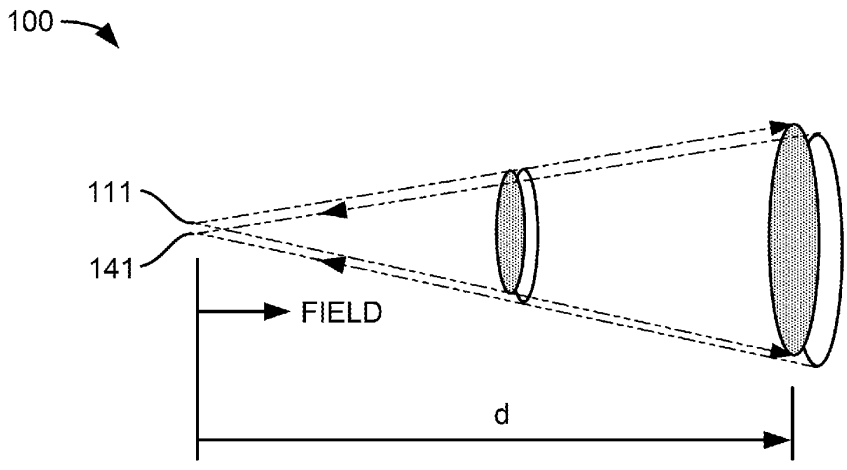


FIG. 4

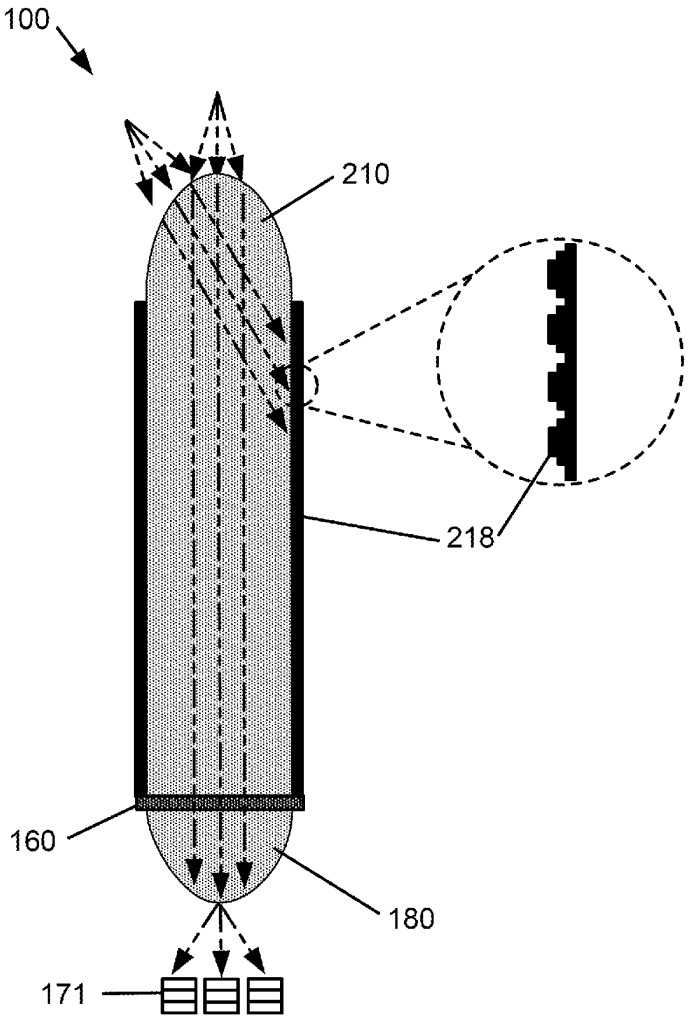


FIG. 5

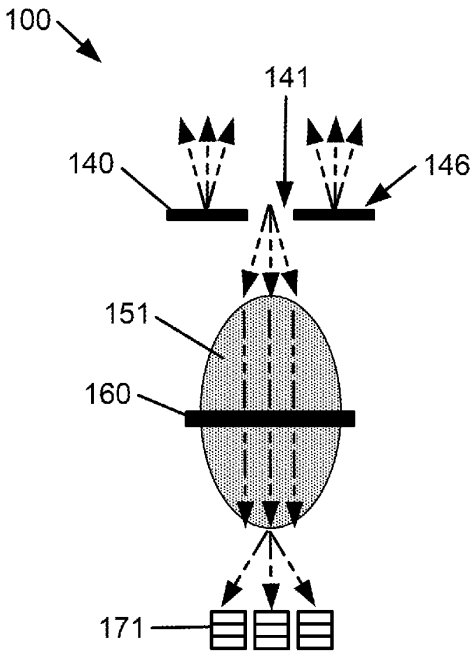


FIG. 6

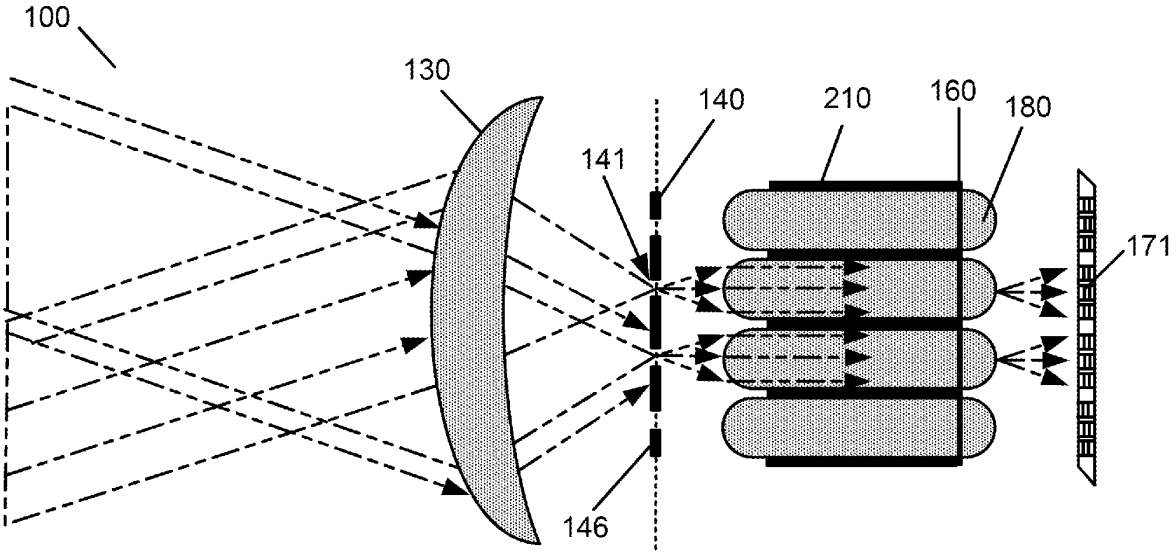

100
130
140
210
160
180
141
171
146

FIG. 7

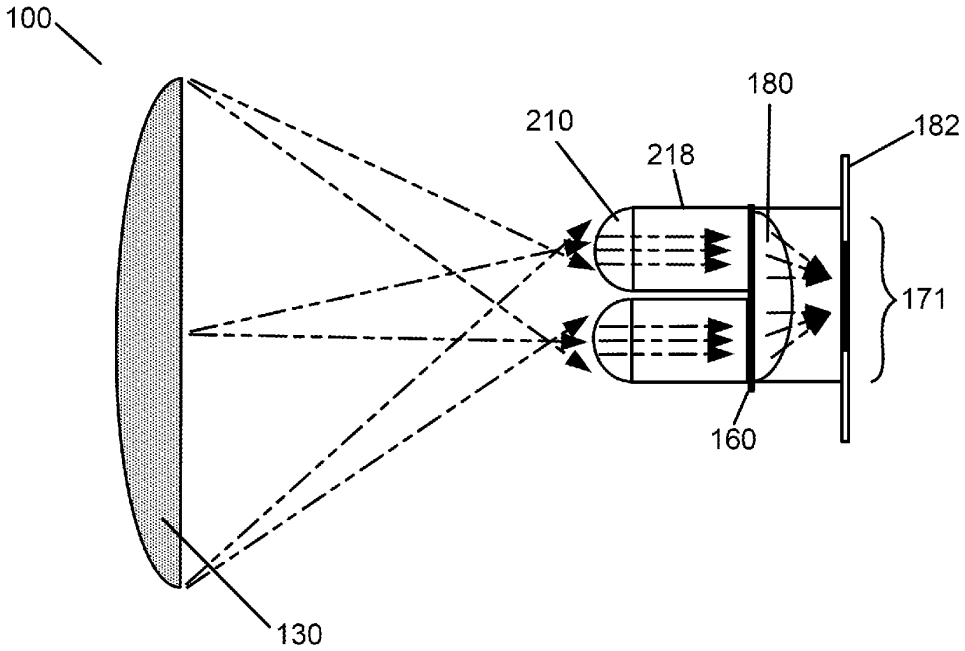

100
180
210
182
218
171
160
130

FIG. 8

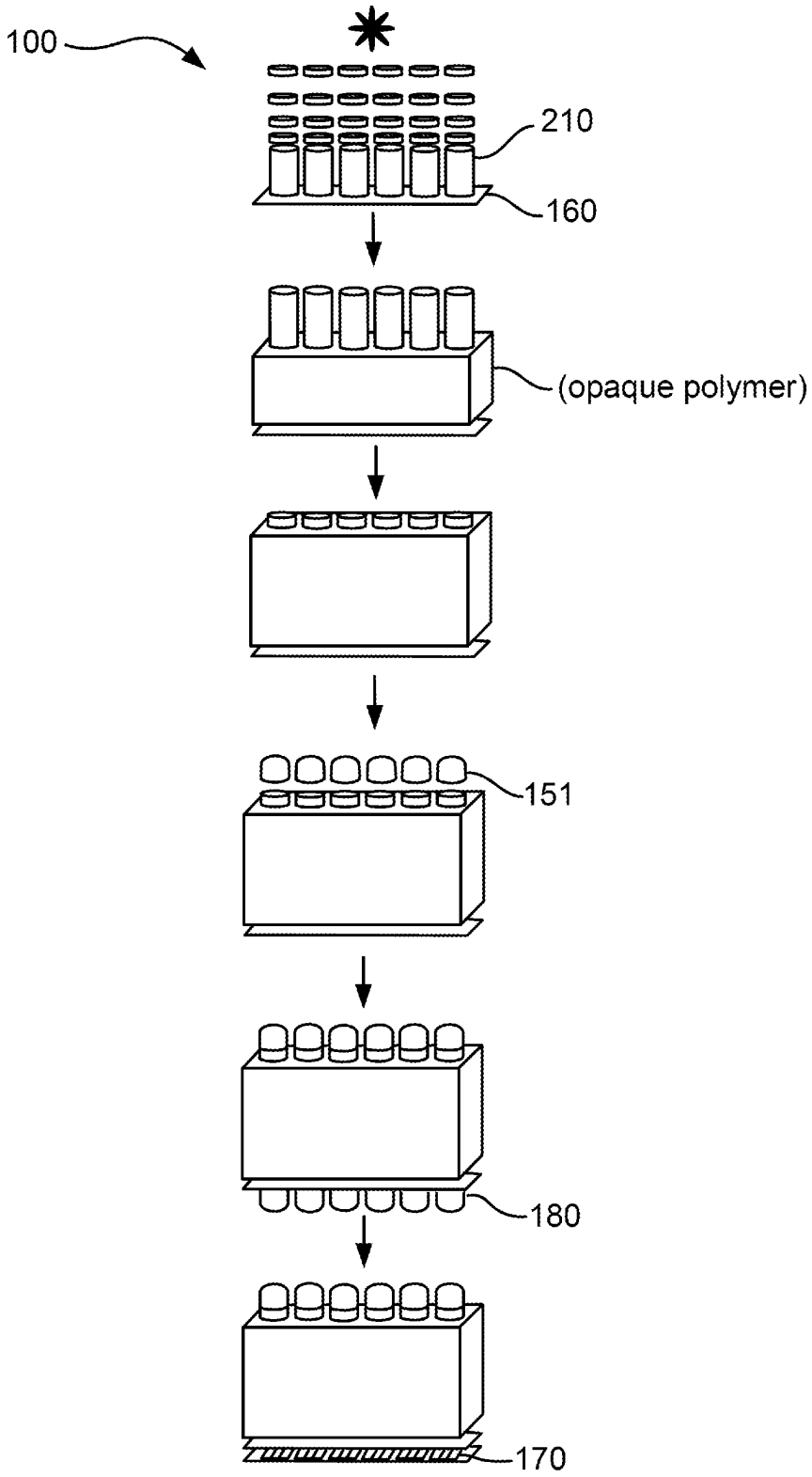


FIG. 9

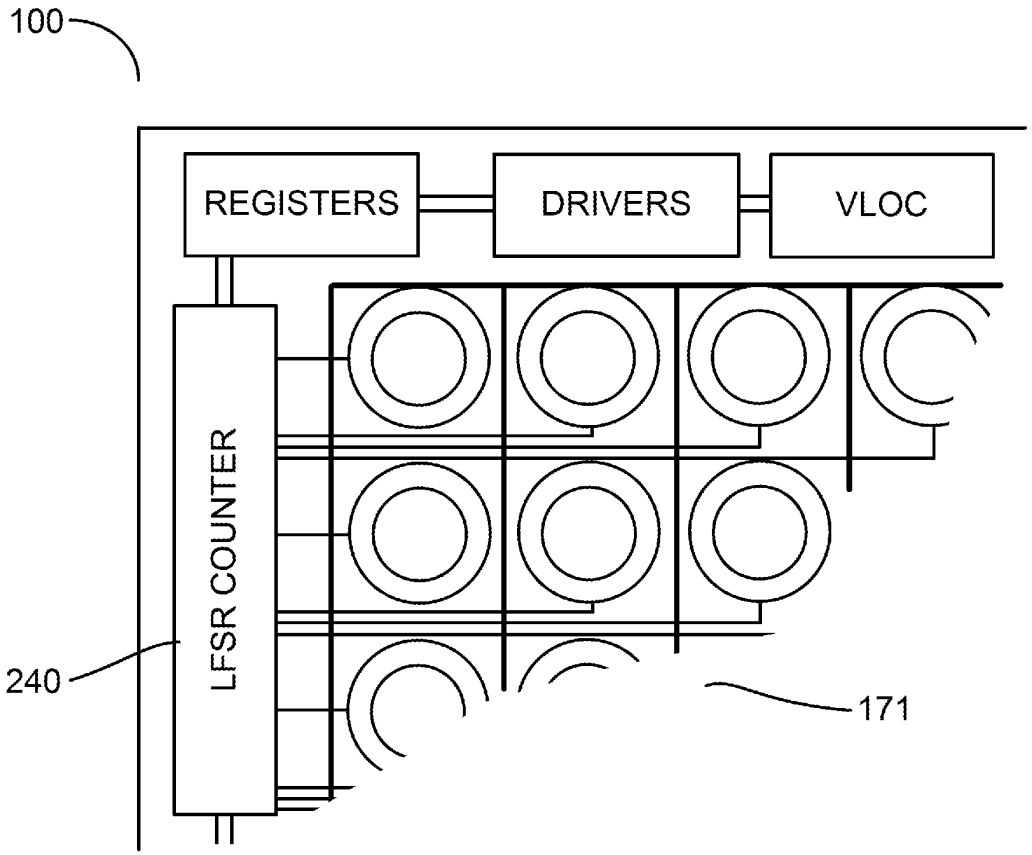
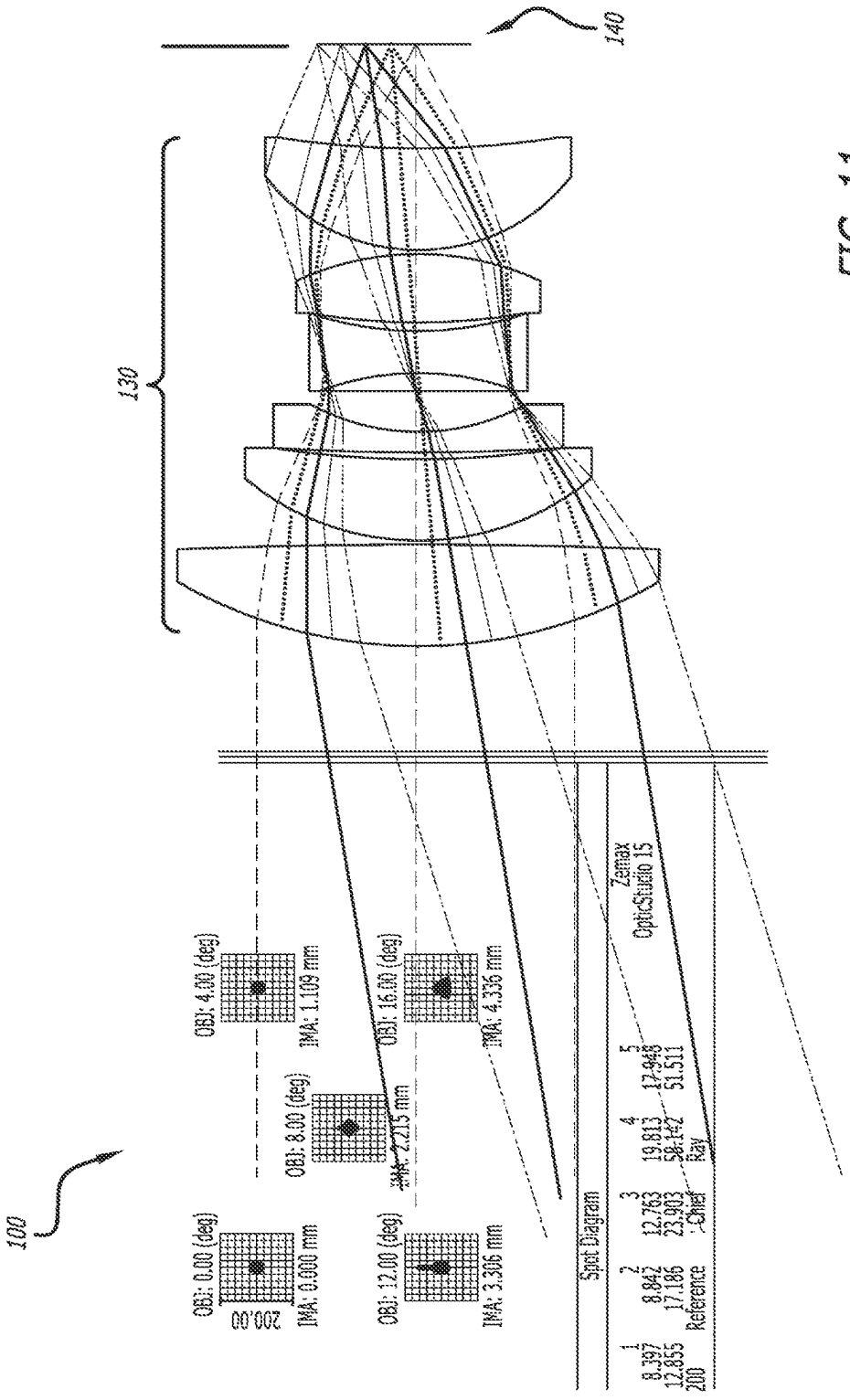


FIG. 10


100
130
140
OBJ: 0.00 (deg)
IMA: 0.000 mm
OBJ: 4.00 (deg)
IMA: 1.109 mm
OBJ: 8.00 (deg)
IMA: 2.215 mm
OBJ: 12.00 (deg)
IMA: 3.306 mm
OBJ: 16.00 (deg)
IMA: 4.336 mm
Spot Diagram
Zemax
OpticStudio 15
1 2 3 4 5
8.397 8.842 12.763 19.813 17.948
12.855 17.186 23.903 50.142 51.511
200 Reference Chief Ray

FIG, 11

DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)		
☐ Declaration Submitted with Initial Filing OR ☒ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16(f)) required)	**Attorney Docket Number**	10176P001
	First Named Inventor	Angus Pacala
	COMPLETE IF KNOWN	
	Application Number	15/276,532
	Filing Date	September 26, 2016
	Art Unit	
	Examiner Name	

Optical System for Collecting Distance Information Within a Field

(Title of the Invention)

As a below named inventor, I hereby declare that:

This declaration is directed to:

☐ The attached application,

OR

☒ United States Application Number or PCT International Application Number **15/276,532**

filed on **09/26/2016**

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

I believe 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 above-identified application, including the claim(s).

I am aware of the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability as defined in 37 CFR 1.56, including for a continuation-in-part application, information material to patentability that became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

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.

Willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. 1001), and may jeopardize the validity of the application or any patent issuing thereon. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true.

Authorization To Permit Access to Application by Participating Offices

☒

If 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 World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the above-identified patent application is filed access to the above-identified patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the above-identified patent application is filed to have access to the above-identified patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the above-identified patent application with respect to: 1) the above-identified patent application-as-filed; 2) any foreign application to which the above-identified patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the above-identified patent application; and 3) any U.S. application-as-filed from which benefit is sought in the above-identified patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing the Authorization to Permit Access to Application by Participating Offices.

Based on Forms PTO/AIA/08 and PTO/AIA/10 (06-12) as modified by Blakely, Sokoloff, Taylor & Zafman LLP on 09/17/2012.

DECLARATION -- Utility or Design Patent Application

Direct all correspondence to: ☒	The address associated with Customer Number:	08791	OR ☐	Correspondence address below:

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Address	BLAKELY SOKOLOFF TAYLOR & ZAFMAN LLP 1279 Oakmead Parkway	
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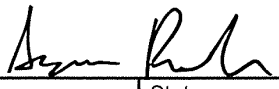
WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available. Petitioner/applicant is advised that documents which form the record of a patent application (such as the PTO/SB/01) are placed into the Privacy Act system of records DEPARTMENT OF COMMERCE, COMMERCE-PAT-7, System name: *Patent Application File* . Documents not retained in an application file (such as the PTO-2038) are placed into the Privacy Act system of COMMERCE/PAT-TM-10, System name: *Deposit Accounts and Electronic Funds Transfer Profiles.*

Legal Name of Sole or First Inventor:

(*E.g.*, Given Name (first and middle (if any)) and Family Name or Surname)

Angus Pacala

Inventor's Signature 		Date 11/25/2016
Residence: City San Francisco	State CA	Country US

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10176P001

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DECLARATION -- Utility or Design Patent Application

Legal Name of Additional Joint Inventor, if any:

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Inventor's Signature	Date

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Legal Name of Additional Joint Inventor, if any:

(*E.g.*, Given Name (first and middle (if any)) and Family Name or Surname)

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Based on Forms PTO/AIA/08 and PTO/AIA/10 (06-12) as modified by Blakely, Sokoloff, Taylor & Zafman LLP on 09/17/2012.

I hereby certify that this correspondence is being filed via EFS-Web with the United States Patent and Trademark Office on May 18, 2021.

KILPATRICK TOWNSEND & STOCKTON LLP

By: /Lisa Jeanetta/
Lisa Jeanetta

PATENT
Attorney Docket No.: 103033-P001USC5-1252977
Client Ref. No.: P001USC5

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Confirmation No.:
Angus Pacala et al.	Examiner: Not yet assigned
Application No.:	Technology Center/Art Unit: Not yet assigned
Filed: May 18, 2021	
For: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	**INFORMATION DISCLOSURE STATEMENT**
Customer No.: 20350	

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

Commissioner:

The references cited on attached form PTO/SB/08A are being called to the attention of the Examiner. In accordance with the provisions of 37 CFR §1.98(a)(2), copies of any cited U.S. Patents and U.S. Patent Application Publications are not provided. Copies of the references are not enclosed.

In accordance with the Waiver of the Copy Requirements in 37 CFR §1.98 for Cited Pending U.S. Patent Applications, 1287 O.G. 163 (October 19, 2004), a copy of the cited, unpublished U.S. Patent Application is available in the Image File Wrapper and, therefore, not provided.

In accordance with 37 CFR §1.98(d), copies of the references can be found in Application No. **15/880,491**, filed **January 25, 2018**.

The following applications are related to this application: 15/276,532 filed September 26, 2016; 15/861,330 filed January 3, 2018; 15/880,491, filed January 25, 2018; 16/046,643 filed July 26, 2018; 16/584,515 filed September 26, 2019; and 17/317,809 filed May 11, 2021. Copies of any Office Actions in such Patent Applications are available via the USPTO's PAIR or electronic file wrapper system and are believed to be readily accessible to the Examiner. Thus, although Applicant may submit copies of some such Office Actions, Applicant does not represent that copies of all, or the most significant, Office Actions are being supplied. If the Examiner desires copies of all such Office Actions, the Examiner should contact the undersigned.

It is respectfully requested that the cited references be expressly considered during the prosecution of this application, and the references be made of record therein and appear among the "references cited" on any patent to issue therefrom.

As provided for by 37 CFR §1.97(g) and (h), no inference should be made that the information and references cited are prior art merely because they are in this statement and no representation is being made that a search has been conducted or that this statement encompasses all the possible relevant information.

This Information Disclosure Statement is being filed ***before*** the mailing date of the first Office Action on the merits.

Applicant believes that ***no fee*** is required for submission of this statement. However, if any additional fees are due for the submission of this Information Disclosure Statement, please deduct those fees from Deposit Account No. 20-1430.

Respectfully submitted,

/ William L. Shaffer /

William L. Shaffer
Registration No. 37,234

KILPATRICK TOWNSEND & STOCKTON LLP

Attachment

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	
	Filing Date	Herewith
	First Named Inventor	Angus Pacala
	Art Unit	Unknown
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

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Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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	7	5188286		Feb 23, 1993	Pence, IV	
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	10	5288992		Feb 22, 1994	Fohl	
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	15	6028306		Feb 22, 2000	Hayashi	
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	Art Unit	Unknown
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

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	33	7873601		Jan 18, 2011	Kushwah	
	34	7876456		Jan 25, 2011	Sesko	
	35	7969558		Jun 28, 2011	Hall	
	36	8013983		Sep 6, 2011	Lin et al.	
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	38	8130367		Mar 6, 2012	Stettner et al.	
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	40	8319949		Nov 27, 2012	Cantin et al.	
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	42	8374405		Feb 12, 2013	Lee et al.	
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	47	8675181		Mar 18, 2014	Hall	
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	Examiner Name	Not yet assigned
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	Examiner Name	Not yet assigned
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Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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	Attorney Docket Number	103033-1252977-P001USC5

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	Examiner Name	Not yet assigned
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	182	20160047897		Feb 18, 2016	Dussan	
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	184	20160047899		Feb 18, 2016	Dussan	
	185	20160047900		Feb 18, 2016	Dussan	
	186	20160047901		Feb 18, 2016	Pacala et al.	
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	First Named Inventor	Angus Pacala
	Art Unit	Unknown
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

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Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
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	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

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EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

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CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

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	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2021-05-18
Name/Print	William L. Shaffer	Registration Number	37,234

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Patent Application Fee Transmittal	
Application Number:	
Filing Date:	
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus Pacala
Filer:	William Leland Shaffer/Lisa Jeanetta
Attorney Docket Number:	103033-P001USC5-1252977
Filed as Small Entity	
Filing Fees for Track I Prioritized Examination - Nonprovisional Application under 35 USC 111(a)	

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY FILING FEE (ELECTRONIC FILING)	4011	1	80	80
UTILITY SEARCH FEE	2111	1	350	350
UTILITY EXAMINATION FEE	2311	1	400	400
REQUEST FOR PRIORITIZED EXAMINATION	2817	1	2100	2100
Pages:				
Claims:				
CLAIMS IN EXCESS OF 20	2202	5	50	250
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
PUBL. FEE- EARLY, VOLUNTARY, OR NORMAL	1504	1	0	0
PROCESSING FEE, EXCEPT PROV. APPLS.	2830	1	70	70
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**3250**

Electronic Acknowledgement Receipt	
EFS ID:	42757724
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus Pacala
Customer Number:	20350
Filer:	William Leland Shaffer/Lisa Jeanetta
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	18-MAY-2021
Filing Date:	
Time Stamp:	19:50:12
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$3250
RAM confirmation Number	E20215HJ50464864
Deposit Account	201430
Authorized User	Lisa Jeanetta
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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	TrackOne Request	2021-05-18_TRACK1_103033-P001USC5-1252977.pdf	113928 12dc44fb1e14de01d36b65361a7aaec47bd9a148	no	2
Warnings:					
Information:					
2	Application Data Sheet	2021-05-18_ADS_103033-P001USC5-1252977.pdf	1793723 3360aad8766cca61f55e85e0f44c8e39d1e73389	no	9
Warnings:					
Information:					
3		2021-05-18_SPEC_103033-P001USC5-1252977.pdf	229341 e3f47da5d1164d04120a310cc81206a092db3a54	yes	31

Multipart Description/PDF files in .zip description

Document Description	Start	End
Abstract	31	31
Claims	26	30
Specification	1	25

Warnings:					
Information:					
4	Drawings-only black and white line drawings	2021-05-18_DWGS_103033-P001USC5-1252977.pdf	2047242 37b028e763abf999b4bbaf854c83518ce00862ed	no	8
Warnings:					
Information:					
5	Oath or Declaration filed	2021-05-18_DECS_103033-P001USC5-1252977.pdf	210253 b861f2aeb96c329f5e21f9fea22439faec235110	no	3

Warnings:					
Information:					
6	Transmittal Letter	2021-05-18_IDS_XMTL_103033-P001USC5-1252977.pdf	131246 a4399d293900c3df5d3adaeb4996ec697f158999	no	2
Warnings:					
Information:					
7	Information Disclosure Statement (IDS) Form (SB08)	2021-05-18_IDS_SB08_103033-P001USC5-1252977.pdf	231220 7d8ac1194a7e35e7643eaadfce49444f3703d08b	no	18
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8	Fee Worksheet (SB06)	fee-info.pdf	41784 8155beb0ac3c8bcc010099f1ba024783c7083096	no	2
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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
17/323,962	05/18/2021	2636	1080	103033-P001USC5-1252977	25	3

CONFIRMATION NO. 1014

FILING RECEIPT

20350
Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

OC000000125886990

Date Mailed: 05/27/2021

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)

Angus PACALA, San Francisco, CA;
Mark FRICHTL, San Francisco, CA;

Applicant(s)

Ouster, Inc., San Francisco, CA;

Assignment For Published Patent Application

Ouster, Inc., San Francisco, CA

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CON of 15/880,491 01/25/2018 PAT 11025885
which is a CON of 15/276,532 09/26/2016 PAT 9992477
which claims benefit of 62/232,222 09/24/2015

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: 05/25/2021

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 17/323,962**

Projected Publication Date: 09/02/2021

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Preliminary Class

398

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.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop

technology, manufacture products, deliver services, and grow your business, visit http://www.SelectUSA.gov or call +1-202-482-6800.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 17/323,962

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	80		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	350		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	400		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	25 minus 20 =	* 5	x 50 =	250	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x 240 =	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	1080		TOTAL	

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	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1	11025885		Jun 1, 2021	Pacala et al.	

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code [4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	2.	Application No. 17/317,809, filed May 11, 2021, 81 pages	
	3.	15/880,491 , "Corrected Notice of Allowability", April 28, 2021, 2 pages	

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
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	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document.
[4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2021-06-09
Name/Print	William L. Shaffer	Registration Number	37,234

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977

Electronic Acknowledgement Receipt	
EFS ID:	42945246
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	09-JUN-2021
Filing Date:	18-MAY-2021
Time Stamp:	17:37:08
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)	IDS_P001USC5-1252977.pdf	189431 cf6fb2334c019c42945506726 4c1290eb85abf4f	no	3

Warnings:

Information:					
This is not an USPTO supplied IDS fillable form					
2	Non Patent Literature	IDS_P001USC4-1246267.pdf	186532 c15f61e228243c291e7e32e7b575678e1b14cf0e	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	375963	

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.

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

PTO/AIA/82B (07-13)
Approved for use through 11/30/2014. OMB 0651-0051
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

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
17/323,962	May 18, 2021

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

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 20350

OR

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

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

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

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

Ouster, Inc.

☐ 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	Mark Ouricht	Date (Optional)	2017-10-04
Name	Mark Fricht		
Title	CTO		

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

☑ Total of forms are submitted.

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

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

Electronic Acknowledgement Receipt	
EFS ID:	43056060
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	22-JUN-2021
Filing Date:	18-MAY-2021
Time Stamp:	15:53:28
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	Power of Attorney	POA.pdf	94262 46c3b9242a7ac3c761e706ce8a2f41694e0ff4a9	no	1
Warnings:					

Information:	
Total Files Size (in bytes):	94262

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

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977

CONFIRMATION NO. 1014

20350
Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

POA ACCEPTANCE LETTER

OC000000126532051

Date Mailed: 06/25/2021

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 06/22/2021.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/ggasgedom/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977	1014

20350 7590 07/08/2021

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER	
ART UNIT	PAPER NUMBER
2878	

NOTIFICATION DATE	DELIVERY MODE
07/08/2021	ELECTRONIC

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

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

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

KTSDocketing2@kilpatrick.foundationip.com
ipefiling@kilpatricktownsend.com

PTOL-90A (Rev. 04/07)

Decision Granting Request for Prioritized Examination (Track I)	**Application No.** 17/323,962	**Applicant(s)** PACALA et al.	
	Examiner CHERYL P GIBSON BAYLOR	**Art Unit** OPET	**AIA (FITF) Status** Yes

1. THE REQUEST FILED 18 May 2021 IS **GRANTED** .

The above-identified application has met the requirements for prioritized examination

A. ☑ for an original nonprovisional application (Track I).
B. ☐ for an application undergoing continued examination (RCE).

2. **The above-identified application will undergo prioritized examination**. The application will be accorded special status throughout its entire course of prosecution until one of the following occurs:

A. filing a **petition for extension of time** to extend the time period for filing a reply;

B. filing an **amendment to amend the application to contain more than four independent claims, more than thirty total claims** , or a multiple dependent claim;

C. filing a **request for continued examination** ;

D. filing a notice of appeal;

E. filing a request for suspension of action;

F. mailing of a notice of allowance;

G. mailing of a final Office action;

H. completion of examination as defined in 37 CFR 41.102; or

I. abandonment of the application.

Telephone inquiries with regard to this decision should be directed to CHERYL GIBSON BAYLOR at (571)272-3213. In his/her absence, calls may be directed to Petition Help Desk at (571) 272-3282.

/CHERYL GIBSON BAYLOR/ Paralegal Specialist, OPET	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	
	Attorney Docket Number	103033-1252977-P001USC5

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code [4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2011063347	WO		May 26, 2011	Pelican Imaging Corporation		
	2	20120137432	KR		Dec 20, 2012	Qualcomm Incorporated		
	3	20130038388	KR		Apr 17, 2013	Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V.		
	4	2015037211	WO		Mar 19, 2015	Sony Corporation		
	5	20150072439	KR		Jun 29, 2015	Qualcomm Incorporated		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	
	Attorney Docket Number	103033-1252977-P001USC5

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document.
[4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/William Shaffer/	Date (YYYY-MM-DD)	2021-07-09
Name/Print	William L. Shaffer	Registration Number	37,234

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Espacenet

Bibliographic data: KR20120137432 (A) — 2012-12-20

COMBINING DATA FROM MULTIPLE IMAGE SENSORS

Inventor(s): ALEKSIC MILIVOJE [CA]; GOMA SERGIU R [CA]; HWANG HAU [US]; CHEUNG JOSEPH [US] ± (ALEKSIC MILIVOJE, ; GOMA SERGIU R, ; HWANG HAU, ; CHEUNG JOSEPH, ; 알렉식 밀리보제, ; 고마 세르지우 알, ; 황 하우, ; 청 조셉)

Applicant(s): QUALCOMM INC [US] ± (QUALCOMM INCORPORATED, ; 퀄컴 인코포레이티드)

Classification: - international: *H04N5/341*
- cooperative: H04N13/161 (EP, KR, US); H04N13/239 (EP, KR, US); H04N13/296 (EP, KR, US); H04N5/2258 (EP, KR, US); H04N5/23227 (EP, KR, US); H04N5/23238 (EP, KR, US); H04N5/247 (EP, KR, US); H04N9/04557 (EP, KR, US); H04N9/045 (EP)

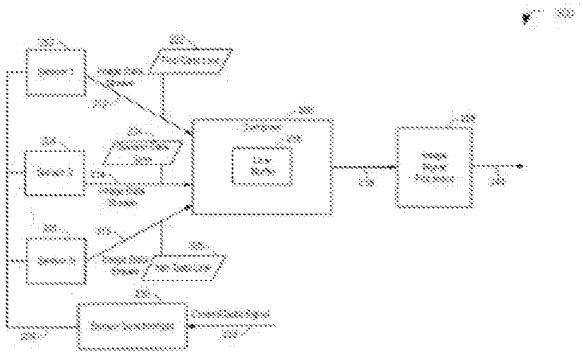
Application number: KR20127029028 20110405 Global Dossier

Priority number(s): US201113079629 20110404 ; US20100320940P 20100405 ; US20100324259P 20100414 ; US20100359312P 20100628 ; US20100412755P 20101111 ; WO2011US31285 20110405

Also published as: AR081160 (A1) AR081161 (A1) AR081486 (A1) AU2011237801 (A1) BR112012025182 (A2) more

Abstract not available for KR20120137432 (A)
Abstract of corresponding document: US2011242342 (A1)

A method of combining data from multiple sensors is disclosed. The method includes providing a common control signal to multiple image sensors to be synchronized. The method further includes receiving a first data line from a first image sensor of the multiple image sensors, receiving a second data line from a second image sensor of the multiple image sensors, and combining the first data line and the second data line to generate a synchronized data line.



(19) 대한민국특허청(KR)
(12) 공개특허공보(A)

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심사청구일자 2012년11월05일
(85) 번역문제출일자 2012년11월05일
(86) 국제출원번호 PCT/US2011/031285
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국제공개일자 2011년10월13일
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01/079,629 2011년04월04일 미국(US)
(뒷면에 계속)

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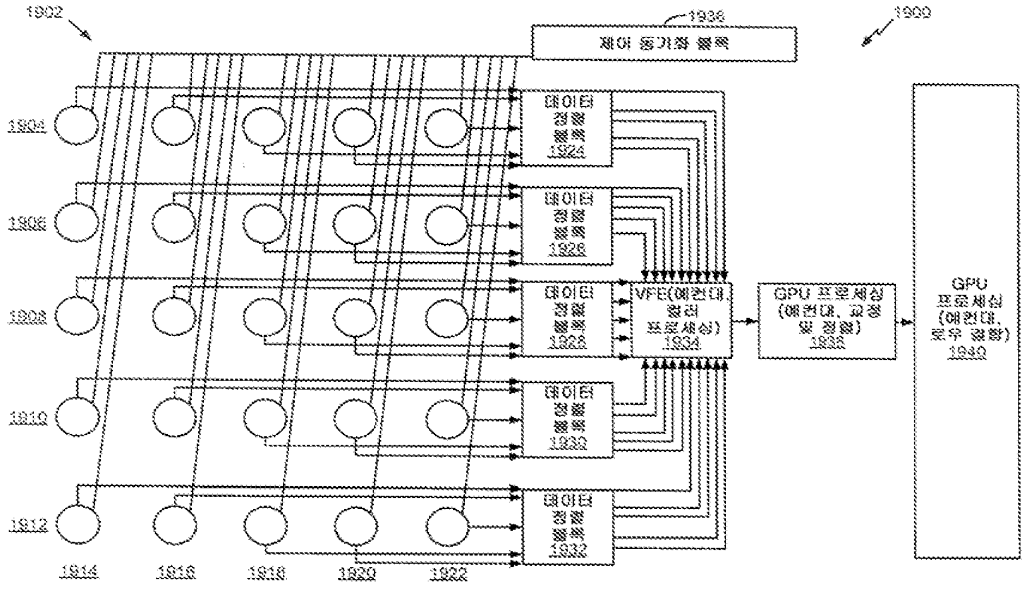
전체 청구항 수 : 총 35 항

(54) 발명의 명칭 **다중 이미지 센서들로부터 데이터의 결합**

(57) 요 약

다중 센서들로부터의 데이터를 결합하는 방법이 개시된다. 그 방법은 공통 제어 신호를 다중 이미지 센서들에 제공하는 단계를 포함한다. 다중 이미지 센서들 각각은 상기 공통 제어 신호에 응답하여 이미지 데이터를 생성한다. 그 방법은 또한 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신하는 단계를 포함한다.

대 표 도



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(30) 우선권주장

61/320,940 2010년04월05일 미국(US)

61/324,259 2010년04월14일 미국(US)

61/359,312 2010년06월28일 미국(US)

61/412,755 2010년11월11일 미국(US)

특허청구의 범위

청구항 1

공통 제어 신호를 다중 이미지 센서들에 제공하는 단계로서, 상기 다중 이미지 센서들 각각은 상기 공통 제어 신호에 응답하여 이미지 데이터를 생성하는, 상기 공통 제어 신호를 제공하는 단계; 및

상기 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신하는 단계를 포함하는, 방법.

청구항 2

제 1 항에 있어서,

상기 동기화된 데이터 출력은 제 1 이미지 센서로부터 수신된 제 1 데이터 라인들 및 제 2 이미지 센서로부터 수신된 제 2 데이터 라인들을 포함하고,

상기 제 1 이미지 센서로부터의 각각의 수신된 데이터 라인과 상기 제 2 이미지 센서로부터의 각각의 대응하는 데이터 라인 간의 위상 오프셋은 실질적으로 일정한, 방법.

청구항 3

제 1 항에 있어서,

상기 공통 제어 신호는 상기 다중 이미지 센서들 각각에 커플링된 센서 동기화기에 의해 제공되는, 방법.

청구항 4

제 3 항에 있어서,

상기 센서 동기화기는 I2C (inter-integrated circuit) 제어 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 방법.

청구항 5

제 4 항에 있어서,

상기 공통 제어 신호는 카메라 리셋 신호, 카메라 클록 신호, 제어 클록 신호 및 제어 데이터 신호를 포함하는, 방법.

청구항 6

제 3 항에 있어서,

상기 센서 동기화기는 카메라 직렬 인터페이스 (CSI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 방법.

청구항 7

제 3 항에 있어서,

상기 센서 동기화기는 카메라 병렬 인터페이스 (CPI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 방법.

청구항 8

다중 이미지 센서들에서 공통 제어 신호를 수신하는 단계로서, 상기 다중 이미지 센서들 각각은 상기 공통 제어 신호에 응답하여 이미지 데이터를 생성하는, 상기 공통 제어 신호를 수신하는 단계; 및

상기 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 생성하는 단계를 포함하는, 방법.

청구항 9

제 8 항에 있어서,

상기 동기화된 데이터 출력은 제 1 이미지 센서에 의해 생성된 제 1 데이터 라인들 및 제 2 이미지 센서에 의해 생성된 제 2 데이터 라인들을 포함하고,

상기 제 1 이미지 센서로부터의 각각의 데이터 라인 출력과 상기 제 2 이미지 센서로부터의 각각의 대응하는 데이터 라인 출력 간의 위상 오프셋은 실질적으로 일정한, 방법.

청구항 10

제 8 항에 있어서,

상기 공통 제어 신호는 상기 다중 이미지 센서들 각각에 커플링된 센서 동기화기로부터 수신되는, 방법.

청구항 11

제 8 항에 있어서,

상기 공통 제어 신호는 I2C (inter-integrated circuit) 제어 인터페이스를 통해 상기 다중 이미지 센서들 각각에서 수신되는, 방법.

청구항 12

제 11 항에 있어서,

상기 공통 제어 신호는 카메라 리셋 신호, 카메라 클록 신호, 제어 클록 신호 및 제어 데이터 신호를 포함하는, 방법.

청구항 13

제 8 항에 있어서,

상기 공통 제어 신호는 카메라 직렬 인터페이스 (CSI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에서 수신되는, 방법.

청구항 14

제 8 항에 있어서,

상기 공통 제어 신호는 카메라 병렬 인터페이스 (CPI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에서 수신되는, 방법.

청구항 15

다중 이미지 센서들로 하여금 이미지 데이터를 생성하게 하기 위해 공통 제어 신호를 상기 다중 이미지 센서들에 제공하도록 구성된 센서 동기화기; 및

상기 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신하도록 구성된 센서 데이터 인터페이스를 포함하는, 장치.

청구항 16

제 15 항에 있어서,

상기 센서 동기화기는 I2C (inter-integrated circuit) 제어 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 장치.

청구항 17

제 15 항에 있어서,

상기 공통 제어 신호는 카메라 리셋 신호, 카메라 클록 신호, 제어 클록 신호 및 제어 데이터 신호를 포함하는, 장치.

청구항 18

제 15 항에 있어서,

상기 센서 동기화기는 카메라 직렬 인터페이스 (CSI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 장치.

청구항 19

제 15 항에 있어서,

상기 센서 동기화기는 카메라 병렬 인터페이스 (CPI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 장치.

청구항 20

제 1 이미지 센서; 및

제 2 이미지 센서를 포함하며,

상기 제 1 이미지 센서와 상기 제 2 이미지 센서는 공통 제어 신호를 수신하도록 구성되고, 상기 공통 제어 신호에 응답하여 동기화된 데이터 출력을 생성하는, 장치.

청구항 21

제 20 항에 있어서,

상기 동기화된 데이터 출력은 상기 제 1 이미지 센서에 의해 생성된 제 1 데이터 라인들 및 상기 제 2 이미지 센서에 의해 생성된 제 2 데이터 라인들을 포함하고,

상기 제 1 이미지 센서로부터의 각각의 데이터 라인 출력과 상기 제 2 이미지 센서로부터의 각각의 대응하는 데이터 라인 출력 간의 위상 오프셋은 실질적으로 일정한, 장치.

청구항 22

제 20 항에 있어서,

상기 제 1 이미지 센서와 상기 제 2 이미지 센서는 I2C (inter-integrated circuit) 제어 인터페이스를 통해 상기 공통 제어 신호를 수신하도록 구성되는, 장치.

청구항 23

제 20 항에 있어서,

상기 제 1 이미지 센서와 상기 제 2 이미지 센서는 카메라 직렬 인터페이스 (CSI) 사양에 부합하는 인터페이스를 통해 상기 공통 제어 신호를 수신하도록 구성되는, 장치.

청구항 24

제 20 항에 있어서,

상기 제 1 이미지 센서와 상기 제 2 이미지 센서는 카메라 병렬 인터페이스 (CPI) 사양에 부합하는 인터페이스를 통해 상기 공통 제어 신호를 수신하도록 구성되는, 장치.

청구항 25

다중 이미지 센서들로 하여금 이미지 데이터를 생성하게 하기 위해 공통 제어 신호를 상기 다중 이미지 센서들에 제공하는 수단; 및

상기 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신하는 수단을 포함하는, 장치.

청구항 26

제 25 항에 있어서,

상기 공통 제어 신호를 제공하는 수단은 I2C (inter-integrated circuit) 제어 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 장치.

청구항 27

제 25 항에 있어서,

상기 공통 제어 신호를 제공하는 수단은 카메라 직렬 인터페이스 (CSI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 장치.

청구항 28

제 25 항에 있어서,

상기 공통 제어 신호를 제공하는 수단은 카메라 병렬 인터페이스 (CPI) 사양에 부합하는 인터페이스를 통해 상기 다중 이미지 센서들 각각에 커플링되는, 장치.

청구항 29

제 1 이미지 데이터를 생성하는 수단; 및

제 2 이미지 데이터를 생성하는 수단을 포함하며,

상기 제 1 이미지 데이터를 생성하는 수단과 상기 제 2 이미지 데이터를 생성하는 수단은 공통 제어 신호를 수신하도록 구성되고, 상기 공통 제어 신호에 응답하여 동기화된 데이터 출력을 생성하는, 장치.

청구항 30

제 29 항에 있어서,

상기 동기화된 데이터 출력은 상기 제 1 이미지 데이터를 생성하는 수단에 의해 생성된 제 1 데이터 라인들 및 상기 제 2 이미지 데이터를 생성하는 수단에 의해 생성된 제 2 데이터 라인들을 포함하고,

상기 제 1 이미지 데이터를 생성하는 수단으로부터의 각각의 데이터 라인 출력과 상기 제 2 이미지 데이터를 생성하는 수단으로부터의 각각의 대응하는 데이터 라인 출력 간의 위상 오프셋은 실질적으로 일정한, 장치.

청구항 31

제 29 항에 있어서,

상기 제 1 이미지 데이터를 생성하는 수단과 상기 제 2 이미지 데이터를 생성하는 수단은 I2C (inter-integrated circuit) 제어 인터페이스를 통해 상기 공통 제어 신호를 수신하도록 구성되는, 장치.

청구항 32

명령들을 포함하는 비-일시적인 컴퓨터 판독가능 매체로서,

상기 명령들은, 프로세서에 의해 실행될 경우, 상기 프로세서로 하여금,

공통 제어 신호를 다중 이미지 센서들에 제공하게 하는 것으로서, 상기 다중 이미지 센서들 각각은 상기 공통 제어 신호에 응답하여 이미지 데이터를 생성하는, 상기 공통 제어 신호를 제공하게 하고; 그리고

상기 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신하게 하는, 비-일시적인 컴퓨터 판독가능 매체.

청구항 33

제 32 항에 있어서,

상기 동기화된 데이터 출력은 제 1 이미지 센서로부터 수신된 제 1 데이터 라인들 및 제 2 이미지 센서로부터 수신된 제 2 데이터 라인들을 포함하고,

상기 제 1 이미지 센서로부터의 각각의 수신된 데이터 라인과 상기 제 2 이미지 센서로부터의 각각의 대응하는 데이터 라인 간의 위상 오프셋은 실질적으로 일정한, 비-일시적인 컴퓨터 판독가능 매체.

청구항 34

명령들을 포함하는 비-일시적인 컴퓨터 판독가능 매체로서,

상기 명령들은, 프로세서에 의해 실행될 경우, 상기 프로세서로 하여금,

다중 이미지 센서들에서 공통 제어 신호를 수신하게 하는 것으로서, 상기 다중 이미지 센서들 각각은 상기 공통 제어 신호에 응답하여 이미지 데이터를 생성하는, 상기 공통 제어 신호를 수신하게 하고; 그리고

상기 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 생성하게 하는, 비-일시적인 컴퓨터 판독가능 매체.

청구항 35

제 34 항에 있어서,

상기 동기화된 데이터 출력은 제 1 이미지 센서로부터 생성된 제 1 데이터 라인들 및 제 2 이미지 센서로부터 수신된 제 2 데이터 라인들을 포함하고,

상기 제 1 이미지 센서로부터의 각각의 데이터 라인 출력과 상기 제 2 이미지 센서로부터의 각각의 대응하는 데이터 라인 출력 간의 위상 오프셋은 실질적으로 일정한, 비-일시적인 컴퓨터 판독가능 매체.

명 세 서

기 술 분 야

[0001] **우선권 주장**

[0002] 본 출원은 각각 2010 년 4 월 5 일에 출원된 미국 가출원 제 61/320,940 호, 2010 년 4 월 14 일에 출원된 미국 가출원 제 61/324,259 호, 2010 년 6 월 28 일에 출원된 미국 가출원 제 61/359,312 호 및 2010 년 11 월 11 일에 출원된 미국 가출원 제 61/412,755 호를 우선권 주장하고 참조로서 통합한다.

[0003] **기술 분야**

[0004] 본 개시물은 일반적으로 다중 이미지 센서들로부터 데이터를 결합하는 것과 관련된다.

배 경 기 술

[0005] 기술의 진보는 더 작고 더 강력한 컴퓨팅 디바이스들을 발생하였다. 예를 들면, 소형이고, 경량이며, 사용자들이 쉽게 운반할 수 있는, 휴대용 무선 전화기들, 개인 휴대 정보 단말기들 (PDAs) 및 페이징 디바이스들과 같은 무선 컴퓨팅 디바이스들을 포함하는 다양한 휴대용 개인 컴퓨팅 디바이스들이 현존하고 있다. 더욱 상세하게는, 셀룰러 전화기들 및 인터넷 프로토콜 (IP) 전화기들과 같은 휴대용 무선 전화기들은 무선 네트워크들을 통해 음성 및 데이터 패킷들을 통신할 수 있다. 추가로, 다수의 이러한 무선 전화기들은 그 내부에 통합되는 다른 타입의 디바이스들을 포함한다. 예를 들어, 무선 전화기는 디지털 스틸 카메라 및 디지털 비디오 카메라를 포함할 수 있다. 또한, 이러한 무선 전화기들은 인터넷에 액세스하는데 이용될 수 있는, 웹 브라우저 애플리케이션과 같은 소프트웨어 애플리케이션들을 포함하는 실행가능한 명령들을 처리할 수도 있다.

[0006] 추가로, 무선 디바이스들은 3 차원 (3D) 애플리케이션들을 실행할 수도 있다. 3D 애플리케이션들에서, 통상적으로 적어도 2 개의 이미지 센서들이 장면으로부터 깊이 (depth) 정보를 캡처하는데 이용된다. 2 개의 이미지 센서들로부터의 프레임 데이터는 거리 정보를 추론하기 위해 결합되고 처리되며, 3D 표현을 구성하기 위해 이용된다. 센서들 각각으로부터의 이미지 데이터를 결합하는 것은 통상적으로 프레임 동기화 및 라인 동기화를 수행하는 것을 포함하며, 이들은 동기화 및 정렬 문제들을 발생할 수도 있다. 추가로, 다중 센서들로부터의 이미지 데이터의 멀티링 및 이러한 이미지 데이터의 인터리빙은 소스 센서들이 상이한 주파수들 또는 위상들로 데이터를 제공할 경우 더 복잡해질 수도 있다. 다중 센서들로부터의 데이터를 효율적으로 동기화하고, 데이터를 효율적으로 처리하여 전체 이미지 프로세싱 시스템 비용 및 복잡도를 감소시키는 것은 유리할 것

이다.

발명의 내용

해결하려는 과제

[0007] 다수의 카메라 어레이 애플리케이션들에서, 다중 센서들 각각으로부터의 이미지 데이터는 라인 레벨로 동기화되고 처리된다. 다중 센서들로부터의 데이터를 결합하기 위한 이미지 프로세싱 시스템이 개시되며, 여기서 제 1 이미지 센서와 제 2 이미지 센서로부터의 이미지 데이터는 동기화되고 처리된다. 동기화된 데이터 라인들은 제 1 이미지 센서에 의해 생성된 제 1 데이터 스트림으로부터의 제 1 데이터와 제 2 이미지 센서에 의해 생성된 제 2 데이터 스트림으로부터의 제 2 데이터를 동기화시키고 결합함으로써 생성된다. 이미지 신호 프로세서는 결합기로부터 수신된 동기화된 데이터 라인들을 처리하여, 처리된 프레임을 디스플레이로 출력하도록 구성된다.

[0008] 특정 실시형태에서, 하나의 방법이 개시된다. 그 방법은 동기화될 다중 이미지 센서들에 공통 제어 신호를 제공하는 단계를 포함한다. 그 방법은 다중 이미지 센서들 중 제 1 이미지 센서로부터 제 1 데이터 라인을 수신하는 단계, 다중 이미지 센서들 중 제 2 이미지 센서로부터 제 2 데이터 라인을 수신하는 단계, 및 동기화된 데이터 라인을 생성하기 위해 제 1 데이터 라인과 제 2 데이터 라인을 결합하는 단계를 더 포함한다.

[0009] 다른 특정 실시형태에서, 하나의 장치가 개시된다. 그 장치는 공통 제어 신호를 통해 동기화될 다중 이미지 센서들 중 제 1 이미지 센서로부터 제 1 데이터 라인을 수신하도록 구성된 제 1 입력을 포함한다. 그 장치는 다중 이미지 센서들 중 제 2 이미지 센서로부터 제 2 데이터 라인을 수신하도록 구성된 제 2 입력, 및 제 1 입력과 제 2 입력에 커플링된 결합기를 더 포함하며, 상기 결합기는 제 1 데이터 라인과 제 2 데이터 라인을 결합하여 동기화된 데이터 라인을 생성하도록 구성된다.

[0010] 또 다른 특정 실시형태에서, 하나의 방법이 개시된다. 그 방법은 공통 제어 신호를 다중 이미지 센서들에 제공하는 단계를 포함한다. 다중 이미지 센서들 각각은 공통 제어 신호에 응답하여 이미지 데이터를 생성한다. 그 방법은 다중 이미지 센서들의 각각으로부터의 동기화된 데이터 출력을 수신하는 단계, 동기화된 데이터 라인을 생성하기 위해 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 결합하는 단계 및 이미지 프로세서의 단일 카메라 입력을 통해 동기화된 데이터 라인을 이미지 프로세서에 제공하는 단계를 더 포함한다.

[0011] 또 다른 특정 실시형태에서, 하나의 장치가 개시된다. 그 장치는 공통 제어 신호를 다중 이미지 센서들에 제공하도록 구성된 센서 동기화기를 포함한다. 다중 이미지 센서들 각각은 공통 제어 신호에 응답하여 이미지 데이터를 생성한다. 그 장치는 이미지 프로세서의 단일 카메라 입력을 통해 이미지 프로세서에 제공될 동기화된 데이터 라인을 생성하기 위해 다중 이미지 센서들 각각으로부터의 동기화된 데이터 출력을 결합하도록 구성된 결합기를 더 포함한다.

[0012] 또 다른 특정 실시형태에서, 하나의 방법이 개시된다. 그 방법은 공통 제어 신호를 다중 이미지 센서들에 제공하는 단계를 포함한다. 다중 이미지 센서들 각각은 공통 제어 신호에 응답하여 이미지 데이터를 생성한다. 그 방법은 다중 이미지 센서들의 각각으로부터 동기화된 데이터 출력을 수신하는 단계를 더 포함한다.

[0013] 또 다른 특정 실시형태에서, 하나의 방법이 개시된다. 그 방법은 다중 이미지 센서들에서 공통 제어 신호를 수신하는 단계를 포함한다. 다중 이미지 센서들 각각은 공통 제어 신호에 응답하여 이미지 데이터를 생성한다. 그 방법은 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 생성하는 단계를 더 포함한다.

[0014] 또 다른 특정 실시형태에서, 하나의 장치가 개시된다. 그 장치는 공통 제어 신호를 다중 이미지 센서들에 제공하여 다중 이미지 센서들이 이미지 데이터를 생성하게 하도록 구성된 센서 동기화기를 포함한다. 그 장치는 다중 이미지 센서들의 각각으로부터의 동기화된 데이터 출력을 수신하도록 구성된 센서 데이터 인터페이스를 더 포함한다.

[0015] 또 다른 특정 실시형태에서, 하나의 방법이 개시된다. 그 방법은 단일 카메라에 대한 입력을 갖는 이미지 프로세서에서 이미지 데이터의 라인들을 수신하는 단계를 포함한다. 이미지 데이터의 각각의 라인은 제 1 카메라에 의해 캡처된 제 1 이미지로부터의 제 1 라인 데이터 및 제 2 카메라에 의해 캡처된 제 2 이미지로부터의 제 2 라인 데이터를 포함한다. 그 방법은 제 1 이미지의 라인 데이터에 대응하는 제 1 섹션 및 제 2 이미지의 라인 데이터에 대응하는 제 2 섹션을 갖는 출력 프레임을 생성하는 단계를 더 포함한다. 제 1 섹션 및 제 2 섹션은 3 차원 (3D) 이미지 포맷 또는 3D 비디오 포맷을 생성하는데 이용되도록 구성된다.

[0016] 또 다른 특정 실시형태에서, 하나의 장치가 개시된다. 그 장치는 단일 카메라에 대한 입력을 갖는 이미지 프로세서를 포함한다. 이미지 프로세서는 입력을 통해 이미지 데이터의 라인들을 수신하도록 구성된다. 이미지 데이터의 각각의 라인은 제 1 카메라에 의해 캡처된 제 1 이미지로부터의 제 1 라인 데이터 및 제 2 카메라에 의해 캡처된 제 2 이미지로부터의 제 2 라인 데이터를 포함한다. 이미지 프로세서는 제 1 이미지의 라인 데이터에 대응하는 제 1 섹션 및 제 2 이미지의 라인 데이터에 대응하는 제 2 섹션을 갖는 출력 프레임을 생성하도록 구성된다. 제 1 섹션 및 제 2 섹션은 3 차원 (3D) 이미지 포맷 또는 3D 비디오 포맷을 생성하는데 이용되도록 구성된다.

[0017] 특정 실시형태에서, 다중 센서들로부터의 데이터를 결합하는 방법이 개시된다. 그 방법은 제 1 이미지 센서로부터 제 1 데이터 스트림을 수신하는 단계, 제 2 이미지 센서로부터 제 2 데이터 스트림을 수신하는 단계, 및 제 1 데이터 스트림과 제 2 데이터 스트림으로부터의 데이터를 결합하여 프레임을 생성하는 단계를 포함한다. 그 방법은 이미지 신호 프로세서에서 프레임을 추가하여 처리된 프레임을 생성하고 처리된 프레임을 디스플레이를 위해 출력하는 단계를 더 포함한다. 제 1 이미지 센서와 제 2 이미지 센서 각각은 이미지 신호 프로세서에 직접 응답한다.

[0018] 다른 특정 실시형태에서, 하나의 장치가 개시된다. 그 장치는 제 1 데이터 스트림을 생성하도록 구성된 제 1 이미지 센서, 제 2 데이터 스트림을 생성하도록 구성된 제 2 이미지 센서, 및 제 1 데이터 스트림으로부터의 제 1 데이터와 제 2 데이터 스트림으로부터의 제 2 데이터를 결합하여 프레임을 생성하도록 구성된 결합기를 포함한다. 그 장치는 프레임을 처리하여 처리된 프레임을 디스플레이에 출력하도록 구성된 이미지 신호 프로세서를 더 포함한다. 제 1 이미지 센서와 제 2 이미지 센서 각각은 이미지 신호 프로세서에 직접 응답한다.

[0019] 또 다른 특정 실시형태에서, 하나의 방법이 개시된다. 그 방법은 제 1 이미지 센서로부터 이미지의 제 1 이미지 데이터를 수신하는 단계, 제 2 이미지 센서로부터 이미지의 제 2 이미지 데이터를 수신하는 단계, 및 이미지 데이터 획득 동안 제 1 이미지 센서와 제 2 이미지 센서의 노출을 라인별로 동기화하는 단계를 포함한다. 제 1 이미지 센서와 제 2 이미지 센서는 서로 독립적이다. 동기화는 라인별로 이루어질 수도 있고, 프레임별로 이루어질 수도 있다.

[0020] 또 다른 특정 실시형태에서, 하나의 장치가 개시된다. 그 장치는 메모리 버퍼를 포함한다. 메모리 버퍼는 각각의 프레임의 스트리밍을 통해 들어온 스트림들을 결정적 순서로 정렬하는 섹션, 및 스트림들 사이에 프로그래밍 가능한 갭 섹션을 포함한다.

[0021] 또 다른 특정 실시형태에서, 하나의 방법이 개시된다. 그 방법은 단일 카메라에 대한 입력을 갖는 이미지 프로세서에서 이미지 데이터의 로우들을 수신하는 단계를 포함한다. 이미지 데이터의 각각의 로우는 제 1 카메라에 의해 캡처된 제 1 이미지의 로우로부터의 데이터 및 제 2 카메라에 의해 캡처된 제 2 이미지의 로우로부터의 데이터를 포함한다. 그 방법은 또한 3 차원 (3D) 이미지 포맷 또는 3D 비디오 포맷을 갖는 출력을 생성하는 단계를 포함한다. 출력은 제 1 이미지와 제 2 이미지에 대응한다.

[0022] 또 다른 특정 실시형태에서, 하나의 장치가 개시된다. 그 장치는 단일 카메라에 대한 입력을 갖는 이미지 프로세서를 포함한다. 그 장치는 또한 이미지 데이터의 로우들을 이미지 프로세서에 송신하도록 구성된 결합기를 포함한다. 이미지 데이터의 각각의 로우는 제 1 카메라에 의해 캡처된 제 1 이미지의 로우로부터의 제 1 데이터 및 제 2 카메라에 의해 캡처된 제 2 이미지의 로우로부터의 제 2 데이터를 포함한다. 이미지 프로세서는 3 차원 (3D) 이미지 포맷 또는 3D 비디오 포맷을 갖는 출력을 생성하도록 구성된다. 출력은 제 1 이미지와 제 2 이미지에 대응한다.

발명의 효과

[0023] 개시된 실시형태들 중 적어도 하나에 의해 제공되는 하나의 특별한 장점은 단일 이미지 신호 프로세서가 다중 이미지 센서들로부터의 이미지 데이터를 동기화하고 제어하는데 이용될 수도 있다. 다른 특별한 장점은 스트림들 사이에 갭들을 가지는 것이 이미지 신호 프로세서에서 결합된 스트림을 단일 프레임으로서 처리하는 유연성을 제공하고, 후속하는 블록-기반 프로세싱에 의한 스트림들의 오염을 방지하는 (즉, 그 갭이 최대 블록 기반 프로세싱과 동일하다면 스트림들의 오염이 방지된다) 것이다.

[0024] 본 개시물의 다른 양태들, 장점들 및 특징들은 하기의 섹션들 : 도면의 간단한 설명, 상세한 설명, 및 청구범위를 포함하는 전체 출원을 검토한 후에 인식될 것이다.

도면의 간단한 설명

[0025] 도 1 은 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 특정 예시적 실시형태의 블록도이다.

도 2 는 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 제 2 예시적 실시형태의 블록도이다.

도 3 은 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 제 3 예시적 실시형태의 블록도이다.

도 4 는 도 2 의 이미지 프로세싱 시스템의 선택된 부분의 특정 예시적 실시형태의 블록도이며, 여기서 제 1 이미지 센서와 제 2 이미지 센서는 공통 제어 데이터를 수신한다.

도 5 는 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 제 4 예시적 실시형태의 블록도이다.

도 6 은 제 1 이미지 센서의 출력에서 제 1 데이터 스트림과 제 2 이미지 센서의 출력에서 제 2 데이터 스트림이 결합되어 동기화된 데이터 라인을 형성하는 제 1 실시형태의 도식적인 표현이다.

도 7 은 제 1 이미지 센서의 출력에서 제 1 데이터 스트림과 제 2 이미지 센서의 출력에서 제 2 데이터 스트림이 결합되어 동기화된 데이터 라인을 형성하는 제 2 실시형태의 도식적인 표현이다.

도 8 은 제 1 센서로부터의 제 1 데이터 스트림과 제 2 센서로부터의 제 2 데이터 스트림 간의 2 라인 위상 차이를 예시하는 위상도의 제 1 실시형태의 도식적인 표현이다.

도 9 는 제 1 센서로부터의 제 1 데이터 스트림과 제 2 센서로부터의 제 2 데이터 스트림 간의 1 라인 위상 차이를 예시하는 위상도의 제 2 실시형태의 도식적인 표현이다.

도 10 은 다중 센서들 각각의 픽셀 데이터를 예시하고 동기화된 데이터 라인들을 예시하는 도식적인 표현이다.

도 11 은 다중 센서들에 대한 프레임 유효 및 라인 유효 신호 타이밍을 예시하는 타이밍도이다.

도 12 는 제 1 센서로부터의 제 1 데이터 스트림과 제 2 센서로부터의 제 2 데이터 스트림 간의 3 라인 위상 차이를 예시하는 위상도의 제 3 실시형태의 도식적인 표현이다.

도 13 은 다중 이미지 센서들로부터의 데이터를 결합하여 3 차원 이미지 포맷을 생성하는 이미지 프로세싱 시스템의 특정 예시적 실시형태의 블록도이다.

도 14 는 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템들을 갖는 모바일 디바이스들의 다양한 실시형태들을 예시하는 도식적 표현이다.

도 15 는 이미지들 사이의 중첩을 포함하는, 카메라 어레이에 의해 캡처된 이미지들의 일 예를 예시하는 도식적인 표현이다.

도 16 은 이미지들 사이의 중첩을 포함하는, 카메라 어레이에 의해 캡처된 이미지들의 일 예를 예시하는 도식적인 표현이며, 여기서 각각의 이미지는 자기 소유의 쉬프팅 성분 및 회전 성분을 가질 수도 있다.

도 17 은 카메라 어레이 및 카메라 어레이와 연관된 전기적 접속들의 특정 실시형태를 예시하는 블록도이다.

도 18 은 카메라 어레이 프로세싱 시스템의 제 1 특정 예시적인 실시형태의 블록도이다.

도 19 는 카메라 어레이 프로세싱 시스템의 제 1 특정 예시적인 실시형태의 블록도이다.

도 20 은 메인 랙 및 하나의 어레이에 배열된 다중 카메라들을 포함하는 카메라 시스템을 예시하는 도식적인 표현이다.

도 21 은 자동차 내의 다중 카메라 모듈을 예시하는 도식적인 표현이다.

도 22 는 다중 센서들로부터의 데이터를 동기화된 데이터 라인으로 결합하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 23 은 공통 제어 신호를 다중 이미지 센서들에 제공하고, 동기화된 데이터 라인을 이미지 프로세서의 단일

카메라 입력을 통해 이미지 프로세서에 제공하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 24 는 공통 제어 신호를 다중 이미지 센서들에 제공하고, 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 25 는 다중 이미지 센서들에서 공통 제어 신호를 수신하고, 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 생성하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 26 은 단일 카메라에 대한 입력을 갖는 이미지 신호 프로세서에서 다중 센서들로부터의 데이터를 결합하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 27 은 다중 센서들로부터의 데이터를 하나의 프레임으로 결합하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 28 은 제 1 이미지 센서와 제 2 이미지 센서의 라인별 노출을 동기화하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 29 는 다중 센서들로부터의 데이터를 결합하여 3 차원 이미지 데이터를 생성하는 방법의 제 1 예시적 실시형태의 흐름도이다.

도 30 은 다중 센서들로부터의 데이터를 결합하여 3 차원 이미지 데이터를 생성하는 방법의 제 2 예시적 실시형태의 흐름도이다.

도 31 은 제 1 이미지 센서와 제 2 이미지 센서의 라인별 노출을 동기화하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 32 는 다중 센서들로부터의 데이터를 결합하여 동기화된 데이터 라인으로부터 3 차원 이미지 데이터를 생성하는 방법의 특정 예시적 실시형태의 흐름도이다.

도 33 은 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 특정 예시적 실시형태의 블록도이다.

도 34 는 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템을 포함하는 무선 디바이스의 제 1 예시적 실시형태의 블록도이다.

도 35 는 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템을 포함하는 무선 디바이스의 제 2 예시적 실시형태의 블록도이다.

발명을 실시하기 위한 구체적인 내용

[0026] 도 1 을 참조하면, 다중 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 특정 예시적 실시형태가 도시되고, 일반적으로 100 으로 지정된다. 이미지 프로세싱 시스템 (100) 은 다중 카메라 모듈 (102), 센서 모듈 (104) 및 단일 카메라 입 모듈 (106) 을 포함한다. 특정 실시형태에서, 센서 모듈 (104) 은 도 2 및 도 3 의 센서들 (202 및 204) 과 같은 다중 센서들을 포함할 수도 있고, 여기서 다중 센서들 각각은 이미지의 데이터 라인들을 포함하는 데이터 스트림을 생성하도록 구성된다. 단일 카메라 모듈 (106) 은 도 2 및 도 3 의 이미지 프로세서 (206) 와 같은 단일 카메라 입력을 갖는 이미지 프로세서를 포함할 수도 있다. 다중 센서들의 이미지 데이터 스트림들의 라인별 이미지 데이터를 동기화된 데이터 라인들 (108) 로 결합하는 것은 이미지 프로세서가 단일 카메라 입력을 가지는데도 불구하고 이미지 프로세서가 다중 카메라 프로세싱을 위한 최적화를 수행하는 것을 가능하게 한다. 결과적으로, 시스템 (100) 은 각각의 카메라에 대하여 별개의 프로세서를 이용하거나 다중 카메라 입력들을 구비한 프로세서를 이용하는 시스템과 비교할 때 감소된 비용으로 구현될 수도 있다.

[0027] 도 2 를 참조하면, 다중 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 특정 예시적인 실시형태가 도시되고, 일반적으로 200 으로 지정된다. 이미지 프로세싱 시스템 (200) 은 제 1 센서 (202) 와 제 2 센서 (204) 를 포함한다. 이미지 프로세싱 시스템 (200) 은 결합기 (206), 이미지 신호 프로세서 또는 비디오 프론트 엔드 (208), 및 센서 동기화기 (230) 를 추가로 포함한다. 이미지 신호 프로세서 (208) 는 디스플레이 디바이스 (미도시) 에 커플링될 수도 있다. 결합기 (206) 는 하나 이상의 라인 버퍼들 (216) 을 포함한다. 이미지 프로세싱 시스템 (200) 은 적어도 하나의 반도체 다이에 집적될 수도 있다.

[0028] 제 1 센서 (202) 는 제 1 이미지 데이터 스트림 (212) 으로 도시된 제 1 데이터 스트림을 생성하도록 구성된다.

제 1 이미지 데이터 스트림 (212) 은 제 1 데이터 라인 (222) 을 포함한다. 제 2 센서 (204) 는 제 2 이미지 데이터 스트림 (214) 으로 도시된 제 2 데이터 스트림을 생성하도록 구성된다. 제 2 이미지 데이터 스트림 (214) 은 제 2 데이터 라인 (224) 을 포함한다. 제 1 및 제 2 센서들 (202, 204) 은 서로에 대하여 독립적이며, 센서 동기화기 (230) 로부터 공통 제어 신호 (234) 를 수신하는 실질적으로 유사한 이미지 센서들일 수도 있다. 센서 동기화기 (230) 는 제어/데이터 신호 (232) 를 수신하고 공통 제어 신호 (234) 를 제 1 및 제 2 센서들 (202, 204) 에 출력하여 제 1 및 제 2 센서들 (202, 204) 이 인접하여 정렬된 데이터 스트림들 (212, 214) 을 생성하게 하도록 구성된다. 예를 들어, 데이터 스트림들 (212, 214) 은 실질적으로 동일한 타이밍 특성들, 예컨대 주파수 및 위상을 가질 수도 있다. 특정 실시형태에서, 제어/데이터 신호 (232) 는 이미지 신호 프로세서 (208) 로부터 수신될 수도 있다.

[0029] 결합기 (206) 는 제 1 이미지 데이터 스트림 (212) 과 제 2 이미지 데이터 스트림 (214) 에 응답한다. 결합기 (206) 는 제 1 이미지 데이터 스트림 (212) 으로부터의 데이터와 제 2 이미지 데이터 스트림 (214) 으로부터의 데이터를 라인 버퍼 (216) 내에서 결합하도록 구성된다. 특정 실시형태에서, 라인 버퍼 (216) 는 제 1 센서 (202) 로부터의 제 1 데이터 라인 (222) 과 같은 제 1 데이터 및 제 2 센서 (204) 로부터의 제 2 데이터 라인 (224) 과 같은 제 2 데이터를 정렬시키도록 구성된다. 특정 실시형태에서, 결합기 (206) 는 라인 버퍼 (216) 내에 저장된 데이터에 응답하여 라인 데이터 (218) 를 이미지 신호 프로세서 (208) 에 제공한다. 특정 실시형태에서, 라인 데이터 (218) 는 복수의 로우들을 포함할 수도 있고, 여기서 각각의 로우는 도 6 을 참조하여 설명된 것과 같이 각각의 센서 (202, 204) 로부터의 대응하는 로우들의 조합이다.

[0030] 이미지 신호 프로세서 (208) 는 라인 데이터 (218) 를 처리하고, 처리된 라인 데이터 (240) 를 생성하도록 구성된다. 특정 실시형태에서, 처리된 라인 데이터 (240) 는 처리된 프레임 데이터로서 제공될 수도 있다. 2 개의 센서들이 도시되지만, 다른 실시형태들은 3 이상의 센서들을 포함할 수도 있다. 예를 들면, 도 3 은 3 이상의 센서들을 포함하는 일 실시형태 (300) 를 도시한다. 제 N 센서 (305) 는 제 N 이미지 데이터 스트림 (315) 으로 도시된 제 N 데이터 스트림을 생성하도록 구성된다. 제 N 이미지 데이터 스트림 (315) 은 제 N 데이터 라인 (325) 을 포함한다. 제 N 센서 (305) 는 제 1 및 제 2 이미지 센서들 (202, 204) 과 실질적으로 유사할 수도 있고, 센서 동기화기 (230) 로부터 공통 제어 신호 (234) 를 수신하여 제 1, 제 2, 및 제 N 센서들 (202, 204, 305) 이 인접하여 정렬된 데이터 스트림들 (212, 214, 315) 을 생성하게 할 수도 있다. 예를 들어, 데이터 스트림들 (212, 214, 315) 은 주파수 및 위상과 같은 실질적으로 동일한 타이밍 특성들을 가질 수도 있다. 결합기 (206) 는 제 1 이미지 데이터 스트림 (212), 제 2 이미지 데이터 스트림 (214) 및 제 N 이미지 데이터 스트림 (315) 에 응답한다. 결합기 (206) 는 제 1 이미지 데이터 스트림 (212), 제 2 이미지 데이터 스트림 (214) 및 제 N 이미지 데이터 스트림 (315) 을 라인 버퍼 (216) 내에서 결합하도록 구성된다.

[0031] 공통 제어되는, 유사한 센서들 (예컨대, 도 2 의 202, 204 또는 도 3 의 202, 204, 305) 로부터 수신된 데이터가 실질적으로 동일한 주파수 및 위상을 가지기 때문에, 결합기 (206) 에서 수신된 데이터 스트림들 간의 동기화는 이미지 데이터의 단일 이미지 라인 내에서 발생할 수도 있다. 특정 실시형태에서, 라인 버퍼 (216) 는 오정렬 (misalignment) 과 같은 최악의 경우를 위한 크기를 가질 수도 있다 (즉, 동기화 오정렬이 3 개의 라인들에서 발생하면, 라인 버퍼 (212) 는 적어도 6 개 라인들을 버퍼링하도록 크기가 정해져야 한다). 결과적으로, 결합된 데이터는 단일 이미지 신호 프로세서를 이용하여 효율적으로 처리될 수도 있다. 따라서, 전체 이미지 시스템 비용 및 복잡도는 다중 프로세서 시스템들 (예컨대, 각각의 센서에 하나의 프로세서가 할당됨) 과 비교할 때 감소될 수도 있다.

[0032] 도 4 를 참조하면, 도 2 의 이미지 프로세싱 시스템 (200) 의 선택된 부분 (400) 의 특정 예시적인 실시형태가 도시된다. 이미지 프로세싱 시스템의 부분 (400) 은 제 1 센서 (202), 제 2 센서 (204) 및 센서 동기화기 (230) 를 포함한다. 특정 실시형태에서, 제 1 센서 (202) 와 제 2 센서 (204) 는 센서 동기화기 (230) 로부터 동일한 시작 또는 리셋 신호들 및 동일한 클록 입력을 수신하는, 동일한 센서들 또는 거의 동일한 센서들이다. 예를 들면, 제 1 센서 (202) 및 제 2 센서 (204) 는 각각 센서 동기화기 (230) 로부터 공통 제어 데이터/신호들을 수신할 수도 있다. 특정 실시형태에서, 제어 데이터/신호들은 제어 클록 신호 (404), 제어 데이터 신호 (406), 카메라 클록 신호 (408) 및 카메라 리셋 신호 (410) 를 포함할 수도 있다. 제어 데이터/신호들 (404-410) 은 I2C (Inter-Integrated Circuit) 멀티-마스터 직렬 컴퓨터 버스와 같은 2 와이어 접속 통신 프로토콜과 호환가능한 인터페이스를 통해 형성되고 송신될 수도 있다. 대안적으로, 제어 데이터/신호들 (404-410) 은 카메라 직렬 인터페이스 (CSI) 와 같이 디지털 카메라 모듈과 모바일 전화 엔진 간의 직렬 인터페이스, 카메라 직렬 인터페이스 2 (CSI-2) 와 같이 주변 장치 (카메라) 와 호스트 프로세서 (베이스밴드, 애플리케이션 엔진) 간의 인터페이스, 카메라 병렬 인터페이스 (CPI) 와 같이 디지털 카메라 모듈과 모바일 전화

엔진 간의 병렬 인터페이스, 또는 다른 제어 인터페이스들의 사양에 부합하는 인터페이스에 따라 형성되고 송신될 수도 있다.

[0033] 제 1 센서 (202) 는 제 1 타이밍 데이터 (420) 와 제 1 센서 이미지 데이터 (422) 를 도 2 또는 도 5 의 시스템에 도시된 것과 같은 결합기 (206) 로 송신하도록 구성될 수도 있다. 유사하게, 제 2 센서 (204) 는 제 2 타이밍 데이터 (430) 와 제 3 센서 이미지 데이터 (432) 를 도 2 또는 도 5 의 시스템에 도시된 것과 같은 결합기 (206) 로 송신하도록 구성될 수도 있다.

[0034] 동작 동안, 제 1 센서 (202) 와 제 2 센서 (204) 는 각각 타이밍 관점에서 동일하거나 거의 동일한 조건들에서 동작한다. 예를 들면, 제 1 및 제 2 센서들 (202, 204) 은 각각 동일한 제어 블록 신호 (404), 동일한 제어 데이터 신호 (406), 동일한 카메라 블록 신호 (408) 및 동일한 카메라 리셋 신호 (410) 를 수신한다. 제 1 및 제 2 센서들 (202, 204) 이 동일하거나 거의 동일하기 때문에, 동일한 타이밍 조건들에서 실질적으로 유사하게 동작한다. 예를 들면, 제 1 센서 (202) 로부터의 데이터 출력은 센서 (204) 로부터의 데이터 출력과 실질적으로 동일한 주파수 및 위상을 갖는다. 설명을 위해, 제 1 센서 (202) 및 제 2 센서 (204) 로부터의 데이터 출력 간의 위상 차이는 단일 수평선의 위상 차이보다 적을 수도 있으며, 이는 단일 이미지 신호 프로세서가 2 개의 이미지 센서들 (202, 204) 로부터의 이미지 데이터를 동기화하고 제어하는데 이용되게 한다.

[0035] 도 5 를 참조하면, 다중 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템의 특정 예시적 실시형태의 블록도가 도시되고, 일반적으로 500 으로 지정된다. 시스템 (500) 은 제 1 이미지 센서 (202), 제 2 이미지 센서 (204), 결합기 (206), 센서 동기화기 (230) 및 이미지 신호 프로세서 (208) 를 포함한다. 시스템 (500) 은 레지스터 인터페이스 (510) 및 클록 관리 디바이스 (512) 를 추가로 포함한다. 특정 실시형태에서, 레지스터 인터페이스 (510) 는 센서 동기화기 (230) 내에 있을 수도 있다. 대안적으로, 레지스터 인터페이스 (510) 는 자립형 모듈일 수도 있다. 특정 실시형태에서, 시스템 (500) 은 (쉐도우로 도시된) 좁은 출력 포맷화기 (506) 와, (쉐도우로 도시된) 전송 제거 및 포맷화기 (508) 를 추가로 포함할 수도 있다.

[0036] 특정 실시형태에서, 결합기 (206) 는 제 1 센서 (202) 로부터 제 1 타이밍 데이터 (420) 와 제 1 센서 이미지 데이터 (422) 를 수신하도록 구성된다. 결합기 (206) 는 또한 제 2 센서 (204) 로부터 제 2 타이밍 데이터 (430) 와 제 2 센서 이미지 데이터 (432) 를 수신하도록 구성된다. 결합기 (206) 는 추가로 클록 관리 디바이스 (512) 로부터 클록 신호 (526) 를 수신하도록 구성된다. 결합기 (206) 는 제 1 타이밍 데이터 (420), 제 1 센서 이미지 데이터 (422), 제 2 타이밍 데이터 (430) 및 제 2 센서 이미지 데이터 (432) 를 이용하여 이미지 프로세서 (208) 에 제공되는 동기화된 데이터 라인을 생성한다. 이미지 신호 프로세서 (208) 는 동기화된 데이터 라인을 처리하여 처리된 데이터 라인 데이터를 생성한다. 처리된 데이터 라인 데이터는 또 다른 컴포넌트, 예컨대 디스플레이 디바이스로 제공될 수도 있다. 따라서, 다중 센서들로부터의 이미지 데이터가 결합되고, 처리되고, 디스플레이에서 디스플레이를 위해 렌더링될 수도 있다.

[0037] 특정 실시형태에서, 제 1 타이밍 데이터 (420) 는 제 1 픽셀 클록과 연관될 수도 있고, 제 1 센서 이미지 데이터 (422) 는 제 1 픽셀 사이즈와 연관될 수도 있고, 제 2 타이밍 데이터 (430) 는 제 2 픽셀 클록과 연관될 수도 있고, 제 2 센서 이미지 데이터 (432) 는 제 2 픽셀 사이즈와 연관될 수도 있다. 결합기 (406) 가 제 1 타이밍 데이터 (420), 제 2 센서 이미지 데이터 (422), 제 2 타이밍 데이터 (430) 및 제 2 센서 이미지 데이터 (432) 를 결합하여 동기화된 데이터 라인을 생성할 경우에, 제 1 이미지 데이터의 제 1 라인 및 제 2 이미지 데이터의 대응하는 라인은 단일 이미지 라인으로 결합된다. 특정 실시형태에서, 단일 이미지 라인의 사이즈는 제 1 이미지 데이터의 제 1 라인 또는 제 2 이미지 데이터의 대응하는 라인의 실질적으로 2 배 (예컨대, 제 1 픽셀 사이즈 또는 제 2 픽셀 사이즈의 2 배) 가 될 수도 있고, 결합된 단일 이미지 라인의 픽셀 클록의 레이트는 제 1 픽셀 클록 또는 제 2 픽셀 클록의 레이트의 실질적으로 2 배일 수도 있다 (예컨대, 제 1 픽셀 클록 주파수 또는 제 2 픽셀 클록 주파수의 2 배인 클록 주파수를 가질 수도 있다). 생성된 동기화된 데이터 라인은 결합기 타이밍 데이터 신호 (528) 와 결합기 이미지 데이터 신호 (530) 를 통해 이미지 신호 프로세서 (208) 로 송신된다.

[0038] 특정 실시형태에서, 결합기 (206) 에 의해 생성된 동기화된 데이터 라인은 포맷화된 데이터를 생성하기 위해 좁은 출력 포맷화기 (506) 로 제공될 수도 있고, 이 포맷화된 데이터는 이미지 신호 프로세서 (208) 로 제공되기 전에 전송 제거 및 포맷화기 (508) 로 제공된다.

[0039] 특정 실시형태에서, 좁은 출력 포맷화기 (506) 는 결합기 타이밍 데이터 신호 (528) 및 결합기 이미지 데이터 신호 (530) 를 수신하여 포맷화된 데이터를 생성한다. 포맷화된 데이터는 출력 포맷화기 타이밍 데이터 신

호 (536), 출력 포맷화기 이미지 데이터 신호 (538), 출력 포맷화기 통계 데이터 신호 (540), 출력 포맷화기 시각 데이터 신호 (542) 및 출력 포맷화기 유효 데이터 신호 (544) 를 포함할 수도 있다. 특정 실시형태에서, 전송 제어 및 포맷화기 (508) 는 앞은 출력 포맷화기 (500) 로부터 포맷화된 데이터 (536-544) 를 수신하고, 전송 타이밍 데이터 신호 (546) 와 전송 이미지 데이터 신호 (548) 를 포함하는 전송 데이터 스트림을 생성한다.

[0040] 특정 실시형태에서, 레지스터 인터페이스 (510) 는 이미지 신호 프로세서 (208) 에 커플링되고, 플룩 관리 디바이스 (512) 에 커플링될 수도 있다. 특정 실시형태에서, 레지스터 인터페이스 (510) 는 플룩 관리 디바이스 (512) 로부터 플룩 신호 (527) 를 수신할 수도 있고, 레지스터 버스 (672) 에 커플링될 수도 있다. 플룩 관리 디바이스 (512) 는 제 2 타이밍 데이터 신호 (430) 를 수신하고 플룩 신호 (526) 를 출력하도록 구성된다.

특정 실시형태에서, 플룩 신호 (526) 는 제 2 타이밍 데이터 신호 (430) 의 주파수의 실질적으로 2 배이며, 이는 결합기 (206) 가 다중 센서들로부터의 동시 데이터를 결합하면서 프레임 프로세싱 레이트를 유지할 수 있게 한다.

[0041] 공통으로 제어된, 유사한 센서들로부터의 데이터 출력이 실질적으로 동일한 주파수 및 위상을 가지기 때문에, 데이터 스트림들 간의 동기화는 이미지 데이터의 단일 이미지 라인 내에서 발생할 수도 있다. 따라서, 결합된 데이터는 이미지 데이터의 단일 라인으로 액세스하는 단일 이미지 신호 프로세서를 이용하여 효율적으로 처리될 수도 있다.

[0042] 도 6 을 참조하면, 제 1 이미지 센서의 출력에서 제 1 데이터 스트림과 제 2 이미지 센서의 출력에서 제 2 데이터 스트림이 결합되어 동기화된 데이터 라인을 형성하는 특정 실시형태의 도식적인 표현이 도시되며, 일반적으로 600 으로 지정된다. 도 2 의 제 1 센서 (202) 와 같은 제 1 센서는 이미지의 제 1 이미지 데이터에 대응하는 제 1 데이터 스트림 (602) 을 생성한다. 도 2 의 제 2 센서 (204) 와 같은 제 2 센서는 이미지의 제 2 이미지 데이터에 대응하는 제 2 데이터 스트림 (604) 을 생성한다. 제 1 데이터 스트림 (602) 으로부터의 데이터 및 제 2 데이터 스트림 (604) 으로부터의 데이터는 데이터 아웃 데이터 스트림 (606) 을 형성하도록 결합된다.

[0043] 특정 실시형태에서, 제 1 데이터 스트림 (602) 은 이미지의 제 1 이미지 데이터의 제 1 라인과 연관된 데이터를 포함하고, 제 2 데이터 스트림 (604) 은 이미지의 제 2 이미지 데이터의 대응하는 라인과 연관된 데이터를 포함한다. 제 1 데이터 스트림 (602) 은 제 1 라인 인덱스 값을 갖는 라인 데이터 (610), 제 2 라인 인덱스 값을 갖는 라인 데이터 (612), 제 3 라인 인덱스 값을 갖는 라인 데이터 (614) 및 제 4 라인 인덱스 값을 갖는 라인 데이터 (616) 를 포함한다. 제 2 데이터 스트림 (604) 은 제 1 데이터 스트림과 대응하는 라인 데이터를 포함하며, 제 1 라인 인덱스 값을 갖는 대응 라인 데이터 (620), 제 2 라인 인덱스 값을 갖는 대응 라인 데이터 (622), 제 3 라인 인덱스 값을 갖는 대응 라인 데이터 (624) 및 제 4 라인 인덱스 값을 갖는 대응 라인 데이터 (626) 를 포함한다.

[0044] 데이터 아웃 데이터 스트림 (606) 은 이미지의 제 1 이미지 데이터의 제 1 라인 및 이미지의 제 2 이미지 데이터의 대응하는 라인의 결합을 포함한다. 도시된 것과 같이, 제 1 데이터 스트림 (602) 과 제 2 데이터 스트림 (604) 은 데이터 아웃 데이터 스트림 (606) 을 형성하도록 인터리빙된다. 예를 들면, 데이터 아웃 데이터 스트림 (606) 은 제 1 라인 인덱스 값을 갖는 결합된 라인 데이터 (630), 제 2 라인 인덱스 값을 갖는 결합된 라인 데이터 (632), 및 제 3 라인 인덱스 값을 갖는 결합된 라인 데이터 (634) 를 포함한다. 결합된 라인 데이터 (630) 는 라인 데이터 (610) 및 대응 라인 데이터 (620) 를 포함한다. 결합된 라인 데이터 (632) 는 라인 데이터 (612) 및 대응 라인 데이터 (622) 를 포함한다. 결합된 라인 데이터 (634) 는 라인 데이터 (614) 및 대응 라인 데이터 (624) 를 포함한다. 각각의 결합된 라인 (630-634) 은 도 2 의 라인 버퍼 (216) 와 같은 라인 버퍼 내에서 대응하는 라인들을 결합함으로써 생성될 수도 있다.

[0045] 특정 실시형태에서, 제 1 데이터 스트림 (602) 으로부터의 데이터는 제 2 데이터 스트림 (604) 으로부터의 데이터와 결합되어 프레임 (660) 을 형성하는 복수의 동기화된 데이터 라인들을 생성한다. 프레임 (660) 은 복수의 로우들 (642) 을 포함할 수도 있고, 여기서 각각의 로우는 라인 인덱스 값에 대응하고, 그 라인 인덱스 값을 갖는 제 1 이미지 데이터의 하나의 라인과 라인 인덱스 값을 갖는 제 2 이미지 데이터의 대응하는 라인을 포함하는 동기화된 데이터 라인을 저장한다. 예를 들면, 프레임 (660) 의 제 1 로우는 결합된 라인 데이터 (630) 를 포함할 수도 있고, 프레임 (660) 의 제 2 로우는 결합된 라인 데이터 (632) 를 포함할 수도 있고, 프레임 (660) 의 제 3 로우는 결합된 라인 데이터 (634) 를 포함할 수도 있다. 각각의 동기화된 이미지 데이터 라인은 프레임 (660) 내의 데이터가 정렬되도록 프레임 (660) 의 일부를 형성한다.

[0046] 프레임 (660) 은 이미지 센서들로부터의 이미지 데이터의 원래 순서에 대응하는 로우들 (642) 의 순서가 함께

도시된다 (즉, 이미지 센서들의 최상위 라인으로부터 결합된 데이터 (라인 인덱스 1) 는 프레임 (660) 의 최상위 라인에 있고, 이미지 센서들의 다음 라인으로부터 결합된 데이터 (라인 인덱스 2) 는 프레임 (660) 의 다음 라인에 있다). 대안적으로, 다른 실시형태들에서, 프레임 (660) 의 로우들은 이미지 데이터의 판독 순서와 매칭하지 않을 수도 있고, 대신에 이미지 데이터의 임의의 다른 순서에 대응할 수도 있다. 예를 들면, 프레임 (660) 의 최상위 로우는 라인 인덱스 2 에 대응할 수도 있고, 프레임 (660) 의 다음 로우는 라인 인덱스 1 에 대응할 수도 있다. 프레임 (660) 은 로우들 (642) 각각이 이미지 데이터의 라인 인덱스 값들 중 임의의 라인 인덱스 값에 대응하게 프로그래밍될 수 있도록 프로그래밍 가능할 수도 있다.

[0047] 특정 실시형태에서, 제 1 이미지 데이터의 제 1 라인 (610) 은 제 1 픽셀 사이즈 (예컨대, 라인당 픽셀 수) 및 제 1 픽셀 클록과 연관되고, 제 2 이미지 데이터의 대응하는 라인 (620) 은 제 2 픽셀 사이즈 및 제 2 픽셀 클록과 연관된다. 데이터 스트림들 (602, 604) 을 생성하는 제 1 센서와 제 2 센서는 공통 제어 신호 및 공통 리셋 신호를 수신하도록 구성된다. 제 1 이미지 데이터의 제 1 라인 (610) 과 제 2 이미지 데이터의 대응하는 라인 (620) 이 단일 이미지 라인으로 결합될 경우에, 단일 이미지 라인의 사이즈는 제 1 이미지 데이터의 제 1 라인 (610) 또는 제 2 이미지 데이터의 대응하는 라인 (620) 의 사이즈의 실질적으로 2 배이고, 결합된 단일 이미지 라인의 픽셀 클록 신호 (예컨대, 제 3 픽셀 클록 신호) 는 제 1 픽셀 클록 신호 또는 제 2 픽셀 클록 신호의 클록 레이트의 실질적으로 2 배의 클록 레이트를 갖는다. 예를 들면, 결합된 라인 데이터 (630) 는 라인 데이터 (610) 의 실질적으로 2 배 또는 대응하는 라인 데이터 (620) 의 실질적으로 2 배인 이미지 사이즈를 가질 수도 있다. 유사하게, 결합된 라인 데이터 (630) 의 픽셀 클록 주파수는 라인 데이터 (610) 와 연관된 제 1 픽셀 클록 신호의 실질적으로 2 배 또는 대응하는 라인 데이터 (620) 와 연관된 제 2 픽셀 클록 신호의 실질적으로 2 배인 주파수를 가질 수도 있으며, 따라서 결합된 라인 데이터 (630) 의 픽셀 클록 주파수는 제 1 픽셀 클록 또는 제 2 픽셀 클록의 주파수의 실질적으로 2 배의 주파수를 갖는 제 3 픽셀 클록 신호와 연관될 수도 있다.

[0048] 대안적으로, 동일한 라인 사이즈들을 갖는 라인 데이터 3 이미지 센서들이 결합되는 일 구현에서, 동기화된 라인 사이즈는 센서 라인 사이즈의 실질적으로 3 배일 수도 있고, 픽셀 클록 레이트는 개별 센서들의 픽셀 클록 레이트의 실질적으로 3 배일 수도 있다. 임의의 수의 센서들이 동일하지 않은 사이즈들을 가질 수 있는 일반적인 경우에, 동기화된 라인 사이즈는 결합된 라인 사이즈들의 합보다 크거나 동일하게 세팅될 수도 있고, 픽셀 클록 레이트는 출력 라인 대역폭이 입력 대역폭의 합보다 크거나 동일하도록 세팅될 수도 있다.

[0049] 프레임 (660) 은 도 2 의 이미지 신호 프로세서 (208) 와 같은 이미지 신호 프로세서에서 처리되어 처리된 프레임 (650) 을 생성할 수도 있다. 처리된 프레임 (650) 은 도 2 의 센서 (202) 와 같은 제 1 이미지 센서로부터의 제 1 이미지 데이터를 포함하는 제 1 섹션 (652), 도 2 의 센서 (204) 와 같은 제 2 이미지 센서로부터의 제 2 이미지 데이터를 포함하는 제 2 섹션 (654) 및 갭 섹션 (656) 을 포함한다. 갭 섹션 (656) 은 제 1 섹션 (652) 과 제 2 섹션 (654) 사이에 배치된 비-이미지 데이터를 포함할 수도 있다.

[0050] 특정 실시형태에서, 제 1 섹션 (652) 은 제 1 이미지 데이터의 라인을 포함하고, 제 2 섹션 (654) 은 제 2 이미지 데이터의 대응하는 라인을 포함한다. 특정 실시형태에서, 갭 섹션 (656) 은 에지 필터링을 위해 이용될 수도 있고, 폭이 대략 5 개 픽셀들인 블랙 갭을 포함할 수도 있다. 추가의 예로서, 갭 섹션 (656) 은 라인들 사이에 부가될 수도 있고, 보간 커널 (interpolation kernel) 의 사이즈 또는 이미지 신호 프로세서에 의해 프레임 (650) 에 적용되는 최대 2 차원 필터의 사이즈와 동일한 사이즈를 가질 수도 있다.

[0051] 특정 예시적인 실시형태에서, 자동 노출, 자동 포커스, 및 자동 화이트 밸런스를 위한 통계치들이 제 1 섹션 (652) 또는 제 2 섹션 (654) 으로부터 수집될 수도 있으며, 이들 각각은 개별 센서들 중 하나의 센서로부터의 관련한 이미지일 수도 있다. 따라서, 자동 노출, 자동 포커스 및 자동 화이트 밸런스에 대한 통계치들은 최종 이미지의 결함 (예컨대, 제 1 섹션 (652)) 으로부터 수집될 수도 있고, 양자의 센서들이 실질적으로 동일한 타이밍 정보를 수신하고 있기 때문에 양자의 센서들로 적용될 수도 있다. 이와 같이, 다중 센서들로부터의 데이터 출력은 이미지의 이미지 데이터의 하나의 이미지 라인에서 동기화가 발생할 수 있도록 실질적으로 동일한 주파수와 위상을 가질 수도 있다.

[0052] 프레임 (650) 은 적어도 하나의 반도체 다이에 집적된 메모리에 저장될 수도있다. 프레임 (650) 은 고객용 전자 디바이스, 예컨대 셋톱 박스, 튜닝 플레이어, 비디오 플레이어, 엔터테인먼트 유닛, 네비게이션 디바이스, 통신 디바이스, 개인 디지털 보조장치 (PDA), 고정 위치 데이터 유닛, 및 컴퓨터 내에 통합된 메모에 저장될 수도 있다. 전자 디바이스들은 다중 센서들로부터의 이미지데이터를 처리하는 3D 애플리케이션들을 포함하여 이미지 프로세싱 방법들을 활용할 수도 있다.

[0053] 도 7 을 참조하면, 제 1 이미지 센서의 출력에서 제 1 데이터 스트림과 제 2 이미지 센서의 출력에서 제 2 데이터 스트림이 결합되어 동기화된 데이터 라인을 형성하는 제 2 실시형태의 도식적인 표현이 도시되고, 일반적으로 700 으로 지정된다. 도 2 의 제 1 이미지 센서 (202) 와 같은 제 1 센서는 이미지의 제 1 이미지 데이터에 대응하는 제 1 데이터 스트림 (702) 을 생성한다. 도 2 의 제 2 이미지 센서 (204) 와 같은 제 2 센서는 이미지의 제 2 이미지 데이터에 대응하는 제 2 데이터 스트림 (704) 을 생성한다. 제 1 데이터 스트림 (702) 으로부터의 데이터와 제 2 데이터 스트림 (704) 으로부터의 데이터는 결합되어 데이터 아웃 데이터 스트림 (706) 을 형성한다.

[0054] 특정 실시형태에서, 제 1 데이터 스트림 (702) 은 이미지의 제 1 이미지 데이터의 제 1 라인과 연관된 데이터를 포함하고, 제 2 데이터 스트림 (704) 은 이미지의 제 2 이미지 데이터의 대응하는 라인과 연관된 데이터를 포함한다. 제 1 데이터 스트림 (702) 은 제 1 라인 인덱스 값을 갖는 라인 데이터 (710), 제 2 라인 인덱스 값을 갖는 라인 데이터 (712), 제 3 라인 인덱스 값을 갖는 라인 데이터 (714) 및 제 4 라인 인덱스 값을 갖는 라인 데이터 (716) 를 포함한다. 제 2 데이터 스트림 (704) 은 제 1 데이터 스트림과 대응하는 라인 데이터를 포함하며, 제 1 라인 인덱스 값을 갖는 대응 라인 데이터 (720), 제 2 라인 인덱스 값을 갖는 대응 라인 데이터 (722), 제 3 라인 인덱스 값을 갖는 대응 라인 데이터 (724) 및 제 4 라인 인덱스 값을 갖는 대응 라인 데이터 (726) 를 포함한다.

[0055] 데이터 아웃 데이터 스트림 (706) 은 이미지의 제 1 이미지 데이터의 제 1 라인 및 이미지의 제 2 이미지 데이터의 대응하는 라인의 결합을 포함한다. 도시된 것과 같이, 제 1 데이터 스트림 (702) 과 제 2 데이터 스트림 (704) 은 데이터 아웃 데이터 스트림 (706) 을 형성하도록 갭 섹션 (708) 과 인터리빙된다. 예를 들면, 데이터 아웃 데이터 스트림 (706) 의 도시된 부분은 제 1 라인 인덱스 값을 갖는 결합된 라인 데이터 (730), 제 2 라인 인덱스 값을 갖는 결합된 라인 데이터 (732), 및 제 3 라인 인덱스 값을 갖는 결합된 라인 데이터 (734) 를 포함한다. 결합된 라인 데이터 (730) 는 갭 섹션 (708) 에 의해 대응하는 라인 데이터 (720) 와 분리되는 라인 데이터 (710) 를 포함한다. 결합된 라인 데이터 (732) 는 갭 섹션 (708) 에 의해 대응 라인 데이터 (722) 와 분리되는 라인 데이터 (712) 를 포함한다. 결합된 라인 데이터 (734) 는 갭 섹션 (708) 에 의해 대응 라인 데이터 (724) 와 분리되는 라인 데이터 (714) 를 포함한다. 각각의 결합된 라인 (730-734) 은 도 2 의 라인 버퍼 (216) 와 같은 라인 버퍼 내에서 대응하는 라인들 간의 갭 섹션 (708) 과 대응하는 라인들을 결합함으로써 생성될 수도 있다.

[0056] 특정 실시형태에서, 제 1 데이터 스트림 (702) 으로부터의 데이터는 제 2 데이터 스트림 (704) 으로부터의 데이터와 결합되어 프레임 (740) 을 형성하는 복수의 동기화된 데이터 라인들을 생성한다. 프레임 (740) 은 복수의 로우들 (742) 을 포함할 수도 있고, 여기서 각각의 로우는 라인 인덱스 값에 대응하고, 그 라인 인덱스 값을 갖는 제 1 이미지 데이터의 하나의 라인을 저장하고 그 라인 인덱스 값을 갖는 제 2 이미지 데이터의 대응하는 라인을 저장한다. 예를 들면, 프레임 (740) 의 제 1 로우는 결합된 라인 데이터 (730) 를 포함할 수도 있고, 프레임 (740) 의 제 2 로우는 결합된 라인 데이터 (732) 를 포함할 수도 있고, 프레임 (740) 의 제 3 로우는 결합된 라인 데이터 (734) 를 포함하여 프레임 (740) 내의 데이터가 정렬되도록 한다.

[0057] 특정 실시형태에서, 제 1 이미지 데이터의 제 1 라인 (710) 은 제 1 픽셀 사이즈 (예컨대, 라인당 픽셀 수) 및 제 1 픽셀 클록과 연관되고, 제 2 이미지 데이터의 대응하는 라인 (720) 은 제 2 픽셀 사이즈 및 제 2 픽셀 클록과 연관된다. 데이터 스트림들 (702, 704) 을 생성하는 제 1 센서와 제 2 센서는 공통 클록 신호 및 공통 라잇 신호를 수신하도록 구성된다. 제 1 이미지 데이터의 제 1 라인 (710) 과 제 2 이미지 데이터의 대응하는 라인 (720) 이 단일 이미지 라인으로 결합될 경우에, 단일 이미지 라인의 사이즈는 제 1 이미지 데이터의 제 1 라인 (710) 또는 제 2 이미지 데이터의 대응하는 라인 (720) 의 사이즈의 실질적으로 2 배이다. 추가로, 결합된 단일 이미지 라인의 픽셀 클록 신호 (예컨대, 제 3 픽셀 클록 신호) 는 제 1 픽셀 클록 신호 또는 제 2 픽셀 클록 신호의 클록 레이트의 실질적으로 2 배의 클록 레이트를 갖는다. 예를 들면, 결합된 라인 데이터 (730) 는 라인 데이터 (710) 의 대략 2 배 또는 대응하는 라인 데이터 (720) 의 대략 2 배인 이미지 사이즈를 가질 수도 있다. 유사하게, 결합된 라인 데이터 (730) 의 픽셀 클록 주파수는 라인 데이터 (710) 와 연관된 제 1 픽셀 클록 신호의 대략 2 배 또는 대응하는 라인 데이터 (720) 와 연관된 제 2 픽셀 클록 신호의 대략 2 배인 주파수를 가질 수도 있으며, 따라서 결합된 라인 데이터 (730) 의 픽셀 클록 주파수는 제 1 픽셀 클록 또는 제 2 픽셀 클록의 주파수의 대략 2 배의 주파수를 갖는 제 3 픽셀 클록 신호와 연관될 수도 있다.

[0058] 각각의 갭 섹션 (708) 은 비-이미지 데이터를 포함할 수도 있다. 특정 실시형태에서, 갭 섹션들 (708) 에 의해 형성된 프레임 (740) 내의 비-이미지 데이터 영역은 에러 필터링을 위해 이용될 수도 있다. 갭 섹션 (708) 은 적어 대략 5 픽셀들인 블랙 갭을 포함할 수도 있다. 다른 실시형태들에서, 각각의 갭 섹션 (708)

은 도 2 의 이미지 프로세서 (208) 와 같은 이미지 프로세서에 의해 프레임 (740) 에 적용된 최대 2-차원 필터의 사이즈 또는 프라 거널의 사이즈와 동일한 사이즈를 갖는다. 프레임 (740) 은 이미지 프로세서에 의해 처리되어 3D 이미지를 생성할 수도 있다.

[0059] 도 8 을 참조하면, 제 1 센서로부터의 제 1 데이터 스트림과 제 2 센서로부터의 제 2 데이터 스트림 간의 2 라인 위상 차이를 예시하는 위상도의 제 1 실시형태의 도식적인 표현이 도시되고, 일반적으로 800 으로 지정된다.

도 2 의 제 1 센서 (202) 와 같은 제 1 센서는 제 1 센서 제 1 라인 데이터 (802), 제 1 센서 제 2 라인 데이터 (804) 및 제 1 센서 제 3 라인 데이터 (806) 를 포함하는 제 1 데이터 스트림을 생성한다. 도 2 의 제 2 센서 (204) 와 같은 제 2 센서는 제 2 센서 제 1 라인 데이터 (812), 제 2 센서 제 2 라인 데이터 (814) 및 제 2 센서 제 3 라인 데이터 (816) 를 포함하는 제 2 데이터 스트림을 생성한다. 제 1 데이터 스트림으로부터의 데이터와 제 2 데이터 스트림으로부터의 데이터는 결합되어 결합된 라인 (820) 을 형성한다. 도 8 에 도시된 특정 실시형태에서, 제 1, 제 2 및 제 3 라인 데이터가 도시된다. 대안적으로, 임의의 수의 라인 데이터 (예컨대, 도 6 및 도 7 에 도시된 것과 같은 720 개 라인들) 가 생성될 수도 있다.

[0060] 도 8 의 특정 실시형태에서, 제 1 데이터 스트림의 데이터와 제 2 데이터 스트림의 데이터 간에 2 라인 위상 차이가 발생한다. 예컨대, 제 1 센서 제 1 라인 데이터 (802) 는 제 1 라인 위상 동안 도 2 의 결합기 (216) 와 같은 결합기에 의해 수신될 수도 있고, 제 1 센서 제 2 라인 데이터 (804) 는 제 2 라인 위상 동안 수신될 수도 있고, 제 1 센서 제 3 라인 데이터 (806) 와 제 2 센서 제 1 라인 데이터 (812) 는 제 3 라인 위상 동안 수신될 수도 있다. 이와 같이, 제 1 센서 제 1 라인 데이터 (802) 와 제 2 센서 제 1 라인 데이터 (812) 사이에 2 라인 위상 차이가 존재한다.

[0061] 결합된 라인 (820) 은 이미지의 제 1 이미지 데이터의 제 1 라인과 이미지의 제 2 이미지 데이터의 대응하는 라인의 결합을 포함한다. 도시된 것과 같이, 제 1 데이터 스트림과 제 2 데이터 스트림은 인터리빙되어 결합된 라인 (820) 을 형성한다. 예를 들어, 결합된 라인 (820) 은 제 1 센서 제 1 라인 데이터 (802) 와 제 2 센서 제 1 라인 데이터 (812) 를 갖는 결합된 라인 데이터 (822), 제 1 센서 제 2 라인 데이터 (804) 와 제 2 센서 제 2 라인 데이터 (814) 를 갖는 결합된 라인 데이터 (824), 및 제 1 센서 제 3 라인 데이터 (806) 와 제 2 센서 제 3 라인 데이터 (816) 를 갖는 결합된 라인 데이터 (826) 를 포함한다. 각각의 결합된 라인 (822-826) 은 도 2 의 라인 버퍼 (216) 와 같은 라인 버퍼 내에서 대응하는 라인들을 결합함으로써 생성될 수도 있다. 라인 버퍼는 동기화된 데이터 라인 (예컨대, 결합된 라인 데이터 (822)) 가 생성되기 전에 제 1 이미지 센서로부터 수신되는, 다음 데이터 라인 (예컨대, 제 1 센서 제 2 라인 데이터 (804) 의 적어도 일부분을 버퍼링하도록 구성될 수도 있다. 이와 같이, 2 라인 위상 차이를 갖는 다중 센서들로부터의 데이터 출력은 결합되어 이미지의 이미지 데이터의 하나의 이미지 라인 내에서 동기화가 발생하도록 할 수도 있다.

[0062] 도 9 를 참조하면, 제 1 센서로부터의 제 1 데이터 스트림과 제 2 센서로부터의 제 2 데이터 스트림 간의 1 라인 위상 차이를 예시하는 위상도의 제 1 실시형태의 도식적인 표현이 도시되고, 일반적으로 900 으로 지정된다.

도 2 의 제 1 센서 (202) 와 같은 제 1 센서는 제 1 센서 제 1 라인 데이터 (902), 제 1 센서 제 2 라인 데이터 (904), 제 1 센서 제 3 라인 데이터 (906) 및 제 1 센서 제 4 라인 데이터 (908) 를 포함하는 제 1 데이터 스트림을 생성한다. 도 2 의 제 2 센서 (204) 와 같은 제 2 센서는 제 2 센서 제 1 라인 데이터 (912), 제 2 센서 제 2 라인 데이터 (914), 제 2 센서 제 3 라인 데이터 (916) 및 제 2 센서 제 4 라인 데이터 (918) 를 포함하는 제 2 데이터 스트림을 생성한다. 제 1 데이터 스트림으로부터의 데이터와 제 2 데이터 스트림으로부터의 데이터는 결합되어 결합된 라인 (920) 을 형성한다. 도 9 에 도시된 특정 실시형태에서, 제 1, 제 2, 제 3 및 제 4 라인 데이터가 도시된다. 대안적으로, 임의의 수의 라인 데이터 (예컨대, 도 6 및 도 7 에 도시된 것과 같은 720 개 라인들) 가 생성될 수도 있다.

[0063] 도 9 의 특정 실시형태에서, 제 1 데이터 스트림의 데이터와 제 2 데이터 스트림의 데이터 간에 1 라인 위상 차이가 발생한다. 예컨대, 제 1 센서 제 1 라인 데이터 (902) 는 제 1 라인 위상 동안 도 2 의 결합기 (216) 와 같은 결합기에 의해 수신될 수도 있고, 제 1 센서 제 2 라인 데이터 (904) 및 제 2 센서 제 1 라인 데이터 (912) 는 제 2 라인 위상 동안 수신될 수도 있다. 이와 같이, 제 1 센서 제 1 라인 데이터 (902) 와 제 2 센서 제 1 라인 데이터 (912) 사이에 1 라인 위상 차이가 존재한다.

[0064] 결합된 라인 (920) 은 이미지의 제 1 이미지 데이터의 제 1 라인과 이미지의 제 2 이미지 데이터의 대응하는 라인의 결합을 포함한다. 도시된 것과 같이, 제 1 데이터 스트림과 제 2 데이터 스트림은 인터리빙되어 결합된 라인 (920) 을 형성한다. 예를 들어, 결합된 라인 (920) 은 제 1 센서 제 1 라인 데이터 (902) 와 제 2 센서 제 1 라인 데이터 (912) 를 갖는 결합된 라인 데이터 (922), 제 1 센서 제 2 라인 데이터 (904) 와 제 2

센서 제 2 라인 데이터 (914) 를 갖는 결합된 라인 데이터 (924), 제 1 센서 제 3 라인 데이터 (906) 와 제 2 센서 제 3 라인 데이터 (916) 를 갖는 결합된 라인 데이터 (926), 및 제 1 센서 제 4 라인 데이터 (908) 와 제 2 센서 제 4 라인 데이터 (918) 를 갖는 결합된 라인 데이터 (928) 를 포함한다. 각각의 결합된 라인 (922-926) 은 도 2 의 라인 버퍼 (216) 와 같은 라인 버퍼 내에서 대응하는 라인들을 결합함으로써 생성될 수도 있다. 이와 같이, 1 라인 위상 차이를 갖는 다중 센서들로부터의 데이터 출력은 결합되어 이미지의 이미지 데이터의 하나의 이미지 라인 내에서 동기화가 발생하도록 할 수도 있다.

[0065] 도 10 을 참조하면, 다중 센서들 각각에 대한 적색-녹색-청색 (RGB) 데이터를 예시하고 동기화된 데이터 라인들을 예시하는 도식적인 표현이 도시되고, 일반적으로 1000 으로 지정된다. 도 10 에 도시된 실시형태에서, 도 3 의 제 1 센서 (202) 와 같은 제 1 센서는 제 1 센서 제 1 라인 데이터 (1002), 제 1 센서 제 2 라인 데이터 (1004), 및 제 1 센서 제 3 라인 데이터 (1006) 를 포함하는 제 1 데이터 스트림을 생성한다. 도 3 의 제 2 센서 (204) 와 같은 제 2 센서는 제 2 센서 제 1 라인 데이터 (1012), 제 2 센서 제 2 라인 데이터 (1014), 및 제 2 센서 제 3 라인 데이터 (1016) 를 포함하는 제 2 데이터 스트림을 생성한다. 도 3 의 제 N 센서 (305) 와 같은 제 3 센서는 제 3 센서 제 1 라인 데이터 (1022), 제 3 센서 제 2 라인 데이터 (1024), 및 제 3 센서 제 3 라인 데이터 (1026) 를 포함하는 제 3 데이터 스트림을 생성한다. 제 1 데이터 스트림으로부터의 데이터, 제 2 데이터 스트림으로부터의 데이터, 및 제 3 데이터 스트림으로부터의 데이터는 결합되어 결합된 라인 (1020) 을 형성한다.

[0066] 일 예로서, 베이어 (Bayer) 필터 패턴에 따라, 제 1 라인 데이터 (1002, 1012, 1022) 각각은 교번하는 적색 및 녹색 픽셀 값들을 포함하고, 제 2 라인 데이터 (1004, 1014, 1024) 의 각각은 교번하는 녹색 및 청색 픽셀 값들을 포함하고, 제 3 라인 데이터 (1006, 1016, 1026) 의 각각은 교번하는 적색 및 녹색 픽셀 값들을 포함한다.

[0067] 도시된 것과 같이, 제 1 데이터 스트림, 제 2 데이터 스트림 및 제 3 데이터 스트림은 결합된 라인 데이터 스트림 (1020) 을 형성하도록 인터리빙된다. 예를 들어, 결합된 라인 데이터 스트림 (1020) 은 제 1 센서 제 1 라인 데이터 (1002), 제 2 센서 제 1 라인 데이터 (1012), 및 제 3 센서 제 1 라인 데이터 (1002) 를 갖는 결합된 라인 데이터 (1040), 제 1 센서 제 2 라인 데이터 (1004), 제 2 센서 제 2 라인 데이터 (1014) 및 제 3 센서 제 2 라인 데이터 (1024) 를 갖는 결합된 라인 데이터 (1050), 및 제 1 센서 제 3 라인 데이터 (1006), 제 2 센서 제 3 라인 데이터 (1016) 및 제 3 센서 제 3 라인 데이터 (1026) 를 갖는 결합된 라인 데이터 (1060) 를 포함한다. 각각의 결합된 라인 (1040-1060) 은 도 3 의 라인 버퍼 (216) 와 같은 라인 버퍼 내에서 대응하는 라인들을 결합함으로써 생성될 수도 있다. 각각의 결합된 라인 (1040-1060) 은 그 개별 센서 라인 데이터로부터 판독된 또우 픽셀 (예컨대, R, G 및 B) 값들을 포함하며, 이 값들은 도 3 의 이미지 신호 프로세서 (208) 와 같은 이미지 신호 프로세서에서 디모자이크 (demosaic) 될 수도 있다. 이와 같이, 다중 센서들로부터의 데이터 출력은 결합되어 이미지의 이미지 데이터의 하나의 이미지 라인 내에서 동기화가 발생하게 할 수도 있다.

[0068] 도 10 은 원시 (raw) 픽셀 값들을 베이어 필터 패턴에 따라 RGB 데이터를 포함하는 것으로 도시하지만, 다른 실시형태들에서, 센서들로부터의 라인 데이터는 베이어 RGB 픽셀 값들을 포함하지 않을 수도 있다. 예를 들어, 대신에 센서들은: 루아, 청색-차이 크로마, 적색-차이 크로마 (YCbCr) 값들: 시안, 노랑색, 녹색 및 마젠타 (CYGM) 값들: 적색, 녹색, 청색 및 에메랄드 (RGBE) 값들: 적색, 녹색, 청색 및 백색 (RGBW) 값들; 또는 예시적이고 비제한적인 예들로서 임의의 다른 타입의 값들을 제공할 수도 있다. 대안적으로 또는 추가로, 센서들 중 하나 이상은 랜드로마틱 겔들, 포토 리셉터 그룹상의 마이크로 렌즈들, 수직 컬러 필터들 또는 원시 이미지 데이터의 라인별 판독이 가능한 임의의 다른 센서 기술을 구현할 수도 있다.

[0069] 도 11 을 참조하면, 다중 센서들을 갖는 장치와 인터리빙 신호 타이밍을 예시하는 타이밍도의 특정 실시형태가 도시되고, 일반적으로 1100 으로 지정된다. 신호들은 제 1 센서의 프레임 유효 (FV) 신호 (1102) 및 라인 유효 (LV) 신호 (1104), 제 2 센서의 FV (1106) 및 LV (1108), 및 제 3 센서의 FV (1110) 및 LV (1112) 를 포함한다. 특정 실시형태에서, 제 1 센서, 제 2 센서, 및 제 3 센서는 도 3 의 제 1, 제 2, 및 제 3 센서들 (202, 204, 305) 일 수도 있다. 결합된 프레임 유효 신호 (1114) 는 결합된 라인 유효/데이터 신호 (1116) 와 라인 무하 (LL) 신호 (1118) 와 함께 도시된다.

[0070] 특정 실시형태에서, 신호들 (1114-1118) 은 결합기에 의해 생성된 도 6 의 프레임 (660) 과 같은, 프레임의 하나 이상의 동기화된 데이터 라인들과 관련된 시그널링에 대응하고, 신호들 (1102-1112) 은 결합기에서 수신된 시그널링에 대응한다. 도시된 것과 같이, 제 1 라인 데이터 (1120), 제 2 라인 데이터 (1122), 및 제 3 라인 데이터 (1124) 는 제 1 센서로부터 수신되고, 제 1 라인 데이터 (1130), 제 2 라인 데이터 (1132), 및 제 3

라인 데이터 (1134) 는 제 2 센서로부터 수신되며, 제 1 라인 데이터 (1140), 제 2 라인 데이터 (1142) 및 제 3 라인 데이터 (1144) 는 제 3 센서로부터 수신된다.

[0071] 제 1 라인 데이터 (1130) 는 제 1 라인 데이터 (1120) 및 제 2 라인 데이터 (1140) 이전에 제 2 센서로부터 수신된다. 제 1 라인 데이터 (1130) 와 제 2 라인 데이터 (1120) 의 수신 간의 위상 차이는 제 1 위상 차이 (1180) 로 도시된다. 제 1 센서의 제 1 라인 데이터 (1120) 는 제 3 센서의 제 1 라인 데이터 (1140) 이전에 수신되며, 이는 제 2 위상 차이 (1182) 로서 도시된다. 센서들 각각으로부터의 라인 데이터는 대응하는 프레임 유효 신호의 상승 에지를 따라 수도 있으며, 이는 이미지 데이터 라인을 통해 수신된 데이터가 각각의 특정 센서로부터 유효한 라인 데이터임을 나타낸다. 도시된 것과 같이, 결합된 프레임 유효 라인 (1114) 은 로우 (low) 를 유지하며, 이는 제 1 라인 데이터 (1120, 1130 및 1140) 각각이 예컨대 도 2 의 결합기 (206) 에서 수신된 이후 까지 비-유효 데이터임을 나타낸다. 제 1 라인들 (1120, 1130 및 1140) 각각이 수신된 후에, 결합된 프레임 유효 신호 (1114) 는 라인 유효 신호 (1116) 상에 유효한 데이터를 나타내도록 상승한다. 제 1 동기화된 데이터 라인 (1150) 은 LL 라인 (1118) 상에서 강조되고 있는 유효 신호와 결합하여 생성된다. 제 1 동기화된 라인 데이터 (1150) 의 생성 이후에, 결합된 프레임 유효 신호 (1114) 는 유효 상태를 유지하지만 LL 신호 (1118) 는 비-유효 상태로 리턴하며, 그 후에 LL 신호 (1118) 는 제 2 동기화된 데이터 라인 (1160) 의 생성 및 그 후의 제 3 동기화된 데이터 라인 (1170) 의 생성시 유효 상태로 복귀한다.

[0072] 도 12 를 참조하면, 제 1 센서로부터의 제 1 데이터 스트림, 제 2 센서로부터의 제 2 데이터 스트림 및 제 3 센서로부터의 제 3 데이터 스트림 간의 3 라인 위상 차이를 예시하는 위상도의 제 1 실시형태의 도식적인 표현이 도시되고, 일반적으로 1200 으로 지정된다. 도 3 의 제 1 센서 (202) 와 같은 제 1 센서는 제 1 센서 제 1 라인 데이터 (1202), 제 1 센서 제 2 라인 데이터 (1204), 제 1 센서 제 3 라인 데이터 (1206) 및 제 1 센서 제 4 라인 데이터 (1208) 를 포함하는 제 1 데이터 스트림을 생성한다. 도 3 의 제 2 센서 (204) 와 같은 제 2 센서는 제 2 센서 제 1 라인 데이터 (1212), 제 2 센서 제 2 라인 데이터 (1214), 제 2 센서 제 3 라인 데이터 (1216) 및 제 2 센서 제 4 라인 데이터 (1218) 를 포함하는 제 2 데이터 스트림을 생성한다. 도 3 의 제 N 센서 (305) 와 같은 제 3 센서는 제 3 센서 제 1 라인 데이터 (1222), 제 3 센서 제 2 라인 데이터 (1224), 제 3 센서 제 3 라인 데이터 (1226) 및 제 3 센서 제 4 라인 데이터 (1228) 를 포함하는 제 3 데이터 스트림을 생성한다. 제 1 데이터 스트림으로부터의 데이터, 제 2 데이터 스트림으로부터의 데이터, 및 제 3 데이터 스트림으로부터의 데이터는 결합되어 결합된 라인 (1220) 을 형성한다. 도 12 에 도시된 특정 실시형태에서, 제 1, 제 2, 제 3 및 제 4 라인 데이터가 도시된다. 대안적으로, 임의의 수의 라인 데이터 (예컨대, 도 6 및 도 7 에 도시된 것과 같은 720 개 라인들) 가 생성될 수도 있다.

[0073] 특정 실시형태에서, 제 1 데이터 스트림의 데이터, 제 2 데이터 스트림의 데이터 및 제 3 데이터 스트림의 데이터 간에 3 라인 위상 차이가 발생한다. 예컨대, 제 3 센서 제 1 라인 데이터 (1222) 는 제 1 라인 위상 동안 도 2 의 결합기 (216) 와 같은 결합기에 의해 수신될 수도 있고, 제 1 센서 제 1 라인 데이터 (1202) 와 제 3 센서 제 2 라인 데이터 (1224) 는 제 2 라인 위상 동안 수신될 수도 있고, 제 1 센서 제 2 라인 데이터 (1204) 와 제 3 센서 제 3 라인 데이터 (1226) 는 제 3 라인 위상 동안 수신될 수도 있으며, 제 1 센서 제 3 라인 데이터 (1206), 제 2 센서 제 1 라인 데이터 (1212) 및 제 3 센서 제 4 라인 데이터 (1228) 는 제 4 라인 위상 동안 수신될 수도 있다. 이와 같이, 제 1 센서 제 1 라인 데이터 (1202), 제 2 센서 제 1 라인 데이터 (1212) 및 제 3 센서 제 1 라인 데이터 (1222) 사이에 3 라인 위상 차이가 존재한다.

[0074] 결합된 라인 (1220) 은 이미지의 제 1 이미지 데이터의 제 1 라인과 이미지의 제 2 이미지 데이터 및 이미지의 제 3 이미지 데이터의 대응하는 라인의 결합을 포함한다. 도시된 것과 같이, 제 1 데이터 스트림, 제 2 데이터 스트림 및 제 3 데이터 스트림은 인터리빙되어 결합된 라인 (1220) 을 형성한다. 예를 들어, 결합된 라인 (1220) 은 제 1 센서 제 1 라인 데이터 (1202), 제 2 센서 제 1 라인 데이터 (1212) 및 제 3 센서 제 1 라인 데이터 (1222) 를 갖는 결합된 라인 데이터 (1232), 제 1 센서 제 2 라인 데이터 (1204), 제 2 센서 제 2 라인 데이터 (1214) 및 제 3 센서 제 2 라인 데이터 (1224) 를 갖는 결합된 라인 데이터 (1234), 및 제 1 센서 제 3 라인 데이터 (1206), 제 2 센서 제 3 라인 데이터 (1216) 및 제 3 센서 제 3 라인 데이터 (1226) 를 갖는 결합된 라인 데이터 (1236) 를 포함한다. 각각의 결합된 라인 (1232-1236) 은 도 3 의 라인 버퍼 (216) 와 같은 라인 버퍼 내에서 대응하는 라인들을 결합함으로써 생성될 수도 있다. 이와 같이, 3 라인 위상 차이를 갖는 다중 센서들로부터의 데이터 출력은 결합되어 이미지의 이미지 데이터의 하나의 이미지 라인 내에서 동기화가 발생하도록 할 수도 있다.

[0075] 도 13 을 참조하면, 다중 센서들로부터의 데이터를 결합하여 3D 데이터를 생성하는 이미지 프로세싱 시스템의 특정 예시적 실시형태가 도시되고, 일반적으로 1300 으로 지정된다. 이미지 프로세싱 시스템 (1300) 은 제

1 이미지 센서 (1302) 및 제 2 이미지 센서 (1304) 를 포함한다. 이미지 프로세싱 시스템 (1300) 은 추가로 결합기 (1306) 및 이미지 프로세서 (1308) 를 포함한다. 이미지 프로세서 (1308) 는 디스플레이 디바이스 (1310) 에 커플링된다. 결합기 (1306) 는 적어도 하나의 라인 버퍼 (1312) 를 포함한다. 이미지 프로세싱 시스템 (1300) 은 적어도 하나의 반도체 다이에 집적될 수도 있다.

[0076] 제 1 이미지 센서 (1302) 는 제 1 이미지 데이터 스트림 (1314) 으로 도시된 제 1 데이터 스트림을 생성하도록 구성되고, 제 2 이미지 센서 (1304) 는 제 2 이미지 데이터 스트림 (1316) 으로 도시된 제 2 데이터 스트림을 생성하도록 구성된다. 특정 실시형태에서, 제 1 이미지 데이터 스트림 (1314) 은 제 2 이미지 데이터 스트림 (1316) 과 비동기적일 수도 있다. 제 1 및 제 2 이미지 센서들 (1302, 1304) 은 커트에 대하여 독립적이고 프로세서 (예컨대, 결합기 (1306) 또는 이미지 프로세서 (1308)) 로부터 공통 제어 신호를 수신하여 인접하게 정렬된 이미지 데이터 스트림들 (1314, 1316) 을 생성할 수도 있는 실질적으로 유사한 이미지 센서들일 수도 있다. 예를 들면, 이미지 데이터 스트림들 (1314, 1316) 은 주파수 및 위상과 같이 실질적으로 동일한 타이밍 특성들을 가질 수도 있다. 공통 제어 신호는 도 2 의 신호 동기화기 (230) 를 통해서와 같이 프로세서에 의해 생성될 수도 있기 때문에, 이미지 센서들 (1302, 1304) 각각은 단일 프로세서에 직접 응답하고 단일 프로세서에 의해 제어될 수도 있다. 2 개의 이미지 센서들 (1302, 1304) 이 도시되지만, 3 이상의 이미지 센서들이 이미지 프로세싱 시스템 (1300) 과 함께 사용될 수도 있음이 이해되어야 한다.

[0077] 결합기 (1306) 는 제 1 이미지 데이터 스트림 (1314) 과 제 2 이미지 데이터 스트림 (1316) 에 대응한다. 결합기 (1306) 는 제 1 이미지 데이터 스트림 (1314) 으로부터의 데이터와 제 2 이미지 데이터 스트림 (1316) 으로부터의 데이터를 라인 버퍼 (1312) 내에서 결합하도록 구성된다. 특정 실시형태에서, 라인 버퍼 (1312) 는 제 1 이미지 센서 (1302) 로부터의 제 1 데이터와 제 2 이미지 센서 (1304) 로부터의 제 2 데이터를 정렬하도록 구성된다. 특정 실시형태에서, 결합기 (1306) 는 라인 버퍼 (1312) 내에 저장된 데이터에 응답하고, 프레임 데이터 (1318) 를 이미지 프로세서 (1308) 에 제공한다. 특정 실시형태에서, 프레임 데이터 (1318) 는 이미지 데이터의 복수의 로우들로 구성되고, 여기서 각각의 로우는 도 3 과 관련하여 설명된 것과 같은 각각의 센서 (1302, 1304) 로부터의 대응하는 로우들의 조합이다.

[0078] 이미지 센서 (1308) 는 프레임 데이터 (1318) 를 처리하여 처리된 프레임 데이터 (1320) 를 디스플레이 디바이스 (1310) 에 제공하도록 구성된다. 처리된 프레임 데이터 (1320) 는 3D 이미지 포맷 또는 3D 비디오 포맷을 가질 수도 있다.

[0079] 디스플레이 디바이스 (1310) 는 처리된 프레임 데이터 (1320) 를 수신하는데 응답하여 이미지 데이터를 렌더링하고 디스플레이한다. 따라서, 다중 이미지 센서들로부터의 이미지 데이터는 결합되고, 처리된 후, 디스플레이 디바이스 (1310) 에서의 디스플레이를 위해 렌더링될 수도 있다. 특정 실시형태에서, 디스플레이 디바이스 (1310) 는 이미지 프로세서 (1308) 에 직접 응답하지 않도록 이미지 프로세서 (1308) 로부터 디커플링될 수도 있다. 예를 들면, 디스플레이 디바이스 (1310) 는 이미지 프로세서 (1308) 와 별개의 디바이스일 수도 있다.

[0080] 공통으로 제어되는, 유사한 이미지 센서들 (1302, 1304) 로부터 수신된 데이터가 실질적으로 동일한 주파수 및 위상을 가지기 때문에, 데이터 스트림들 (1314, 1316) 간의 동기화는 이미지 데이터의 단일 이미지 라인 내에서 발생할 수도 있다. 특정 실시형태에서, 라인 버퍼 (1312) 는 오정렬과 같은 최악의 경우를 위한 크기를 가질 수도 있다 (예컨대, 동기화 오정렬이 3 개의 라인들에서 발생하면, 라인 버퍼 (1312) 는 적어도 6 개 라인들을 저장하도록 크기가 정해져야 한다). 결과적으로, 결합된 데이터는 단일 이미지 프로세서 (1308) 를 이용하여 효율적으로 처리될 수도 있다. 따라서, 전체 이미지 시스템 비용 및 복잡도는 다중 프로세서 시스템들 (예컨대, 각각의 센서에 하나의 프로세서가 할당됨) 과 비교할 때 감소될 수도 있다.

[0081] 실시형태들은 3D/입체 이미지들 및/또는 비디오 데이터를 제공하도록 구성될 수도 있다. 예를 들면, 일 실시형태에서, 제 1 이미지 센서 (1302) 와 제 2 이미지 센서 (1304) 는 좌/우 (입체) 이미지들을 제공하기 위해 나란히 위치될 수도 있다. 결합기 (1306) 에 의해 제공된 신호가 수신되어, 이미지 프로세서 (1308) 에 의해 3D 이미지들을 생성하도록 처리될 수도 있다. 사용자 명령은 이미지 프로세서 (1308) 로 하여금 오직 단일 센서 (즉, 제 1 이미지 센서 (1302) 또는 제 2 이미지 센서 (1304)) 로부터 데이터를 수신하고 처리하여 3D 이미지들을 생성하는 대신 2 차원 (2D) 이미지들을 생성하게 할 수도 있다.

[0082] 이미지 프로세서 (1308) 와 같이, 단일 카메라에 대한 입력을 갖는 이미지 프로세서는 결합기 (1306) 에 의해 제공된 2 개의 카메라들로부터의 결합된 데이터를 이용함으로써 3D 프로세싱을 위해 이용될 수 있는 데이터를 처리할 수 있다. 이미지 프로세서 (1308) 는 결합기 (1306) 로부터 또는 결합기 (1306) 로부터의 이미지 데

이터를 저장하는 메모리로부터 이미지 데이터를 수신할 수도 있다. 이러한 실시형태에서, 이미지 프로세서 (1308) 는 수신된 이미지 데이터를 2D 이미지/비디오 데이터로서 처리하여, 이미지 프로세서 (1308) 에 의한 후속 프로세싱이 이미지 프로세서 (1308) 로부터의 처리된 데이터에 기초하여 3D 입체 이미지/비디오 스트림을 제공할 수 있게 한다. 대안적으로, 이미지 프로세서 (1308) 는 수신된 이미지 데이터에 기초하여 3D 입체 이미지/비디오 스트림을 직접 제공하도록 구성될 수도 있다. 일 실시형태에서, 3D 캡처 시스템은 제 1 집적 회로로 구현된 결합기 (1306) 및 제 2 집적 회로로 구현된 이미지 프로세서 (1308) 를 포함한다. 제 1 및 제 2 집적 회로들은 예컨대, 직렬, 병렬 또는 I2C 버스 중 하나 이상의 버스에 의해 접속될 수도 있다.

[0083] 프레임 데이터 (1318) 를 생성하기 위해 이미지 데이터 스트림 (1314, 1316) 을 결합하는 것은 이미지 프로세서 (1308) 가 단일 카메라 입력을 가지는데도 불구하고 이미지 프로세서 (1308) 가 다중 카메라 3D 프로세싱을 위한 포맷화를 수행하는 것을 가능하게 한다. 결과적으로, 시스템 (1300) 은 각각의 카메라에 대하여 별개의 프로세서를 이용하거나 다중 카메라 입력들을 구비한 프로세서를 이용하는 시스템과 비교할 때 감소된 비용으로 구현될 수도 있다.

[0084] 도 14 를 참조하면, 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템들을 갖는 모바일 디바이스들의 다양한 실시형태들을 예시하는 도식적 표현이 도시되고, 일반적으로 1400 으로 지정된다. 1402 에 도시된 특정 실시형태에서, 모바일 디바이스는 2 개의 인접하는 카메라들의 어레이를 갖는 이미지 프로세싱 시스템을 포함한다. 1404 에 도시된 특정 실시형태에서, 모바일 디바이스는 인라인 (in-line) 구성으로 배열된 3 개의 카메라들의 어레이를 갖는 이미지 프로세싱 시스템을 포함한다. 대안적으로, 임의의 수의 카메라들이 인라인 구성으로 배열될 수도 있다. 1406 에 도시된 특정 실시형태에서, 모바일 디바이스는 카메라들의 3×3 어레이를 갖는 이미지 프로세싱 시스템을 포함한다. 1408 에 도시된 특정 실시형태에서, 모바일 디바이스는 카메라들의 5×5 어레이를 갖는 이미지 프로세싱 시스템을 포함한다. 대안적으로, 임의의 수의 카메라들이 2-차원 어레이에 배열될 수도 있다.

[0085] 도 15 를 참조하면, 다중 카메라들 또는 이미지 센서들에 의해 캡처되는 이미지들의 어레이의 일 예가 도시되고, 일반적으로 1500 으로 지정된다. 도 15 에 도시된 것과 같이, 하나의 카메라에 의해 캡처된 이미지는 다른 인접 카메라들에 의해 캡처된 이미지들과 중첩할 수도 있다. 이미지 중첩은 카메라들 각각에 의해 캡처된 이미지들을 단일 이미지로 결합하는데 있어 유용할 수도 있다. 도 15 에 도시된 특정 실시형태에서, 어레이 (1500) 는 카메라들 또는 이미지 센서들의 4×4 어레이에 대응한다. 대안적으로, 임의의 수의 카메라들이 2 차원 어레이 (예컨대, 도 18 및 도 19 에 도시된 것과 같은 5×5 어레이) 로 배열될 수도 있다.

[0086] 각각의 카메라는 어레이 (1500) 의 단일 카메라 이미지를 캡처한다. 도 15 에 도시된 실시형태에서, 어레이 (1500) 는 4×4 어레이이다. 이와 같이, 어레이 (1500) 는 제 1 로우 (1502), 제 2 로우 (1504), 제 3 로우 (1506) 및 제 4 로우 (1608) 를 포함한다. 추가로, 어레이 (1500) 는 제 1 컬럼 (1510), 제 2 컬럼 (1512), 제 3 컬럼 (1514) 및 제 4 컬럼 (1516) 을 포함한다. 일 예로서, 단일 카메라 이미지 (1518) 는 제 1 로우 (1502) 및 제 4 컬럼(1516) 에 대응하는 카메라에 의해 캡처될 수도 있다. 단일 카메라 이미지 (1518) 는 인접 셀들의 다른 카메라들에 의해 캡처된 카메라 이미지들과 중첩할 수도 있다. 제 1 로우 (1502) 및 제 4 컬럼 (1516) 에 대응하는 카메라의 경우에, 인접 셀의 카메라는 제 1 로우 (1502) 및 제 3 컬럼 (1514) 에 대응하는 카메라, 제 2 로우 (1504) 및 제 3 컬럼 (1514) 에 대응하는 카메라, 또는 제 2 로우 (1504) 및 제 4 컬럼 (1516) 에 대응하는 카메라를 포함할 수도 있다. 예를 들면, 단일 카메라 이미지 중첩 (1520) 은 제 1 로우 (1502) 및 제 4 컬럼 (1516) 에 대응하는 카메라에 의해 캡처된 단일 카메라 이미지 (1508) 와 연관될 수도 있다. 도 15 는 로우들 (1502-1508) 각각의 각 카메라와 컬럼들 (1510-1516) 각각의 각 카메라에 대한 절대적인 정렬의 이론적인 경우를 도시한다. 이와 같이, 인접하는 로우 (예컨대, 제 2 로우 (1504)) 에 대응하는 카메라에 의해 캡처된 이미지와의 이미지 중첩은 이웃하는 컬럼 (예컨대, 제 3 컬럼 (1514)) 에 대응하는 카메라에 의해 캡처된 이미지와의 이미지 중첩과 동일할 수도 있다.

[0087] 특정 수평 해상도 ("H-res") 에 따라 개별 이미지가 캡처될 수도 있다. 설명을 위해, 수평 해상도 (1522) 는 제 1 로우 (1502) 와 제 4 컬럼 (1516) 에 대응하는 카메라에 의해 캡처된 단일 카메라 이미지 (1518) 와 연관될 수도 있다. 도 15 는 각각의 카메라가 동일한 수평 해상도 (1522) 를 갖는 이미지 중첩의 이론적인 케이스를 도시한다. 이와 같이, 전체 수평 해상도 (1524) (즉, 로우들 (1502-1508) 각각에서 픽셀들의 수) 는 개별 카메라의 수평 해상도 (1522) 와 하나의 로우에서 셀들의 수 ("n") 의 조합에 기초하여 계산될 수도 있다. 도 15 의 4×4 어레이 (1500) 의 경우에, 각각의 로우에는 4 개의 셀들이 존재한다 (즉, 하나의 셀은 컬럼들 (1510-1516) 각각과 연관된다). 전체 수평 해상도 (1524) 는 이미지 중첩을 고려할 수도 있다. 예를 들면, 전체 수평 해상도 (1524) 는 H_res*n - overlap*(n-2) 로 계산될 수도 있으며, 여기서 overlap 은 인접하

는 이미지들의 중첩하는 픽셀들의 개수를 나타낸다. 전체 수직 해상도를 결정하기 위해 유사한 계산이 수행될 수도 있다.

[0088] 도 15 는 동일한 이미지 중첩을 갖는 각각의 카메라의 일대일인 정렬의 이론적인 케이스를 도시한다. 개별 카메라들에 의해 캡처된 이미지들 간의 이미지 중첩은 개별 이미지들 각각이 단일 이미지 내에 "함께 스티치(stitched together)" 되게 할 수도 있다.

[0089] 도 16 을 참조하면, 다중 카메라들 또는 이미지 센서들에 의해 캡처된 이미지들의 어레이의 일 예가 도시되고, 일반적으로 1600 으로 지정된다. 도 16 에 도시된 것과 같이, 하나의 카메라에 의해 캡처된 이미지는 다른 인접 카메라들에 의해 캡처된 이미지들과 중첩할 수도 있다. 이미지 중첩은 카메라들 각각에 의해 캡처된 이미지들을 단일 이미지로 결합하는데 있어 유용할 수도 있다. 도 16 에 도시된 특정 실시형태에서, 어레이 (1600) 는 카메라들 또는 이미지 센서들의 4×4 어레이에 대응한다. 대안적으로, 임의의 수의 카메라들이 2-차원 어레이에 배열될 수도 있다. 도 16 은 기계적인 제약들로 인해, (도 15 에 도시된 것과 같이) 로우 또는 컬럼에서 카메라들의 절대적인 정렬을 달성하는 것이 가능하지 않을 수도 있는 것을 도시한다.

[0090] 어레이 (1600) 의 각각의 이미지는 자신의 회전 (1602), 쉬프트 (1604) 및 틸트 (미도시) 를 가질 수도 있다. 하나 이상의 포지셔닝 오차들 (1606) 은 각각의 이미지와 연관될 수도 있다 포지셔닝 오차들 (1606) 은 회전 오차, 쉬프트 오차, 틸트 오차 또는 이들의 조합을 포함할 수도 있다. 이미지 중첩은 카메라들 각각에 의해 캡처된 이미지들을 단일 이미지로 결합하는데 있어 유용할 수도 있다. 도 16 은 디바이스를 구성하는 것과 관련된 기계적인 제약들에서 기인하는 각각의 이미지의 회전 (1602), 쉬프트 (1604) 및 틸트를 고려할 수도 있다. 디바이스가 구성되면, 이미지 중첩은 알려지거나 안정적일 수도 있다. 이와 같이, 이미지 중첩은 경량화될 수도 있고, 후속 단계에서 수정될 수도 있다.

[0091] 도 17 을 참조하면, 카메라들의 어레이 및 그 카메라 어레이와 연관된 전기적 접속들의 특정 실시형태가 도시되고, 일반적으로 1700 으로 지정된다. 도 17 은 어레이 (1700) 의 각 카메라가 제 1 타입 인터페이스 (즉, 데이터 인터페이스 (1702)) 및 제 2 타입 인터페이스 (즉, 제어 인터페이스 (1704)) 를 가지는 것을 도시한다.

도 17 에 도시된 실시형태에서, 어레이 (1700) 는 카메라들의 3×3 어레이를 포함한다. 대안적으로, 어레이 (1700) 는 (예컨대, 도 15 및 16 의 어레이들 (1500, 1600) 과 같은) 4×4 어레이에 배열된 카메라들 또는 2 차원 어레이에 배열된 임의의 다른 수의 카메라들을 포함할 수도 있다.

[0092] 데이터 인터페이스 (1702) 는 직렬 데이터 버스 (예컨대, 모바일 산업 프로세서 인터페이스 또는 표준 모바일 이미징 아키텍처 인터페이스) 를 포함할 수도 있다. 도 17 의 데이터 인터페이스 (1702) 는 어레이 (1700) 의 제 1 로우 (1706), 어레이 (1700) 의 제 2 로우 (1708) 및 어레이 (1700) 의 제 3 로우 (1710) 와 연관된다. 데이터 인터페이스 (1702) 와 연관된 라인들은 로우들 (1706-1710) 의 각각에서의 카메라들의 데이터를 수집하여 병렬로 처리되도록 하는데 이용될 수도 있다. 일 예로서, 5 메가픽셀 (mpix) 및 초당 10 프레임 까지의 해상도에 대하여, 4 개의 와이어들이 요구될 수도 있다 (예컨대, 상이한 데이터 및 클럭).

[0093] 도 17 의 예시적인 3×3 어레이 (1700) 에서, 로우들 (1706-1710) 각각은 어레이 (1700) 의 제 1 컬럼 (1712) 에서 일 카메라, 어레이 (1700) 의 제 2 컬럼 (1714) 에서 일 카메라, 및 어레이 (1700) 의 제 3 컬럼(1716) 에서 일 카메라를 포함한다. 따라서, 데이터 인터페이스 (1702) 는 9 개의 카메라들로부터의 데이터를 수집하여 병렬로 처리되도록 하는데 이용될 수도 있다.

[0094] 제어 인터페이스 (1704) 는 어레이 (1700) 에서 모든 카메라를 동기화하는데 이용되는 라인들을 포함할 수도 있다. 예를 들면, 제어 인터페이스 라인들은 클록, 리셋 및 I2C 통신과 연관될 수도 있다. 도 17 의 예시적인 3×3 어레이 (1700) 에서, 제어 인터페이스 (1704) 는 어레이 (1700) 의 9 개 카메라들을 동기화시키는데 이용될 수도 있다.

[0095] 도 18 을 참조하면, 카메라 어레이 프로세싱 시스템의 특정 실시형태가 도시되고, 일반적으로 1800 으로 지정된다. 어레이 (1802) 에서 모든 카메라들은 공통 제어 신호에 응답하고, 정렬되고, 처리된 후에 결과적인 이미지 데이터가 최종 이미지로 결합될 수도 있다. 도 18 에 도시된 실시형태에서, 어레이 (1802) 는 카메라들의 5×5 어레이를 포함한다. 대안적으로, 어레이 (1802) 는 (예컨대, 도 17 의 3×3 어레이 (1700) 와 같은) 2 차원 어레이에 배열된 임의의 다른 수의 카메라들을 포함할 수도 있다.

[0096] 어레이 (1802) 에서 모든 카메라들은 단일 ISP 파이프라인을 이용하는 동시 이미지 센서 지원 방식을 이용하여 동기화될 수도 있다. 또한, 카메라들의 각각의 로우는 정렬 방법을 이용하여 정렬될 수도 있다. 즉, 이미지들의 하나의 로우가 수집되고, 동일한 순서로 정렬되며, 사이즈 n×line 을 갖는 단일 라인으로 처리하기 위

해 송신될 수도 있고, 여기서 n 은 하나의 로우에서 카메라들의 수이고, line 은 하나의 카메라의 수평 사이즈(즉, 도 15 에 도시된 것과 같은 "H_res") 이다. 도 18 에 도시된 5×5 어레이 (1802) 는 제 1 로우 (1804), 제 2 로우 (1806), 제 3 로우 (1808), 제 4 로우 (1810) 및 제 5 로우 (1812) 를 포함한다. 추가로, 5×5 어레이 (1802) 는 제 1 컬럼 (1814), 제 2 컬럼 (1816), 제 3 컬럼 (1818), 제 4 컬럼 (1820) 및 제 5 컬럼 (1822) 을 포함한다. 로우들 (1804-1812) 각각은 VFE 성분에서의 컬러에 대하여 병렬로 처리될 수도 있고, 로우들 (1804-1812) 각각은 하나의 로우에서 각각의 개별 이미지를 정렬하고 교정하기 위해 그래픽 프로세서 또는 그래픽 프로세싱 유닛 (GPU) 성분에서 처리될 수도 있다. 교정 및 정렬 이후, GPU 프로세싱이 수행되어 로우들 (1804-1812) 전부를 함께 결합하고, 그 결과 최종 이미지를 발생한다.

[0097] 제 1 로우 (1804) 는 제 1 이미지 정렬 블록 (1824) 과 연관될 수도 있고, 제 2 로우 (1806) 는 제 2 이미지 정렬 블록 (1826) 과 연관될 수도 있고, 제 3 로우 (1808) 는 제 3 이미지 정렬 블록 (1828) 과 연관될 수도 있고, 제 4 로우 (1810) 는 제 4 이미지 정렬 블록 (1830) 과 연관될 수도 있으며, 제 5 로우 (1812) 는 제 5 이미지 정렬 블록 (1832) 과 연관될 수도 있다. 설명을 위해, 제 1 정렬 블록 (1824) 은 제 1 로우 (1804) 에서 각각의 카메라 (즉, 어레이 (1802) 의 5 개 컬럼들 (1814-1822) 에서의 5 개 카메라들) 로부터 이미지 데이터 라인들을 수집하도록 구성될 수도 있다. 제 1 정렬 블록 (1824) 은 이미지 데이터 라인들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지 데이터 라인들을 송신하도록 구성될 수도 있다. 제 1 정렬 블록 (1824) 은 단일 라인으로서 처리를 위해 이미지 데이터 라인들을 제 1 VFE 성분 (1834) 에 송신하여도 2, 도 3 및 도 5 의 결합기 (206) 와 관련하여 설명된 것과 같이 컬러에 대하여 처리되도록 구성될 수도 있다. 단일 라인의 사이즈는 카메라들의 수 (즉, 5 개 카메라) 및 제 1 로우 (1804) 의 각각의 카메라의 수평 사이즈 (즉, 도 15 에서 설명된 것과 같은 "H_res") 에 기초하여 결정될 수도 있다.

[0098] 제 2 정렬 블록 (1826) 은 제 2 로우 (1806) 에서 각각의 카메라로부터 이미지들을 수집하고, 이미지들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지들을 제 2 VFE 성분 (1836) 에 송신하도록 구성될 수도 있다. 제 3 정렬 블록 (1828) 은 제 3 로우 (1808) 에서 각각의 카메라로부터 이미지들을 수집하고, 이미지들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지들을 제 3 VFE 성분 (1838) 에 송신하도록 구성될 수도 있다. 제 4 정렬 블록 (1830) 은 제 4 로우 (1810) 에서 각각의 카메라로부터 이미지들을 수집하고, 이미지들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지들을 제 4 VFE 성분 (1840) 에 송신하도록 구성될 수도 있다. 제 5 정렬 블록 (1832) 은 제 5 로우 (1812) 에서 각각의 카메라로부터 이미지들을 수집하고, 이미지들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지들을 제 5 VFE 성분 (1842) 에 송신하도록 구성될 수도 있다.

[0099] 제어 동기화 블록 (1844) 은 센서 동기화기 (230) 와 유사한 방식으로 어레이 (1802) 의 카메라들 (즉, 도 18 의 예시적인 5×5 어레이 (1802) 의 경우에 25 개 카메라들) 각각을 동기화하는데 이용될 수도 있다. 특정 실시형태에서, 제어 동기화 블록 (1834) 은 도 17 의 제어 인터페이스 (1704) 를 구현할 수도 있다. 제어 동기화 블록 (1844) 은 어레이 (1802) 의 카메라들 각각과 VFE 성분들 (1834-1842) 각각에 통신적으로 커플링될 수도 있다. 어레이 (1802) 에서 모든 카메라들의 동기화는 고 해상도에서 롤링 셔터 (rolling shutter) 의 이용을 허용할 수도 있다. 모든 카메라들이 동시에 판독될 수도 있기 때문에, 롤링 셔터 영향은 (어레이의 사이즈에 따라) 감소될 수도 있다. 예를 들어, 도 18 의 5×5 어레이 (1802) 에서, 25 개 카메라들의 동기화는 상보적 금속 산화물 반도체 (CMOS) 카메라와 연관된 롤링 셔터 영향을 감소시킬 수도 있다.

[0100] 제 1 VFE 성분 (1834) 은 제 1 GPU 성분 (1846) 에 통신적으로 커플링되어 제 1 로우 (1804) 에서 각각의 개별 이미지 (즉, 5 개 컬럼들 (1814-1822) 에서의 카메라들에 의해 캡처된 5 개 이미지들) 를 정렬시키고 교정할 수도 있다. 제 2 VFE 성분 (1836) 은 제 2 GPU 성분 (1848) 에 통신적으로 커플링되어 제 2 로우 (1806) 에서 각각의 개별 이미지를 정렬시키고 교정할 수도 있다. 제 3 VFE 성분 (1838) 은 제 3 GPU 성분 (1850) 에 통신적으로 커플링되어 제 3 로우 (1808) 에서 각각의 개별 이미지를 정렬시키고 교정할 수도 있다. 제 4 VFE 성분 (1840) 은 제 4 GPU 성분 (1852) 에 통신적으로 커플링되어 제 4 로우 (1810) 에서 각각의 개별 이미지를 정렬시키고 교정할 수도 있다. 제 5 VFE 성분 (1842) 은 제 5 GPU 성분 (1854) 에 통신적으로 커플링되어 제 5 로우 (1812) 에서 각각의 개별 이미지를 정렬시키고 교정할 수도 있다. GPU 성분들 (1846-1854) 각각은 로우들 (1804-1812) 전부를 함께 결합하여 최종 이미지를 발생하도록 구성된 GPU 프로세싱 성분 (1856) 에 통신적으로 커플링될 수도 있다.

[0101] 도 18 에 도시된 실시형태에서, 정렬 블록들 (1824-1832) 각각은 자신의 VFE 성분 및 GPU 교정 및 정렬 성분과 연관된다. 따라서, 도 18 은 로우들 (1804-1812) 각각이 별개의 VFE 성분들을 이용하여 컬러에 대하여 병렬로 처리될 수도 있고, 로우들 (1804-1812) 각각이 별개의 GPU 성분들을 이용하여 특정 로우에서 각각의 개별 이

이미지를 정렬하고 교정하도록 처리될 수도 있는 것을 도시한다. 대안적으로, 정렬 블록들 (1824-1832) 각각은 단일 VFE 성분 및 단일 GPU 교정 및 정렬 성분과 결합될 수도 있다 (도 19 참조).

[0102] 도 19 를 참조하면, 카메라 어레이 프로세싱 시스템의 특정 실시형태가 도시되고, 일반적으로 1900 으로 지정된다. 어레이 (1902) 에서 모든 카메라들은 동기화되고, 정렬되고, 처리된 후에 최종 이미지로 결합될 수도 있다. 도 19 에 도시된 실시형태에서, 어레이 (1902) 는 카메라들의 5×5 어레이를 포함한다. 대안적으로, 어레이 (1902) 는 2 차원 어레이에 배열된 임의의 다른 수의 카메라들을 포함할 수도 있다. 도 19 는, 도 18 에 도시된 복수의 VFE 및 GPU 교정 및 정렬 성분들보다는 단일 VFE 성분과 단일 GPU 교정 및 정렬 성분이 어레이 (1902) 의 모든 로우들을 처리하기 위해 이용될 수도 있는 것을 도시한다.

[0103] 도 19 에 도시된 5×5 어레이 (1902) 는 제 1 로우 (1904), 제 2 로우 (1906), 제 3 로우 (1908), 제 4 로우 (1910) 및 제 5 로우 (1912) 를 포함한다. 추가로, 5×5 어레이 (1902) 는 제 1 컬럼 (1914), 제 2 컬럼 (1916), 제 3 컬럼 (1918), 제 4 컬럼 (1920) 및 제 5 컬럼 (1922) 을 포함한다. 제 1 로우 (1904) 는 제 1 이미지 정렬 블록 (1924) 과 연관될 수도 있고, 제 2 로우 (1906) 는 제 2 이미지 정렬 블록 (1926) 과 연관될 수도 있고, 제 3 로우 (1908) 는 제 3 이미지 정렬 블록 (1928) 과 연관될 수도 있고, 제 4 로우 (1910) 는 제 4 이미지 정렬 블록 (1930) 과 연관될 수도 있으며, 제 5 로우 (1912) 는 제 5 이미지 정렬 블록 (1932) 과 연관될 수도 있다. 설명을 위해, 제 1 정렬 블록 (1924) 은 제 1 로우 (1904) 에서 각각의 카메라 (즉, 어레이 (1902) 의 5 개 컬럼들 (1914-1922) 에서의 5 개 카메라들) 로부터 이미지 데이터 라인들을 수집하도록 구성될 수도 있다.

[0104] 제 1 정렬 블록 (1924) 은 이미지 데이터 라인들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지 데이터 라인들을 송신하도록 구성될 수도 있다. 제 2 정렬 블록 (1926) 은 제 2 로우 (1906) 에서 각각의 카메라로부터 이미지 데이터 라인들을 수집하고, 이미지 데이터 라인들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지 데이터 라인들을 송신하도록 구성될 수도 있다. 제 3 정렬 블록 (1928) 은 제 3 로우 (1908) 에서 각각의 카메라로부터 이미지 데이터 라인들을 수집하고, 이미지 데이터 라인들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지 데이터 라인들을 송신하도록 구성될 수도 있다. 제 4 정렬 블록 (1930) 은 제 4 로우 (1910) 에서 각각의 카메라로부터 이미지 데이터 라인들을 수집하고, 이미지 데이터 라인들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지 데이터 라인들을 송신하도록 구성될 수도 있다. 제 5 정렬 블록 (1932) 은 제 5 로우 (1912) 에서 각각의 카메라로부터 이미지 데이터 라인들을 수집하고, 이미지 데이터 라인들을 동일한 순서로 정렬하고, 단일 라인으로서 처리를 위해 이미지 데이터 라인들을 송신하도록 구성될 수도 있다.

[0105] 도 19 에 도시된 실시형태에서, 정렬 블록들 (1924-1932) 각각은 단일 VFE 성분 (1934) 으로의 처리를 위해 그 이미지들을 송신하여 컬러에 대하여 처리되도록 구성될 수도 있다. 단일 VFE 성분 (1934) 은 5 개 정렬 블록들 (1924-1932) 로부터 송신된 5 개 라인들 각각을 처리할 수도 있다. 전술된 것과 같이, 특정 정렬 블록으로부터의 단일 라인의 사이즈는 특정 로우에서 카메라들의 수 (즉, 5 개 카메라들) 및 특정 로우의 각각의 카메라의 수평 사이즈 (즉, 도 5 에서 설명한 "H_res") 에 기초하여 결정될 수도 있다. 이와 같이, 도 19 의 단일 VFE 성분 (1934) 에 의해 처리된 다중 라인들의 사이즈는 도 18 의 VFE 성분들 (1834-1842) 중 하나에 의해 처리된 단일 라인의 사이즈의 5 배일 수도 있다.

[0106] 제어 동기화 블록 (1936) 은 하나 이상의 로우들 (1904-1912) 의 카메라들에 공통 제어 신호들을 제공하여 어레이 (1902) 의 카메라들 각각을 동기화하는데 이용될 수도 있다. 제어 동기화 블록 (1936) 은 어레이 (1902) 의 카메라들 각각과 단일 VFE 성분들 (1934) 에 통신적으로 커플링될 수도 있다. 어레이 (1902) 에서 모든 카메라들의 동기화는 고 해상도에서 롤링 셔터의 이용을 허용할 수도 있다. 모든 카메라들이 동시에 판독될 수도 있기 때문에, 롤링 셔터 영향은 (어레이의 사이즈에 따라) 감소될 수도 있다. 예를 들어, 도 19 의 5×5 어레이 (1902) 에서, 25 개 카메라들의 동기화는 CMOS 카메라와 연관된 롤링 셔터 영향을 감소시킬 수도 있다.

[0107] 단일 VFE 성분 (1934) 은 단일 GPU 성분 (1938) 에 통신적으로 커플링되어 로우들 (1904-1912) 각각에서 각각의 개별 이미지를 정렬시키고 교정할 수도 있다. 이와 같이, 도 19 의 단일 GPU 성분 (1938) 은 도 18 의 GPU 정렬 및 교정 성분들 (1846-1854) 의 각각에서 처리된 5 개의 이미지들과 비교할 때 25 개의 이미지들을 정렬하고 교정할 수도 있다. 단일 GPU 성분 (1938) 은 로우들 (1904-1912) 전부를 함께 결합하여 최종 이미지를 발생하도록 구성된 GPU 프로세싱 성분 (1940) 에 통신적으로 커플링될 수도 있다.

[0108] 도 20 은 들어오는 광 (2004) 을 포커싱하도록 구성된 메인 렌즈 (2002) 및 하나의 어레이 (2006) 에 배열된 다

중 카메라들을 포함하는 고 해상도 디지털 카메라 시스템 (2000) 을 도시한다. 고 해상도 이미지는 어레이 (2006) 의 카메라들 각각에서 캡처되는 이미지들을 결합함으로써 합성 (또는 "모자이크") 이미지로서 생성될 수 있다. 예를 들면, 어레이 (2006) 의 카메라들 각각은 CMOS-타입 카메라 또는 전하 결합 디바이스 (CCD) 타입 카메라일 수도 있다. 메인 렌즈 (2002) 는 (어레이 (2006) 에서 메인 렌즈 (200) 의 "초점 평면" 과 카메라들의 "객체 평면" 으로 지칭되는) 평면 (2008) 에 캡처된 장면을 포커싱할 수도 있고, 어레이 (2006) 에서 각각의 카메라는 전체 이미지의 일부분을 캡처할 수도 있다. 어레이 (2006) 의 각각의 카메라는 평면 (2008) 에서 인접 카메라의 시계와 부분적으로 중첩하는 시계를 갖는다. 이러한 중첩은 어레이 (2006) 에서 인접 카메라들로부터 취득된 이미지들이 모두 함께 정렬되고 후속 프로세싱 동안 함께 "스티치" 될 수 있게 하며, (도 16 과 관련하여 설명된 것과 같은) 어레이 내의 카메라들의 비-이상적인 위치 및 정렬에 대한 오차를 제공할 수도 있다.

[0109] 합성 이미지는 어레이 (2006) 의 카메라들로부터 이미지 데이터를 로우 별로 정렬함으로써 생성될 수 있다. 예를 들면, 도 20 의 어레이 (2006) 는 3 개의 로우들을 갖는 3×3 어레이를 포함한다. 어레이 (2006) 의 특정 로우 ("어레이 로우") 내의 각각의 카메라는 컬럼들 및 로우들 ("센서 컬럼" 및 "센서 로우") 로 배열된 광 검출기들을 갖는 이미지 센서를 포함할 수도 있다. 어레이 로우 내의 카메라들은 센서 로우들이 실질적으로 정렬될 수 있도록 포지셔닝될 수도 있다. 설명을 위해, 하나의 어레이 로우에서 각각의 카메라의 제 1 센서 로우는 동일한 어레이 로우 에서 모든 다른 카메라의 제 1 센서 로우와 실질적으로 정렬된다.

[0110] 이미지 캡처 동안, 이미지 데이터의 제 1 센서 로우는 하나의 어레이 로우에서 각각의 카메라로부터 판독되고, (도 17 내지 도 19 와 관련하여 설명된 것과 같은) 이미지 프로세싱 회로에 제공된다. 제 1 센서 로우로부터의 이미지 데이터는 그 어레이 로우의 각각의 카메라의 위치에 따라 통합된다. 통합된 이미지 데이터는 더 큰 카메라로부터의 이미지 데이터의 단일 로우가 존재하는 것처럼 처리된다. 제 2, 제 3 및 후속 이미지 센서 로우들이 통합되어 이미지 프로세싱 회로에 제공되고, 합성 이미지의 로우들로서 처리된다. 각각의 어레이 로우는 다른 어레이 로우들과 병렬로 처리될 수도 있다.

[0111] 도 20 의 배열은 고 해상도 카메라들에 대한 저렴한 대안을 제공할 수도 있다. 예를 들면, 100 메가픽셀 (mpix) 카메라는 메인 렌즈 뒤의 20 개의 5 mpix CMOS 카메라들의 어레이를 이용하여 구성될 수 있다. 각 카메라가 이미지의 일부분을 캡처하는 다중 CMOS 카메라들을 이용하여 이미지 캡처가 수행될 수 있기 때문에, 전체 이미지를 캡처하는 단일 100 mpix CMOS 카메라와 비교하여 "롤링 셔터" 아티팩트가 감소될 수도 있다.

[0112] 도 21 을 참조하면, 다중 카메라 모듈의 일 구현의 특정 실시형태가 도시되고, 일반적으로 2100 으로 지정된다.

시스템 (2100) 은 다중 카메라 모듈, 예컨대 도 1 내지 도 5 에 도시된 것과 같은 다중 카메라 모듈이 자동차에 장착된 것을 도시한다. 다중 카메라 모듈은 도 6 및 도 7 과 관련하여 설명된 것과 같은 3 차원 이미지 또는 비디오 데이터로서 포맷화하기 위한, 동기화된 라인 데이터 프레임들을 생성하도록 구성될 수도 있다.

다중 카메라 모듈을 자동차의 후면부에 장착함으로써, 3차원 뷰가 획득되며, 이는 자동차를 후진하는 동안 내부 디스플레이 (미도시) 상에 거리 감각 (depth perception) 을 자동차의 운전자에게 제공할 수도 있다. 다중 카메라 모듈은 자동차에 대한 제한 없이 임의의 타입의 차량에 장착될 수도 있다.

[0113] 도 22 를 참조하면, 다중 센서들로부터의 데이터를 동기화된 데이터 라인으로 결합하는 방법의 특정 예시적 실시형태의 흐름도가 도시되고, 일반적으로 2200 으로 지정된다. 일 예로서, 방법 (2200) 은 도 2 의 시스템, 도 3 의 시스템, 도 5 의 시스템 또는 이들의 임의의 조합에 의해 수행될 수도 있다.

[0114] 공통 제어 신호는 동기화될 다중 이미지 센서들에 제공될 수도 있다 (2202). 예를 들면, 공통 제어 신호는 도 4 에 도시된 공통 제어 신호들 (404-410) 과 같이 공통 클록 신호 및 공통 리셋 신호를 포함할 수도 있다.

[0115] 다중 이미지 센서들 중 제 1 이미지 센서로부터 제 1 데이터 라인이 수신될 수도 있다 (2204). 다중 이미지 센서들 중 제 2 이미지 센서로부터 제 2 데이터 라인이 수신될 수도 있다 (2206). 예를 들어, 제 1 센서와 제 2 센서는 도 2 의 센서들 (202, 204) 일 수도 있다.

[0116] 제 1 데이터 라인 및 제 2 데이터 라인은 동기화된 데이터 라인을 생성하도록 라인 결합될 수도 있다 (2208).

예를 들어, 방법 (2200) 은 제 1 이미지 센서로부터 수신된 제 1 데이터 스트림과 제 2 이미지 센서로부터 수신된 제 2 데이터 스트림을 라인별로 인터리빙하는 것을 포함할 수도 있다. 동기화된 데이터 라인은 도 5 에 도시된 제 1 센서 이미지 데이터 (422) 와 제 2 센서 이미지 데이터 (432) 를 결합하는 결합기 (406) 와 관련하여 설명된 것과 같이 형성될 수도 있다.

[0117] 동기화된 데이터 라인은 도 6 의 프레임 (660) 과 같은 일 프레임의 부분을 형성할 수도 있다. 프레임은 제

1 이미지 센서로부터의 제 1 이미지 데이터를 포함하는 제 1 섹션 (예컨대, 제 1 섹션 (652)), 제 2 이미지 센서로부터의 제 2 이미지 데이터를 포함하는 제 2 섹션 (예컨대, 제 2 섹션 (654)) 및 제 1 섹션과 제 2 섹션 사이에 보간된 비-이미지 데이터를 포함하는 갭 섹션 (예컨대, 갭 섹션 (656)) 을 포함할 수 있다. 다른 실시형태들에서, 프레임은 제 1 섹션과 제 2 섹션 사이에 갭 섹션을 포함하지 않을 수도 있다.

[0118] 제 1 데이터 라인을 수신하는 것은 제 2 데이터 라인을 수신하는 것이 완료되기 전에 종료될 수도 있고, 동기화된 데이터 라인은 제 2 데이터 라인을 수신하는 것이 완료된 이후에 발생될 수도 있다. 일 예로서, 도 8 의 결합된 데이터 라인 (822) 은 제 2 센서 제 1 라인 데이터 (812) 가 수신된 후에 생성된다.

[0119] 3 이상의 이미지 센서들을 갖는 일 실시형태에서, 제 3 데이터 라인은 도 11 에 도시된 것과 같은 다중 이미지 센서들 중 제 3 이미지 센서로부터 수신될 수도 있다. 제 3 데이터 라인은 제 1 데이터 라인 및 제 2 데이터 라인과 결합되어 도 11 의 제 1 동기화된 데이터 라인 (1150) 과 같은 동기화된 데이터 라인을 생성할 수 있다.

[0120] 도 23 을 참조하면, 공통 제어 신호를 다중 이미지 센서들에 제공하고, 동기화된 데이터 라인을 이미지 프로세서의 단일 카메라 입력을 통해 이미지 프로세서에 제공하는 방법의 특정 예시적 실시형태의 흐름도가 도시되며, 일반적으로 2300 으로 지정된다. 방법 (2300) 은 예시적이고 제한되지 않는 예들로서 도 2, 도 3, 도 5 의 시스템들 중 하나 이상에서 수행될 수도 있다.

[0121] 공통 제어 신호는 다중 이미지 센서들에 제공될 수도 있다 (2302). 다중 이미지 센서들 각각은 공통 제어 신호에 응답하여 이미지 데이터를 생성할 수도 있다. 예를 들면, 공통 제어 신호는 도 2 의 센서 동기화기 (230) 와 같이, 다중 이미지 센서들의 각각에 커플링된 센서 동기화기에 제공될 수도 있다. 설명을 위해, 센서 동기화기는 I2C (inter-integrated circuit) 제어 인터페이스를 통해, 카메라 직렬 인터페이스 (CSI) 사양에 부합하는 인터페이스를 통해, 또는 카메라 병렬 인터페이스 (CPI) 사양에 부합하는 인터페이스를 통해 다중 이미지 센서들 각각에 커플링될 수도 있다.

[0122] 다중 이미지 센서들 중 각각으로부터 출력된 동기화된 데이터가 수신될 수도 있다 (2304). 제 1 데이터 라인은 다중 이미지 센서들 중 제 1 이미지 센서로부터 수신될 수도 있고, 제 2 데이터 라인은 다중 이미지 센서들 중 제 2 이미지 센서로부터 수신될 수도 있다. 제 1 데이터 라인을 수신하는 것은 제 2 데이터 라인을 수신하는 것이 완료되기 전에 종료될 수도 있고, 동기화된 데이터 라인은 제 2 데이터 라인을 수신하는 것이 완료된 이후에 발생될 수도 있으며, 예컨대 도 8 에서 결합된 데이터 라인 (822) 은 제 2 센서 제 1 라인 데이터 (812) 가 수신된 후에 생성된다.

[0123] 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력은 결합되어 동기화된 데이터 라인을 생성할 수도 있다 (2306). 예를 들면, 도 2 의 결합기 (206) 는 제 1 이미지 센서 (202) 로부터 수신된 제 1 데이터 스트림과 제 2 이미지 센서 (204) 로부터 수신된 제 2 데이터 스트림을 라인별로 인터리빙할 수도 있다.

[0124] 동기화된 데이터 라인은 이미지 프로세서의 단일 카메라 입력을 통해 이미지 프로세서에 제공될 수도 있다 (2308). 동기화된 데이터 라인은 도 6 의 프레임 (660) 과 같이, 복수의 로우들을 갖는 일 프레임의 부분을 형성할 수도 있다. 예를 들면, 프레임은 제 1 이미지 센서로부터의 제 1 이미지 데이터를 포함하는 제 1 섹션, 제 2 이미지 센서로부터의 제 2 이미지 데이터를 포함하는 제 2 섹션 및 제 1 섹션과 제 2 섹션 사이의 갭 섹션을 포함할 수 있다.

[0125] 도 24 를 참조하면, 공통 제어 신호를 다중 이미지 센서들에 제공하고, 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신하는 방법의 특정 예시적 실시형태의 흐름도가 도시되고, 일반적으로 2400 으로 도시된다.

[0126] 다중 이미지 센서들로의 공통 제어 신호가 제공될 수도 있다 (2402). 다중 이미지 센서들의 각각은 공통 제어 신호에 응답하여 이미지 데이터를 생성한다. 예를 들면, 공통 제어 신호는 다중 이미지 센서들의 각각에 커플링된 센서 동기화기, 예컨대 도 2 내지 도 5 중 임의의 것의 센서 동기화기 (230), 도 18 의 제어 동기화 블록 (1844), 도 19 의 제어 동기화 블록 (1930), 또는 이들의 임의의 조합에 의해 제공될 수도 있다.

[0127] 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력이 수신될 수도 있다 (2404). 동기화된 데이터 출력은 제 1 이미지 센서로부터 수신된 제 1 데이터 라인들 및 제 2 이미지 센서로부터 수신된 제 2 데이터 라인들을 포함할 수도 있다. 제 1 이미지 센서로부터의 각각의 수신된 데이터 라인과 제 2 이미지 센서로부터의 각각의 대응하는 데이터 라인 사이의 위상 오프셋은, 예시적이고 제한되지 않는 예들로서 도 9 의 1-라인 위상

차이, 도 8 의 2-라인 위상 차이, 또는 도 12 의 3-라인 위상 차이와 같이 실질적으로 일정할 수도 있다.

[0128] 도 25 를 참조하면, 공통 제어 신호를 다중 이미지 센서들에 제공하고, 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 생성하는 방법의 특정 예시적 실시형태의 흐름도가 도시되고, 일반적으로 2500 으로 지정된다.

[0129] 다중 이미지 센서들에서 공통 제어 신호가 수신될 수도 있다 (2502). 다중 이미지 센서들의 각각은 공통 제어 신호에 응답하여 이미지 데이터를 생성한다. 예를 들면, 공통 제어 신호는 다중 이미지 센서들의 각각에 커플링된 센서 동기화기, 예컨대 도 2 내지 도 5 중 임의의 것의 센서 동기화기 (230), 도 18 의 제어 동기화 블록 (1844), 도 19 의 제어 동기화 블록 (1936), 또는 이들의 임의의 조합으로부터 수신될 수도 있다.

[0130] 다중 이미지 센서들 각각으로부터 동기화된 데이터 출력이 생성될 수도 있다 (2504). 동기화된 데이터 출력은 제 1 이미지 센서로부터 수신된 제 1 데이터 라인들 및 제 2 이미지 센서로부터 수신된 제 2 데이터 라인들을 포함할 수도 있다. 제 1 이미지 센서로부터의 각각의 수신된 데이터 라인과 제 2 이미지 센서로부터의 각각의 대응하는 데이터 라인 사이의 위상 오프셋은, 예시적이고 제한되지 않는 예들로서 도 9 의 1-라인 위상 차이, 도 8 의 2-라인 위상 차이, 또는 도 12 의 3-라인 위상 차이와 같이 실질적으로 일정할 수도 있다.

[0131] 도 26 을 참조하면, 단일 카메라에 대한 입력을 갖는 이미지 신호 프로세서에서 다중 센서들로부터의 데이터를 결합하는 방법의 특정 예시적 실시형태의 흐름가 도시되고, 일반적으로 2600 으로 지정된다.

[0132] 이미지 데이터의 라인들은 단일 카메라에 대한 입력을 갖는 이미지 프로세서에서 수신될 수도 있다 (2602). 이미지 데이터의 각 라인은 제 1 카메라에 의해 캡처된 제 1 이미지로부터의 제 1 라인 데이터 및 제 2 카메라에 의해 캡처된 제 2 이미지로부터의 제 2 라인 데이터를 포함할 수도 있다. 예시적이고 제한되지 않은 예로서, 이미지 프로세서는 도 2 및 도 3 또는 도 5 의 이미지 신호 프로세서 (208), 도 13 의 이미지 프로세서 (1308), 도 18 의 VFE들 (1834-1842), 도 19 의 VFE들 (1934-1942), 또는 이들의 임의의 조합을 포함할 수도 있다.

[0133] 이미지 데이터의 라인들은 제 1 카메라 및 제 2 카메라에 커플링된 결합기로부터 제 1 이미지 프로세서에서 수신될 수도 있다. 제 1 카메라로부터의 제 1 이미지 데이터와 제 2 카메라로부터의 제 2 이미지 데이터의 라인별 판독은 결합기를 이용하여 이미지 데이터의 각 라인을 생성하도록 동기화될 수도 있다. 예를 들면, 결합기는 도 2 및 도 3 또는 도 5 의 결합기 (206), 도 13 의 결합기 (1306), 도 18 의 데이터 정렬 블록들 (1824-1832), 도 19 의 데이터 정렬 블록들 (1924-1932), 또는 이들의 임의의 조합을 포함할 수도 있다.

[0134] 제 1 이미지의 라인 데이터에 대응하는 제 1 섹션과 제 2 이미지의 라인 데이터에 대응하는 제 2 섹션을 갖는 출력 프레임이 생성될 수도 있다 (2604). 제 1 섹션 및 제 2 섹션은 3 차원 (3D) 이미지 포맷 또는 3D 비디오 포맷을 생성하는데 이용되도록 구성될 수도 있다.

[0135] 특정 실시형태에서, 출력 프레임은 3D 이미지 데이터를 생성하도록 처리되고, 3D 이미지 데이터는 디스플레이 디바이스로 송신된다. 다른 실시형태에서, 출력 프레임은 3D 비디오 데이터를 생성하도록 처리되고, 3D 비디오 데이터는 도 13 의 디스플레이 디바이스 (1310) 와 같은 디스플레이 디바이스로 송신된다. 설명을 위해, 디스플레이 디바이스는 통신 디바이스, 카메라, 개인 휴대 정보 단말기, 및 컴퓨터 중 적어도 하나의 구성요소일 수도 있다.

[0136] 도 27 을 참조하면, 다중 센서들로부터의 데이터를 하나의 프레임으로 결합하는 방법의 특정 예시적 실시형태의 흐름도가 도시되고, 일반적으로 2700 으로 지정된다. 일 예로서, 방법 (2700) 은 도 2 의 시스템, 도 5 의 시스템, 또는 이들의 임의의 조합에 의해 수행될 수도 있다.

[0137] 제 1 데이터 스트림은 도 2 의 제 1 센서 (202) 와 같은 제 1 이미지 센서로부터 수신될 수도 있다 (2702). 도 2 의 제 1 이미지 데이터 스트림 (212), 도 6 의 제 1 데이터 스트림 (602), 또는 도 5 의 타이밍 데이터 신호 (420) 와 이미지 데이터 신호 (422) 와 같은 제 1 데이터 스트림은 이미지의 제 1 이미지 데이터에 대응할 수도 있다. 제 2 데이터 스트림은 도 2 의 제 2 센서 (204) 와 같은 제 2 이미지 센서로부터 수신될 수도 있다 (2704). 도 2 의 이미지 데이터 스트림 (214) 과 같은 제 2 데이터 스트림, 도 6 의 제 2 데이터 스트림 (604) 또는 도 5 의 타이밍 신호 데이터 (430) 와 이미지 데이터 신호 (432) 는 이미지의 제 2 이미지 데이터에 대응할 수도 있다.

[0138] 제 1 데이터 스트림으로부터의 데이터와 제 2 데이터 스트림으로부터의 데이터가 결합될 수도 있다 (2706). 예를 들면, 도 2 의 결합기 (206) 또는 도 5 의 결합기 (206) 와 같은 결합기는 제 1 데이터 스트림으로부터의

제 1 이미지 데이터와 제 2 데이터 스트림으로부터의 제 2 이미지 데이터를 결합하여 결과적인 프레임을 생성할 수도 있다. 설명을 위해, 제 1 데이터 스트림은 제 1 라인 인덱스 값을 갖는 라인 데이터, 제 2 라인 인덱스 값을 갖는 라인 데이터, 등을 포함하는 제 1 이미지 데이터의 제 1 라인과 연관된 데이터를 포함할 수도 있다. 제 2 데이터 스트림은 제 1 라인 인덱스 값을 갖는 대응하는 라인 데이터, 제 2 라인 인덱스 값을 갖는 대응하는 라인 데이터, 등을 포함하는, 제 1 데이터 스트림의 라인 데이터에 대응하는 라인 데이터를 포함할 수도 있다. 제 1 라인 인덱스 값을 갖는 제 1 데이터 스트림으로부터의 라인 데이터 및 대응하는 제 1 라인 인덱스 값을 갖는 제 2 데이터 스트림으로부터의 라인 데이터는 서로 부가되거나 결합되어 단일 이미지 라인을 형성할 수도 있다. 프로세스는 도 6 의 프레임 (660) 과 같은 결과적인 프레임을 생성하기 위해 각각의 라인 인덱스 값에 대하여 반복될 수도 있다. 특정 실시형태에서, 프레임은 복수의 로우들을 포함할 수도 있고, 여기서 각각의 로우는 라인 인덱스 값에 대응하고, 라인 인덱스 값을 갖는 제 1 이미지 데이터의 라인을 저장하고, 라인 인덱스 값을 갖는 제 2 이미지 데이터의 대응하는 라인을 저장한다. 특정 실시형태에서, 제 1 이미지 데이터의 제 1 라인과 제 2 이미지 데이터의 대응하는 라인이 단일 이미지 라인으로 결합될 경우, 단일 이미지 라인의 사이즈는 제 1 이미지 데이터의 제 1 라인 또는 제 2 이미지 데이터의 대응하는 라인의 사이즈의 실질적으로 2 배이다.

[0139] 프레임은 이미지 신호 프로세서에서 처리되어 처리된 프레임을 생성할 수도 있다 (2708). 특정 실시형태에서, 이미지 신호 프로세서는 도 2 의 이미지 신호 프로세서 (208) 또는 도 5 의 이미지 신호 프로세서 (208) 일 수도 있고, 처리된 프레임은 도 2 의 처리된 프레임 (240) 또는 도 6 의 처리된 프레임 (650) 일 수도 있다. 특정 실시형태에서, 처리된 프레임은 제 1 섹션 (652) 과 같이 제 1 이미지 센서로부터의 제 1 이미지 데이터를 포함하는 제 1 섹션, 제 2 섹션 (654) 과 같이 제 2 이미지로부터의 제 2 이미지 데이터를 포함하는 제 2 섹션 및 도 6 의 갭 섹션 (656) 과 같은 갭 섹션을 포함할 수도 있다. 갭 섹션은 제 1 섹션과 제 2 섹션 사이에 배치된 비-이미지 데이터를 포함할 수도 있다. 특정 실시형태에서, 제 1 섹션은 제 1 이미지 데이터의 라인을 포함할 수도 있고, 제 2 섹션은 제 2 이미지 데이터의 대응하는 라인을 포함할 수도 있다.

[0140] 처리된 프레임은 디스플레이 디바이스에 디스플레이 되도록 출력될 수도 있다 (2710). 특정 실시형태에서, 제 1 이미지 센서와 제 2 이미지 센서는 각각 이미지 신호 프로세서에 직접 응답하고, 디스플레이 디바이스는 이미지 신호 프로세서로부터 디커플링될 수도 있다.

[0141] 도 28 을 참조하면, 제 1 이미지 센서와 제 2 이미지 센서를 동기화하는 방법의 예시적인 실시형태의 흐름도가 도시되며, 일반적으로 2800 으로 지정된다. 일 예로서, 방법 (2800) 은 도 2 의 시스템 (200), 도 5 의 시스템 (500), 또는 이들의 임의의 조합에서 수행될 수도 있다.

[0142] 이미지의 제 1 이미지 데이터는 제 1 이미지 센서로부터 수신될 수도 있다 (2802). 특정 실시형태에서, 제 1 이미지 센서는 도 2 의 제 1 센서 (202) 일 수도 있다. 제 1 이미지 데이터와 연관된 제 1 데이터 스트림은 제 1 이미지 센서로부터 수신될 수도 있다 (2804). 특정 실시형태에서, 제 1 데이터 스트림은 이미지 센서에 의해 생성될 수도 있고, 도 2 의 제 1 이미지 데이터 스트림 (212), 도 6 의 제 1 데이터 스트림 (602), 또는 도 5 의 타이밍 데이터 신호 (420) 와 이미지 데이터 신호 (422) 일 수도 있다.

[0143] 이미지의 제 2 이미지 데이터는 제 2 이미지 센서로부터 수신될 수도 있다 (2806). 특정 실시형태에서, 제 2 이미지 센서는 도 2 의 제 2 센서 (204) 일 수도 있다. 제 2 이미지 데이터와 연관된 제 2 데이터 스트림은 제 2 이미지 센서로부터 수신될 수도 있다 (2808). 특정 실시형태에서, 제 2 데이터 스트림은 이미지 센서에 의해 생성될 수도 있고, 도 2 의 제 2 이미지 데이터 스트림 (214), 도 6 의 제 2 데이터 스트림 (604), 또는 도 5 의 타이밍 데이터 신호 (430) 와 이미지 데이터 신호 (432) 일 수도 있다.

[0144] 이미지 데이터 획득 동안 제 1 이미지 센서와 제 2 이미지 센서의 라인별 노출은 동기화될 수도 있다 (2810). 특정 실시형태에서, 동기화는 도 2 의 결합기 (206) 또는 도 5 의 결합기 (206) 와 같은 결합기를 포함하는 호스트에서 이미지의 이미지 데이터 획득 동안 발생할 수도 있다. 특정 실시형태에서, 제 1 이미지 센서와 제 2 이미지 센서는 서로 독립적이다. 예를 들어, 도 2 의 제 1 및 제 2 센서들 (202, 204) 은 제어 신호 (232) 를 통해 이미지 신호 프로세서 (208) 에 직접 응답하며, 서로 독립적이지만 유사한 타이밍 특성들을 갖는다. 제 1 데이터 스트림과 제 2 데이터 스트림은 인터리빙될 수도 있다 (2812). 특정 실시형태에서, 제 1 데이터 스트림과 제 2 데이터 스트림은 라인별로 인터리빙될 수도 있다. 예를 들어, 제 1 라인 인덱스 값을 갖는 제 1 데이터 스트림으로부터의 라인 데이터와 대응하는 제 1 라인 인덱스 값을 갖는 제 2 데이터 스트림으로부터의 라인 데이터는 서로 부가되어 인터리빙된 단일 이미지 라인을 형성할 수도 있다.

[0145] 따라서, 결합된 데이터는 단일 이미지 신호 프로세서를 이용하여 효율적으로 처리될 수도 있다. 따라서, 건

제 이미지 시스템 비용 및 복잡도는 프로세서가 각각의 센서에 할당되는 다중 프로세서 시스템들과 비교할 때 감소될 수도 있다.

[0146] 도 29 를 참조하면, 다중 이미지 센서들로부터의 데이터를 결합하여 3D 이미지 데이터를 생성하는 방법의 제 1 예시적 실시형태의 흐름도가 도시되며, 일반적으로 2900 으로 지정된다. 일 예로서, 방법 (2900) 은 도 13 의 시스템에 의해 수행될 수도 있다.

[0147] 방법은 제 1 카메라와 제 2 카메라로부터 제 1 이미지의 라인별 판독을 동기화하여 이미지 데이터의 로우들을 생성하는 것을 포함한다 (2902). 제 1 카메라로부터의 제 1 이미지 데이터는 도 1 의 제 1 이미지 센서 (1302) 로부터의 이미지 데이터 스트림 (1314) 일 수도 있고, 제 2 이미지 데이터는 도 13 의 제 2 이미지 센서 (1304) 로부터의 이미지 데이터 스트림 (1316) 일 수도 있다.

[0148] 방법은 단일 카메라에 대한 입력을 갖는 이미지 프로세서에서 이미지 데이터의 로우들을 수신하는 것을 포함한다 (2904). 이미지 데이터의 각 로우는 제 1 카메라에 의해 캡처된 제 1 이미지의 로우로부터의 데이터와 제 2 카메라에 의해 캡처된 제 2 이미지의 로우로부터의 데이터를 포함한다. 이미지 데이터의 로우들은 도 7 에 도시된 데이터 아웃 스트림 (706) 일 수도 있다.

[0149] 방법은 이미지 프로세서를 사용하여 3D 이미지 포맷과 3D 비디오 포맷 중 하나를 갖는 출력을 생성하는 것을 포함한다 (2906). 출력은 제 1 이미지와 제 2 이미지에 대응한다. 출력은 디스플레이 디바이스 (예컨대, 도 13 의 디스플레이 디바이스 (1310)) 로 송신된다 (2908).

[0150] 도 30 을 참조하면, 다중 센서들로부터의 데이터를 하나의 프레임으로 결합하는 방법의 예시적 실시형태의 흐름도가 도시되고, 일반적으로 3000 으로 지정된다. 일 예로서, 방법 (3000) 은 도 13 의 시스템에 의해 수행될 수도 있다.

[0151] 제 1 데이터 스트림은 도 13 의 제 1 이미지 센서 (1302) 와 같은 제 1 이미지 센서로부터 수신된다 (3002). 도 13 의 제 1 이미지 데이터 스트림 (1314) 또는 도 7 의 제 1 데이터 스트림 (702) 와 같은 제 1 데이터 스트림은 제 1 이미지의 제 1 이미지 데이터에 대응할 수도 있다. 제 2 데이터 스트림은 도 13 의 제 2 이미지 센서 (1304) 와 같은 제 2 이미지 센서로부터 수신될 수도 있다 (3004). 도 13 의 제 2 이미지 데이터 스트림 (1316), 도 7 의 제 2 데이터 스트림 (704) 과 같은 제 2 데이터 스트림은 제 2 이미지의 제 2 이미지 데이터에 대응할 수도 있다. 제 1 이미지와 제 2 이미지는 장면의 이미지들일 수도 있다. 장면의 제 1 이미지와 제 2 이미지는 실질적으로 동시에 취득될 수도 있거나, 상이한 시간에 취득될 수도 있다. 제 1 이미지는 제 2 이미지와 서로 다른 유리한 지점으로부터 취득되며, 따라서 깊이 정보는 장면의 제 1 이미지와 제 2 이미지로부터 결정될 수도 있다.

[0152] 제 1 데이터 스트림으로부터의 데이터와 제 2 데이터 스트림으로부터의 데이터가 결합된다 (3006). 예를 들면, 도 13 의 결합기 (1306) 와 같은 결합기는 제 1 데이터 스트림으로부터의 제 1 이미지 데이터와 제 2 데이터 스트림으로부터의 제 2 이미지 데이터를 결합하여 결과적인 프레임을 생성할 수도 있다. 설명을 위해, 제 1 데이터 스트림은 제 1 라인 인덱스 값을 갖는 라인 데이터, 제 2 라인 인덱스 값을 갖는 라인 데이터, 등을 포함하는 제 1 이미지 데이터의 제 1 라인과 연관된 데이터를 포함할 수도 있다. 제 2 데이터 스트림은 제 1 라인 인덱스 값을 갖는 대응하는 라인 데이터, 제 2 라인 인덱스 값을 갖는 대응하는 라인 데이터, 등을 포함하는, 제 1 데이터 스트림의 라인 데이터에 대응하는 라인 데이터를 포함할 수도 있다. 제 1 라인 인덱스 값을 갖는 제 1 데이터 스트림으로부터의 라인 데이터 및 대응하는 제 1 라인 인덱스 값을 갖는 제 2 데이터 스트림으로부터의 라인 데이터는 서로 부가되거나 결합되어 단일 이미지 라인을 형성할 수도 있다. 프로세스는 도 7 의 프레임 (740) 과 같은 결과적인 프레임을 생성하기 위해 각각의 라인 인덱스 값에 대하여 반복될 수도 있다. 특정 실시형태에서, 프레임은 복수의 로우들을 포함할 수도 있고, 여기서 각각의 로우는 라인 인덱스 값에 대응하고, 라인 인덱스 값을 갖는 제 1 이미지 데이터의 라인을 저장하고, 라인 인덱스 값을 갖는 제 2 이미지 데이터의 대응하는 라인을 저장한다. 특정 실시형태에서, 제 1 이미지 데이터의 제 1 라인과 제 2 이미지 데이터의 대응하는 라인이 단일 이미지 라인으로 결합될 경우, 단일 이미지 라인의 사이즈는 제 1 이미지 데이터의 제 1 라인 또는 제 2 이미지 데이터의 대응하는 라인의 사이즈의 실질적으로 2 배이다.

[0153] 프레임은 단일 카메라에 대한 입력을 통해 이미지 데이터의 로우들로서 수신된다 (3008). 특정 실시형태에서, 단일 카메라에 대한 입력은 도 13 의 이미지 프로세서 (1308) 과 같은 이미지 프로세서의 입력일 수도 있다. 프레임은 도 7 의 프레임 (740) 일 수도 있다.

[0154] 프레임으로부터 출력이 생성된다 (3010). 출력은 3D 이미지 포맷과 3D 비디오 포맷 중 하나를 갖는다.

출력은 제 1 이미지와 제 2 이미지에 대응한다. 출력은 도 13의 처리된 프레임 데이터 (1320) 일 수도 있다. 출력은 디스플레이 디바이스로 송신된다 (3012). 특정 실시형태에서, 디스플레이 디바이스는 도 13 의 디스플레이 디바이스 (1310) 일 수도 있다.

[0155] 도 31 을 참조하면, 제 1 이미지 센서와 제 2 이미지 센서를 동기화하는 방법의 예시적인 실시형태의 흐름도가 도시되며, 일반적으로 3100 으로 지정된다. 일 예로서, 방법 (3100) 은 도 13 의 시스템 (1300) 에 의해 수행될 수도 있다.

[0156] 이미지의 제 1 이미지 데이터는 제 1 이미지 센서로부터 수신될 수도 있다 (3102). 특정 실시형태에서, 제 1 이미지 센서는 도 13 의 제 1 이미지 센서 (1302) 일 수도 있다. 제 1 이미지 데이터와 연관된 제 1 데이터 스트림은 제 1 이미지 센서로부터 수신될 수도 있다 (3104). 특정 실시형태에서, 제 1 데이터 스트림은 이미지 센서에 의해 생성될 수도 있고, 도 13 의 제 1 이미지 데이터 스트림 (1314) 또는 도 7 의 제 1 데이터 스트림 (702) 일 수도 있다.

[0157] 이미지의 제 2 이미지 데이터는 제 2 이미지 센서로부터 수신될 수도 있다 (3106). 특정 실시형태에서, 제 2 이미지 센서는 도 13 의 제 2 이미지 센서 (1304) 일 수도 있다. 제 2 이미지 데이터와 연관된 제 2 데이터 스트림은 제 2 이미지 센서로부터 수신될 수도 있다 (3108). 특정 실시형태에서, 제 2 데이터 스트림은 이미지 센서에 의해 생성될 수도 있고, 도 13 의 제 2 이미지 데이터 스트림 (1316) 또는 도 7 의 제 2 데이터 스트림 (704) 일 수도 있다.

[0158] 이미지 데이터 획득 동안 제 1 이미지 센서와 제 2 이미지 센서의 라인별 노출은 동기화될 수도 있다 (3110). 특정 실시형태에서, 동기화는 도 13 의 결합기 (1306) 와 같은 결합기를 포함하는 호스트에서 이미지의 이미지 데이터 획득 동안 발생할 수도 있다. 특정 실시형태에서, 제 1 이미지 센서와 제 2 이미지 센서는 서로 독립적이다. 예를 들어, 도 13 의 제 1 및 제 2 이미지 센서들 (1302, 1304) 은 제어 신호를 통해 이미지 프로세서 (1308) 에 직접 응답하며, 서로 독립적이지만 유사한 타이밍 특성들을 갖는다. 다른 실시형태에서, 제 1 및 제 2 이미지 센서들 (1302, 1304) 은 제어 신호를 통해 결합기 (1306) 에 직접 응답하며, 서로 독립적이지만 유사한 타이밍 특성들을 갖는다. 제 1 데이터 스트림과 제 2 데이터 스트림은 인터리빙될 수도 있다 (3112). 특정 실시형태에서, 제 1 데이터 스트림과 제 2 데이터 스트림은 라인별로 인터리빙될 수도 있다. 예를 들어, 제 1 라인 인덱스 값을 갖는 제 1 데이터 스트림으로부터의 라인 데이터와 대응하는 제 1 라인 인덱스 값을 갖는 제 2 데이터 스트림으로부터의 라인 데이터는 서로 부가되어 인터리빙된 단일 이미지 라인을 형성할 수도 있다.

[0159] 따라서, 결합된 데이터는 단일 이미지 신호 프로세서를 이용하여 효율적으로 처리될 수도 있다. 따라서, 전체 이미지 시스템 비용 및 복잡도는 프로세서가 각각의 센서에 할당되는 다중 프로세서 시스템들과 비교할 때 감소될 수도 있다.

[0160] 도 32 를 참조하면, 이미지 프로세서를 이용하여 3D 이미지를 생성하는 방법의 예시적 실시형태의 흐름도가 도시되고, 일반적으로 3200 으로 지정된다. 이미지 프로세서는 도 13 의 이미지 프로세서 (1308) 일 수도 있다. 방법 (3200) 은 이미지 프로세서가 (예컨대, 도 1 의 결합기 (1306) 와 같은) 결합기로부터 수신된 프레임, 메모리로부터의 프레임을 처리할 경우, 또는 사용자가 3D 이미지를 디스플레이하는 디바이스의 몇 특징 또는 전 특징을 이용하여 디스플레이된 3D 이미지를 변경할 것을 선택할 경우에 이용될 수도 있다.

[0161] 이미지 프로세서는 캘리브레이션 행렬의 파라미터들에 기초하여 제 1 이미지와 제 2 이미지를 교정한다 (3202). 캘리브레이션 행렬은 제 1 이미지와 제 2 이미지를 캡처하는 제 1 이미지 센서와 제 2 이미지 센서의 상대적인 위치들에 대한 조정들을 제공할 수도 있다. 2 개의 카메라들의 상대적인 위치들은 피사의 장면 깊이 및 눈의 피로를 보장하도록 선택될 수도 있다. 캘리브레이션 행렬은 3D 이미지를 획득하는 디바이스에 대한 제작 프로세스에서 결정될 수도 있고, 여기서 제 1 이미지 센서와 제 2 이미지 센서의 위치들은 서로에 대하여 고정된다. 캘리브레이션은 디바이스의 메모리 내에 저장될 수도 있다. 제 1 이미지 센서, 제 2 이미지 센서, 또는 이들 양자의 위치들은 조정가능한, 3D 이미지를 취득하는 디바이스에 대하여, 디바이스의 프로세서는 캘리브레이션 행렬을 결정하기 위해 캘리브레이션 루틴을 실행하고 캘리브레이션 행렬을 메모리에 저장하는데 이용될 수도 있다. 캘리브레이션 루틴은 제 1 이미지 센서와 제 2 이미지 센서가 이미지 센서들로부터 설정된 거리에 위치된 특정 캘리브레이션 장면에서 포커싱될 것을 요구할 수도 있다. 캘리브레이션 루틴은 이미지 센서들의 서로에 대한 위치 조정 이후에 수행될 수도 있다.

[0162] 이미지 프로세서는 제 1 이미지에서 키포인트들을 검출한다 (3204). 이미지 프로세서는 제 1 이미지에서 목

특한 (고주파수) 포인트들을 검출할 수도 있다. 이미지 프로세서 블록은 제 1 이미지에서 각각의 검출된 키 포인트에 대한 디스크립터들을 계산하기 위해 제 1 이미지와 제 2 이미지의 로컬 이미지 패치들 간에 매칭한다 (3206). 선택도 추정기는 또한 키포인트들이 에러 있는 매칭들이 제거되는 것을 보장하도록 생성될 수도 있다. 이미지 프로세서는 계산된 디스크립터들로부터 결정된 디스크립터 범위에 기초하여 컨버전스 조정을 결정한다 (3208). 컨버전스 조정은 장면 깊이 및 디스플레이 지오메트리를 고려한다.

[0163] 이미지 프로세서는 컨버전스 조정이 출력을 생성하기 위해 3D 이미지를 디스플레이하는 디스플레이 디바이스의 능력 내에 있을 경우 컨버전스 조정에 기초하여 제 1 이미지와 제 2 이미지 중 적어도 하나를 선택적으로 쉬프트한다 (3210). 이미지 프로세서는 컨버전스 조정이 출력을 생성하기 위한 디스플레이 디바이스의 능력 밖일 경우에 대부분의 장면에 매칭하도록 조정된 디스크립터를 갖는 제 1 이미지를 이용한다 (3212). 이미지 프로세서는 디바이스 디바이스의 하나 이상의 디바이스 특징들에 기초하여 출력을 프롭한다 (3214).

[0164] 도 33 은 다중 이미지 센서들로부터의 데이터를 결합하는 이미지 프로세싱 시스템 (3300) 의 특정 실시형태의 블록도이다. 이미지 프로세싱 시스템 (3300) 은 제 1 렌즈 (3304) 에 커플링되고, 제 2 렌즈 (3306) 에 커플링되고, 휴대용 멀티미디어 디바이스의 애플리케이션 프로세서 칩셋 (3308) 에 커플링된 이미지 센서 디바이스 (3302) 를 포함할 수도 있다. 이미지 센서 디바이스 (3302) 는 결합기 (3310) 및 단일 카메라에 대한 입력을 수신하는 이미지 프로세서 (3312) 를 포함할 수도 있다. 이미지 프로세서 (3312) 는 결합기 (3310) 로부터, 또는 휴대용 멀티미디어 디바이스의 애플리케이션 프로세서 칩셋 (3308) 의 메모리 디바이스 (3314) 로부터 단일 카메라 입력을 수신할 수도 있다. 결합기 (3310) 는, 예컨대 도 13 의 시스템 (1300) 을 구현함으로써, 도 29 내지 도 31 의 임의의 실시형태들에 따라 동작함으로써, 또는 이들의 임의의 조합에 의해 프레임을 생성하기 위해 제 1 데이터 스트림으로부터의 데이터와 제 2 데이터 스트림으로부터의 데이터를 결합할 수도 있다.

[0165] 결합기 (3310) 는 제 1 아날로그-디지털 컨버터 (3318) 를 통해 제 1 센서 (3316) 로부터 이미지 데이터를 수신하도록 커플링된다. 결합기 (3310) 는 제 2 아날로그-디지털 컨버터 (3322) 를 통해 제 2 센서 (3320) 로부터 이미지 데이터를 수신하도록 커플링된다. 결합기 (3310) 또는 이미지 프로세서 (3312) 는 서로 독립적일 수도 있는 제 1 센서 (3316) 와 제 2 센서 (3320) 를 제어할 수도 있다. 특정 실시형태에서, 이미지 프로세서 (3312) 는 (예시적으로 도시된) 센서 동기화기 (3330) 를 통해 제 1 센서 (3316) 와 제 2 센서 (3320) 를 제어할 수도 있다.

[0166] 특정 실시형태에서, 결합기 (3310) 와 같은 이미지 프로세싱 회로를 포함하는 집적 회로는 프레임을 생성하도록 구성된다. 이미지 프로세싱 회로는 제 1 센서 (3316) 와 같은 제 1 이미지 센서로부터 제 1 데이터 스트림을 수신하고, 제 2 센서 (3320) 와 같은 제 2 이미지 센서로부터 제 2 데이터 스트림을 수신하고, 제 1 데이터 스트림으로부터의 데이터와 제 2 데이터 스트림으로부터의 데이터를 결합하여 프레임을 생성하도록 구성된다. 예를 들면, 도 7 의 제 1 데이터 스트림 (702) 과 제 2 데이터 스트림 (704) 은 도 7 의 프레임 (740) 을 형성하기 위해 결합기 (3310) 에 의해 결합될 수도 있다.

[0167] 결합기 (3310) 로부터의 출력은 휴대용 멀티미디어 디바이스의 애플리케이션 프로세서 칩셋 (3308) 의 메모리 디바이스 (3314) 로, 이미지 프로세서 (3312) 로, 또는 이들 양자로 송신될 수도 있다. 이미지 프로세서 (3312) 는 이미지 프로세싱 시스템에 의해 수행된 하나 이상의 동작들과 같은 추가의 이미지 프로세싱 동작들을 수행하도록 구성될 수도 있다. 이미지 프로세서 (3312) 는 결합기 (3310) 로부터 또는 메모리 디바이스 (3314) 로부터 프레임을 수신할 수도 있다. 이미지 프로세서 (3312) 는 3D 이미지 포맷 또는 3D 비디오 포맷을 갖는 처리된 프레임과 같은 처리된 이미지 데이터를 생성할 수도 있다. 일 실시형태에서, 처리되니 이미지 데이터를 생성하기 위한 평균 시간은 약 20 밀리초이다. 이미지 프로세서 (3312) 는 추가의 처리, 송신, 저장, 디스플레이 디바이스 (3324) 로의 디스플레이 또는 이들의 임의의 조합을 위해 처리된 이미지 데이터를 휴대용 멀티미디어 디바이스의 애플리케이션 프로세서 칩셋 (3308) 에 제공할 수도 있다.

[0168] 도 34 를 참조하면, 본 명세서에서 설명된 것과 같은 프레임 생성기 모듈을 포함하여 무선 전화기와 같은 전자 디바이스의 특정 예시적 실시형태의 블록도가 도시되고, 일반적으로 3400 로 지정된다. 디바이스 (3400) 는 메모리 (3432) 에 커플링된 프로세서 (3410) 를 포함한다. 프로세서는 제어기 (3464) 를 포함하거나 커플링된다. 대안적으로, 전자 디바이스는 셋톱 박스, 뮤직 플레이어, 비디오 플레이어, 엔터테인먼트 유닛, 네비게이션 디바이스, 통신 디바이스, 개인 휴대 정보 단말기 (PDA), 카메라, 고정 위치 데이터 유닛, 또는 컴퓨터일 수도 있다.

[0169] 도 34 는 또한 프로세서 (3410) 및 디스플레이 (3428) 에 커플링된 디스플레이 제어기 (3426) 를 도시한다.

코더/디코더 (코덱; 3434) 는 또한 프로세서 (3410) 에 커플링될 수 있다. 스피커 (3439) 및 마이크로폰 (3438) 은 코덱 (3434) 에 커플링될 수 있다. 카메라 제어기 (3470) 는 또한 프로세서 (3410) 에 커플링될 수 있다. 제 1 카메라 (3472) 및 제 2 카메라 (3473) 은 카메라 제어기 (3470) 에 커플링될 수 있다.

[0170] 도 34 는 또한 무선 인터페이스 (3440) 가 프로세서 (3410) 및 무선 안테나 (3442) 에 커플링될 수 있는 것을 나타낸다. 특정 실시형태에서, 프로세서 (3410), 디스플레이 제어기 (3426), 메모리 (3432), 코덱 (3434), 무선 인터페이스 (3440) 및 제어기 (3464) 는 시스템-인-패키지 또는 시스템-온-칩 (3422) 에 포함된다. 특정 실시형태에서, 입력 디바이스 (3430) 및 전원 (3444) 은 온-칩 시스템 (3422) 에 커플링된다. 추가로, 특정 실시형태에서, 도 34 에 도시된 것과 같이, 디스플레이 (3428), 입력 디바이스 (3430), 스피커 (3439), 마이크로폰 (3438), 무선 안테나 (3442), 및 전원 (3444) 이 온-칩 시스템 (3422) 외부에 있다. 그러나, 그 각각이 인터페이스 또는 제어기와 같은 온-칩 시스템 (3422) 의 컴포넌트에 커플링될 수 있다.

[0171] 특정 실시형태에서, 프로세서 (3410) 는 메모리 (3432) 에 저장된 프로그램 명령들 (3482) 과 같은, 프로세서 판독가능 매체로부터의 프로세서 실행가능 프로그램 명령들을 실행한다. 예를 들면, 메모리 (3432) 는 프로세서 (3410) 에 의해 판독될 수도 있고, 명령들 (3482) 은 프로세서 (3410) 에 의해 도 22 의 방법 (2200) 을 수행하도록 실행가능한 동작 명령들일 수도 있다. 예를 들면, 명령들 (3482) 은 프로세서 (3410) 에 의해 카메라 (3473) 와 같은 제 1 이미지 센서로부터의 제 1 데이터 스트림을 수신하고, 카메라 (3472) 와 같은 제 2 이미지 센서로부터의 제 2 데이터 스트림을 수신하고, 제 1 데이터 스트림과 제 2 데이터 스트림으로부터의 데이터를 결합하여 프레임을 생성하도록 실행가능한 명령들을 포함할 수도 있다. 예를 들면, 제 1 이미지 센서는 도 2 의 제 1 센서 (202) 일 수도 있고, 제 2 이미지 센서는 도 2 의 제 2 센서 (204) 일 수도 있다. 명령들 (3482) 은 프로세서 (3410) 에 의해 프로세서 (3410) 또는 이미지 신호 프로세서 (미도시) 에서 프레임을 처리하여 처리된 프레임을 생성하도록 실행가능한 명령들을 추가로 포함할 수도 있다. 명령들 (3482) 은 프로세서 (3410) 에 의해 처리된 프레임을 송력하여 디스플레이 디바이스 (3428) 에 디스플레이 되거나 메모리 (3432) 에 이미지 데이터 (3480) 로서 저장되도록 실행가능한 명령들을 추가로 포함할 수도 있다.

[0172] 도 35 를 참조하면, 모바일 전화기와 같은 전자 디바이스의 특정 예시적 실시형태의 블록도가 도시되고, 일반적으로 3500 로 지정된다. 디바이스 (3500) 는 메모리 (3504) 에 커플링된 프로세서 (3502) 를 포함한다. 프로세서 (3502) 는 이미지 프로세서 (3506) 를 포함하거나 커플링된다. 이미지 프로세서 (3506) 는 단일 카메라 입력을 수신할 수도 있고, 3D 데이터 (3590) 를 출력할 수도 있다. 3D 데이터 (3590) 는 3D 이미지 포맷 또는 3D 비디오 포맷일 수도 있다. 대안적으로, 전자 디바이스 (3500) 는 셋톱 박스, 뮤직 플레이어, 비디오 플레이어, 엔터테인먼트 유닛, 네비게이션 디바이스, 통신 디바이스, 개인 휴대 정보 단말기 (PDA), 카메라, 고정 위치 데이터 유닛, 컴퓨터, 또는 이들의 임의의 조합일 수도 있다.

[0173] 도 35 는 또한 프로세서 (3502) 및 디스플레이 (3510) 에 커플링된 디스플레이 제어기 (3508) 를 도시한다. 코더/디코더 (코덱; 3512) 는 또한 프로세서 (3502) 에 커플링될 수 있다. 스피커 (3514) 및 마이크로폰 (3516) 은 코덱 (3512) 에 커플링될 수 있다. 카메라 제어기 (3518) 는 또한 프로세서 (3502) 에 커플링될 수 있다. 카메라 제어기 (3518) 는 결합기 (3520) 를 포함할 수도 있다. 결합기 (3520) 는 이미지 데이터를 이미지 프로세서 (3506) 에 제공할 수도 있다. 예들로서, 결합기 (3520) 는 도 13 의 결합기 (1306), 또는 도 7 과 관련하여 도시된 것과 같은 다중 카메라들로부터의 데이터를 결합하도록 구성된 다른 하드웨어 회로 또는 프로세서일 수도 있다. 제 1 카메라 (3522) 및 제 2 카메라 (3524) 는 카메라 제어기 (3518) 에 커플링될 수 있다.

[0174] 도 35 는 또한 무선 인터페이스 (3526) 가 프로세서 (3502) 및 무선 안테나 (3528) 에 커플링될 수 있는 것을 나타낸다. 특정 실시형태에서, 프로세서 (3502), 디스플레이 제어기 (3508), 메모리 (3504), 코덱 (3512), 카메라 제어기 (3518) 및 무선 인터페이스 (3526) 는 시스템-인-패키지 또는 시스템-온-칩 (3530) 에 포함된다. 특정 실시형태에서, 입력 디바이스 (3532) 및 전원 (3534) 은 온-칩 시스템 (3530) 에 커플링된다. 추가로, 특정 실시형태에서, 도 35 에 도시된 것과 같이, 디스플레이 (3510), 입력 디바이스 (3532), 스피커 (3514), 마이크로폰 (3516), 무선 안테나 (3528), 및 전원 (3534) 이 온-칩 시스템 (3530) 외부에 있다. 그러나, 그 각각이 인터페이스 또는 제어기와 같은 온-칩 시스템 (3530) 의 컴포넌트에 커플링될 수 있다.

[0175] 특정 실시형태에서, 프로세서 (3502) 는 메모리 (3504) 에 저장된 프로그램 명령들 (3536) 과 같은, 프로세서 판독가능 매체로부터의 프로세서 실행가능 프로그램 명령들을 실행한다. 예를 들면, 메모리 (3504) 는 프로세서 (3502) 에 의해 판독될 수도 있고, 명령들 (3536) 은 프로세서 (3502) 에 의해 도 25 의 방법 (2500) 을 수행하도록 실행가능한 동작 명령들일 수도 있다. 예를 들면, 명령들 (3536) 은 프로세서 (3502) 에 의해

카메라 (3524) 와 같은 제 1 이미지 센서로부터의 제 1 데이터 스트림을 수신하고, 카메라 (3524) 와 같은 제 2 이미지 센서로부터의 제 2 데이터 스트림을 수신하고, 카메라 제어기 (3518) 의 제어기 (3520) 를 이용하여 제 1 데이터 스트림과 제 2 데이터 스트림으로부터의 데이터를 결합하여 프레임을 생성하도록 실행가능한 명령들을 포함할 수도 있다. 예를 들면, 제 1 이미지 센서는 도 13 의 제 1 이미지 센서 (1302) 일 수도 있고, 제 2 이미지 센서는 도 13 의 제 2 이미지 센서 (1304) 일 수도 있다. 명령들 (3536) 은 프로세서 (3502) 에 의해 이미지 프로세서 (3506) 에서 프레임을 처리하여 처리된 프레임을 생성하도록 실행가능한 명령들을 추가로 포함할 수도 있다. 명령들 (3536) 은 프로세서 (3502) 에 의해 디스플레이 디바이스 (3510) 에서 디스플레이를 위해 처리된 프레임을 3D 데이터로서 출력하거나 처리된 프레임을 메모리 (3504) 에 이미지 데이터 (3538) 로서 저장되도록 실행가능한 명령들을 추가로 포함할 수도 있다.

[0176] 당업자는 또한 본 명세서에 개시된 실시형태들과 관련하여 설명되는 다양한 설명의 논리적인 블록들, 구성들, 모듈들, 회로들, 및 알고리즘 단계들이 전자 하드웨어, 프로세서에 의해 실행되는 컴퓨터 소프트웨어, 또는 양자의 조합들로서 구현될 수도 있음을 인식할 것이다. 다양하게 설명되는 컴포넌트들, 블록들, 모듈들, 회로들, 및 단계들이 일반적으로 그들의 기능성에 관련하여 전술되었다. 그러한 기능성이 프로세서에 의해 하드웨어로 구현되는지 또는 소프트웨어로 구현되는지의 여부는 전체 시스템에 부과된 특정 애플리케이션 및 설계 제약에 의존한다. 당업자는 각각의 특정 애플리케이션을 위해 다양한 방식들로 기술된 기능성을 구현할 수도 있지만, 그러한 구현 결정들은 본 발명의 예시적인 실시예들의 범위로부터 벗어나는 것으로 해석되지 않아야 한다.

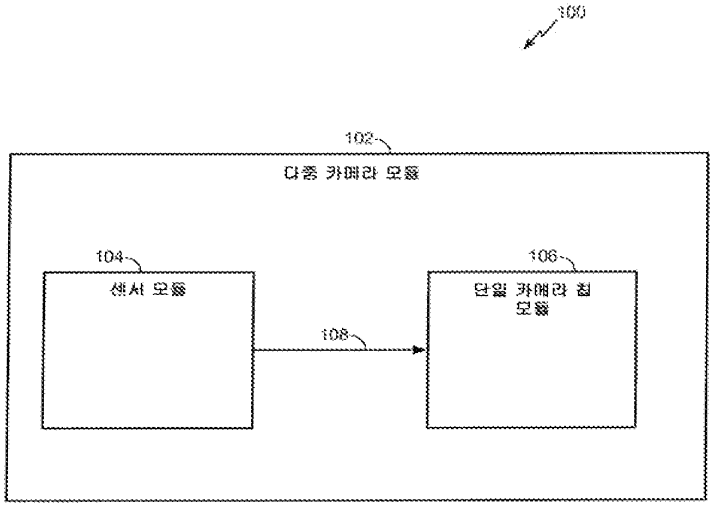
[0177] 도 22 내지 도 32 의 방법들은 컴퓨터 판독가능 명령들의 형태로 메모리에 저장될 수 있는 프로그램 코드를 실행함으로써 수행될 수도 있다. 그 경우, 디지털 신호 프로세서 (DSP), 이미지 신호 프로세서 (ISP) 또는 다른 프로세서와 같은 프로세서는 이미지 프로세싱 방법들 중 하나 이상을 실행하기 위해 메모리에 저장된 명령들을 실행할 수도 있다. 일부 경우에, 방법들은 이미지 프로세싱을 가속화하기 위해 다양한 하드웨어 컴포넌트들을 적용하는 DSP 또는 ISP 에 의해 실행될 수도 있다. 다른 경우에, 본 명세서에서 설명된 유닛들은 마이크로프로세서, 하나 이상의 애플리케이션용 집적 회로들 (ASICs), 하나 이상의 현장 프로그래머블 게이트 어레이들 (FPGAs), 또는 이들의 임의의 조합에 의해 수행될 수도 있다.

[0178] 본 명세서에 개시된 실시형태들과 관련하여 설명되는 방법 또는 알고리즘의 단계들은 하드웨어에서 직접, 프로세서에 의해 실행되는 소프트웨어 모듈에서, 또는 이들의 조합에서 구현될 수도 있다. 소프트웨어 모듈은 랜덤 액세스 메모리 (RAM), 플래시 메모리, 판독 전용 메모리 (ROM), 프로그래머블 판독 전용 메모리 (PROM), 소거가능한 프로그래머블 판독 전용 메모리 (EPROM), 전기적으로 소거가능한 프로그래머블 판독 전용 메모리 (EEPROM), 레지스터들, 하드디스크, 소거가능한 디스크, CD-ROM 또는 당업계에 공지된 임의의 다른 형태의 비-일시적인 컴퓨터 판독가능한 저장 매체에 상주할 수도 있다. 예시적인 저장 매체는 프로세서에 커플링되며, 따라서 프로세서는 저장 매체로부터 정보를 판독하고, 저장 매체에 정보를 기록할 수 있다. 대안적으로, 저장 매체는 프로세서에 필수일 수도 있다. 프로세서 및 저장 매체는 애플리케이션용 집적 회로 (ASIC) 내에 상주할 수도 있다. ASIC 은 컴퓨팅 디바이스 또는 사용자 단말기 내에 상주할 수도 있다. 대안적으로, 프로세서 및 저장 매체는 컴퓨팅 디바이스 또는 사용자 단말기 내에 별개의 컴포넌트들로서 상주할 수도 있다.

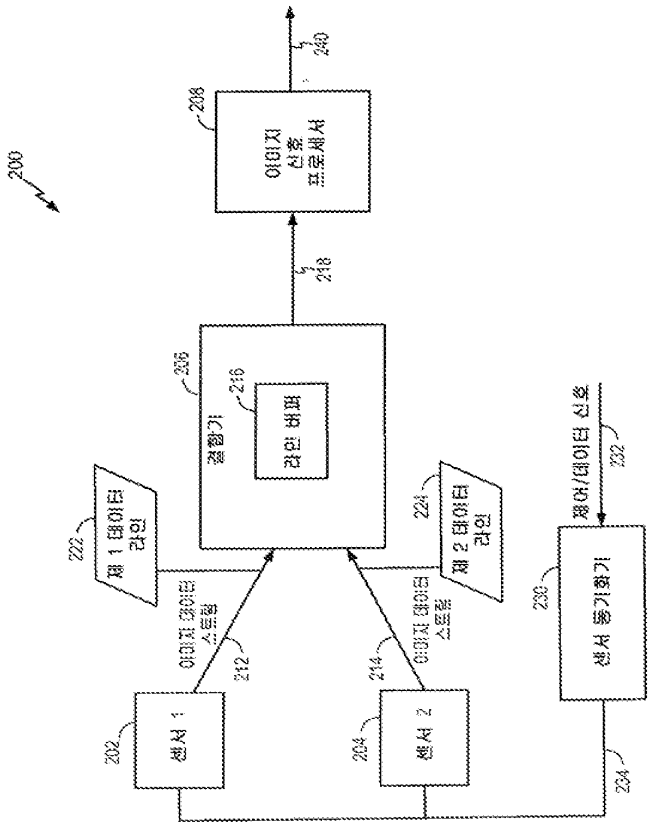
[0179] 개시된 실시예들의 전술된 설명은 당업자가 본 발명을 구현하고 이용하기에 용이하도록 하기 위하여 제공되었다. 이들 실시예에 대한 여러 가지 변형은 당업자에게 자명하며, 여기서 정의된 원칙들은 본 개시물의 범위를 벗어나지 않고 다른 실시형태들에 적용될 수도 있다. 따라서, 본 개시물은 여기에 도시된 실시형태들에 한정되는 것이 아니며, 다음 청구범위들에 의해 정의된 것과 같은 원칙들 및 신규한 특징들과 일치하는 가장 넓은 범위에 따른다.

도면

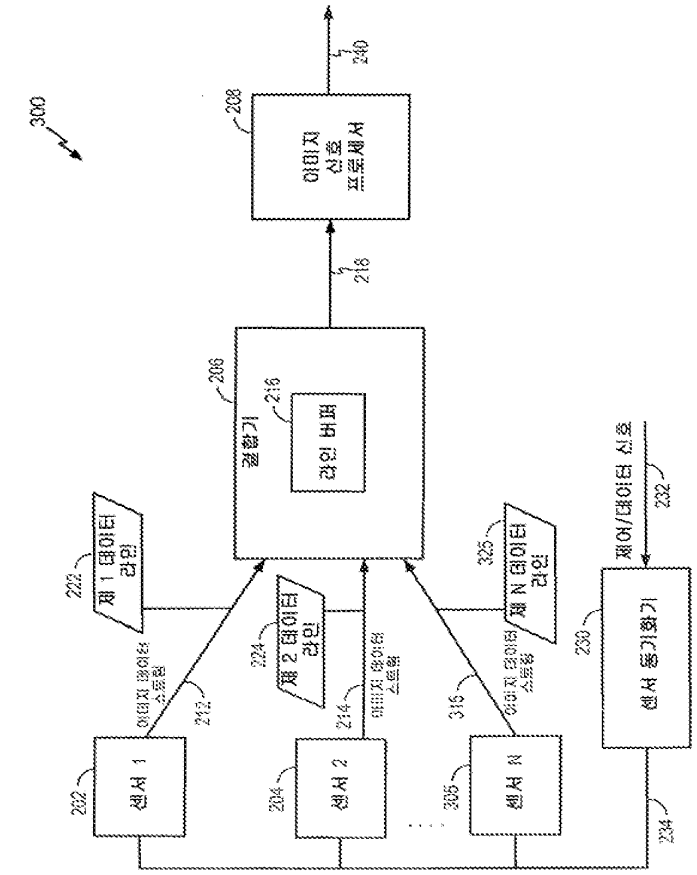
도면1



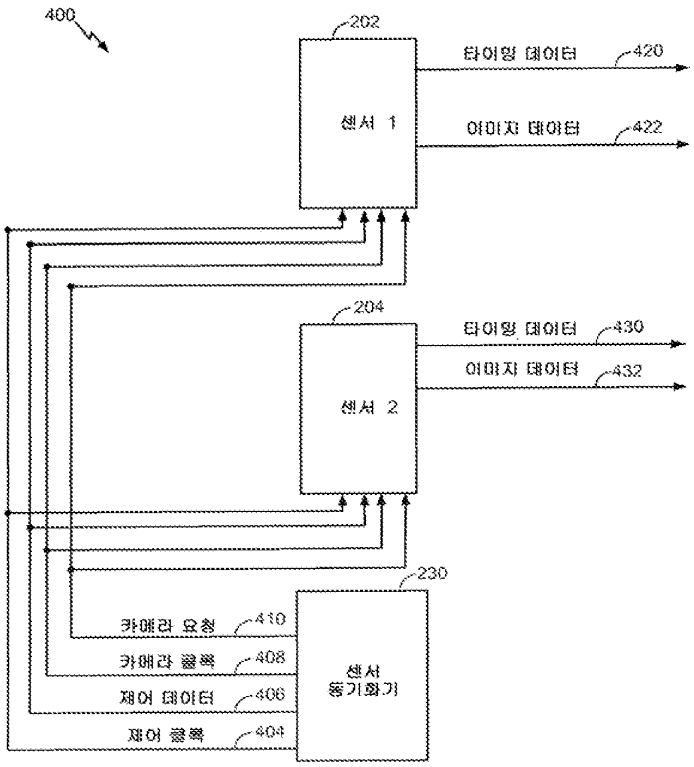
도면3


200
202
센서 1
204
센서 2
206
결합기
216
라인 버퍼
208
이미지 신호 프로세서
210
이미지 데이터 스트림
212
이미지 데이터 스트림
214
218
220
제 1 데이터 라인
222
제 2 데이터 라인
224
230
센서 동기화기
232
제어/데이터 신호
234
240

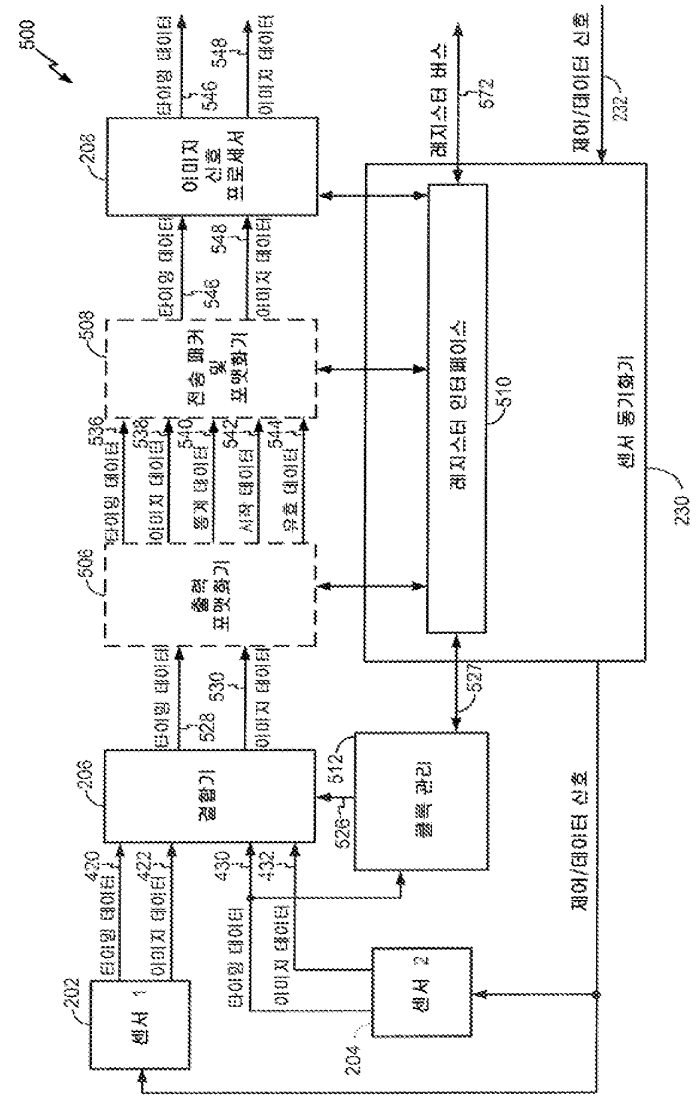
도면3


300
240
208
이미지 신호 프로세서
218
206
결합기
216
라인 버퍼
222
제 1 데이터 라인
224
제 2 데이터 라인
325
제 N 데이터 라인
212
214
316
이미지 데이터 스트림
이미지 데이터 스트림
이미지 데이터 스트림
202
센서 1
204
센서 2
305
센서 N
230
센서 동기화기
232
제어/데이터 신호
234

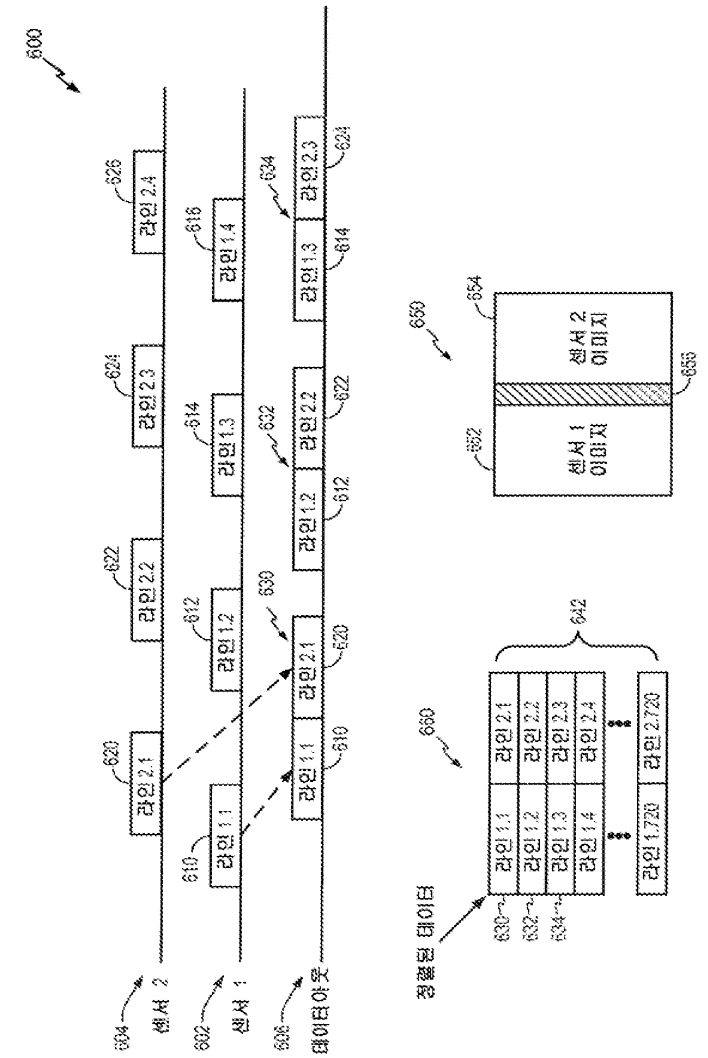
도면4


400
202
센서 1
타이밍 데이터
420
이미지 데이터
422
204
센서 2
타이밍 데이터
430
이미지 데이터
432
230
센서 동기화기
카메라 요청
410
카메라 클록
408
제어 데이터
406
제어 클록
404

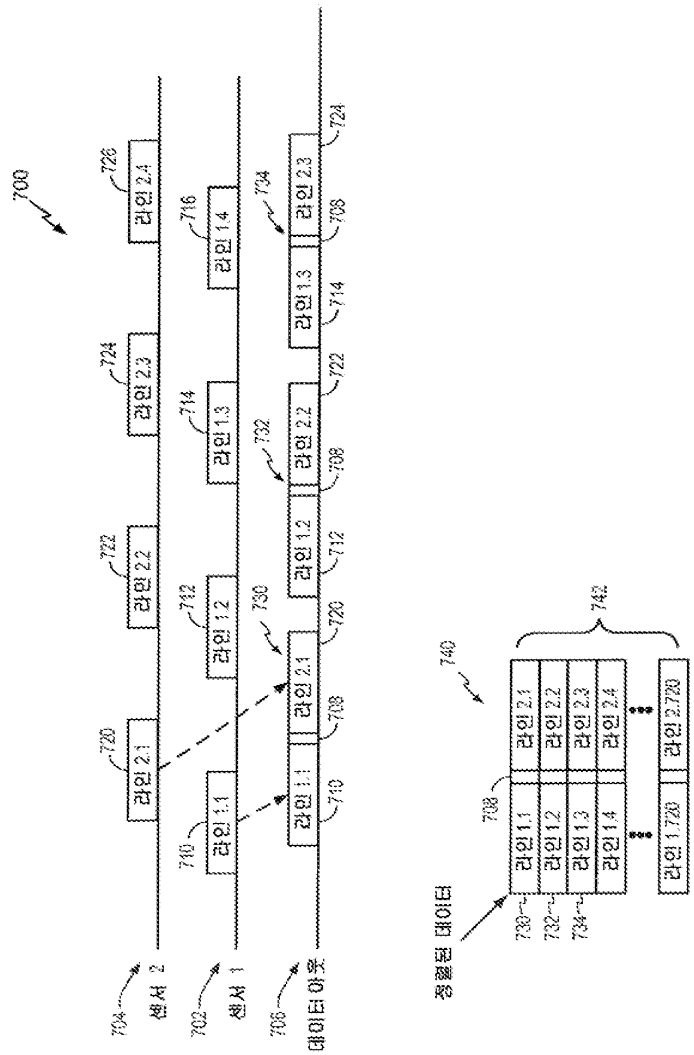
도면5


500
202
센서 1
204
센서 2
206
결합기
208
이미지 신호 프로세서
230
센서 동기화기
232
제어/데이터 신호
508
전송 패커 및 포맷화기
510
레지스터 인터페이스
512
블록 관리
526
527
528
530
536
538
540
542
544
546
548
572
레지스터 버스
타이밍 데이터
이미지 데이터
통계 데이터
시작 데이터
유효 데이터

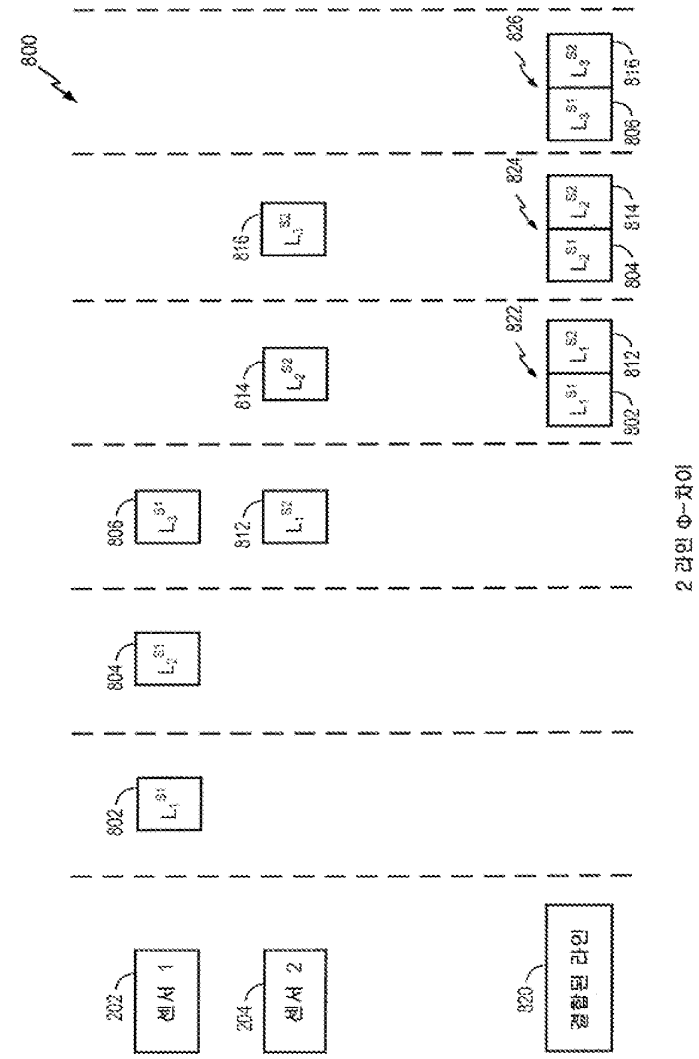
도면6


600
604
센서 2
602
센서 1
606
데이터 아웃
610
라인 1.1
612
라인 1.2
614
라인 1.3
616
라인 1.4
620
라인 2.1
622
라인 2.2
624
라인 2.3
626
라인 2.4
630
632
634
640
642
660
라인 1.720
라인 2.720
652
센서 1 이미지
654
센서 2 이미지
656
정렬된 데이터

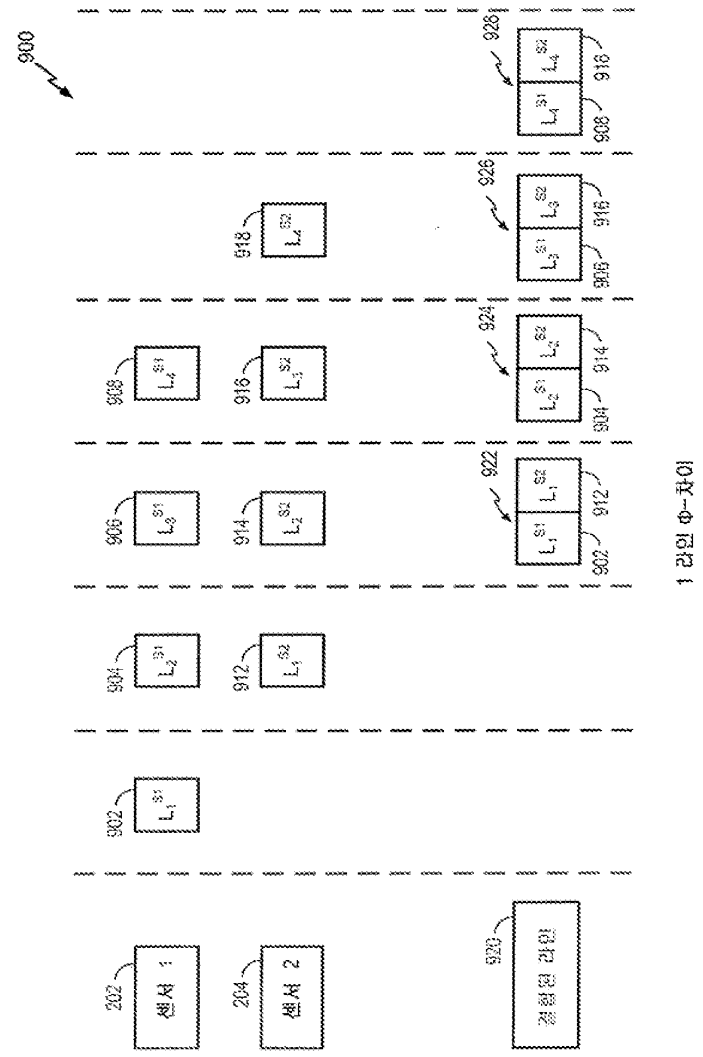
도면7


700
704
센서 2
702
센서 1
706
데이터 아웃
710
712
714
716
720
722
724
726
730
732
734
708
라인 1.1
라인 1.2
라인 1.3
라인 1.4
라인 2.1
라인 2.2
라인 2.3
라인 2.4
740
742
종료된 데이터
738
라인 1.720
라인 2.720

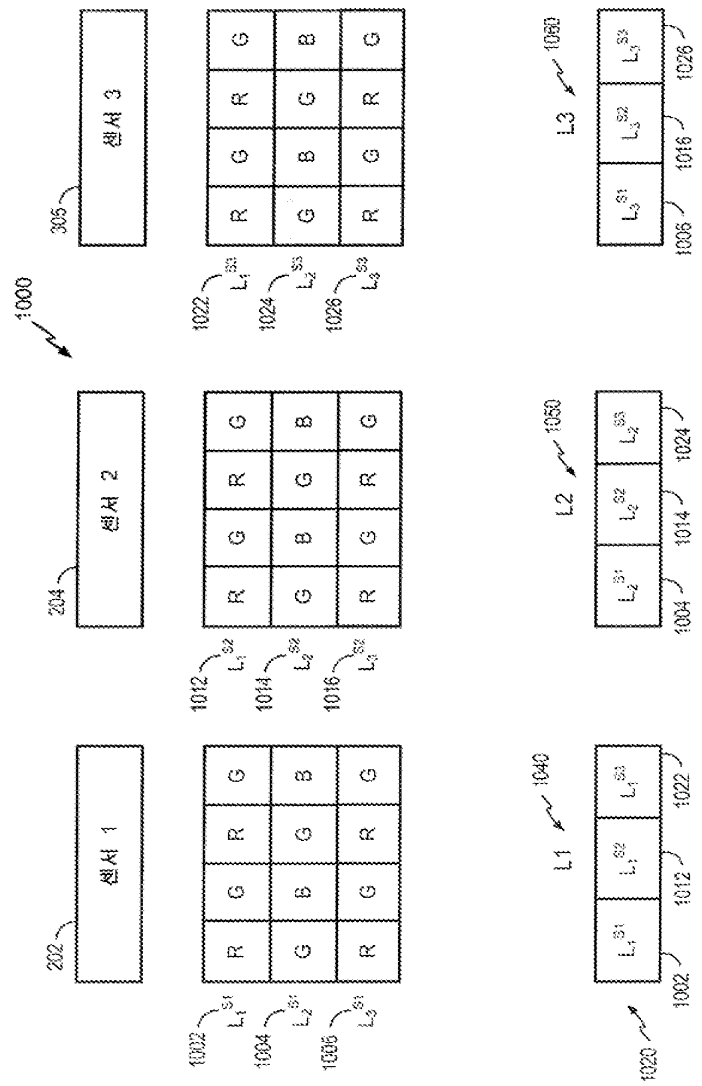
도면8


800
826
816
806
824
814
804
822
812
902
614
816
812
806
804
802
202
204
920
센서 1
센서 2
결합된 라인
2 라인 Φ-자이

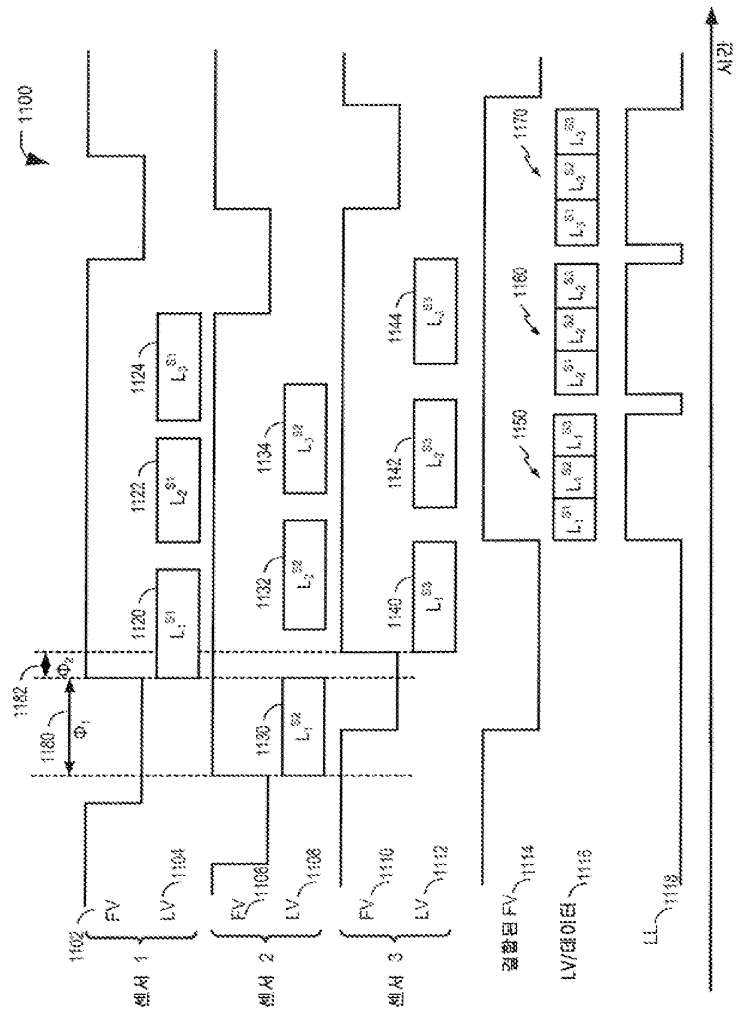
도면9


900
202
센서 1
204
센서 2
920
공통의 라인
902
904
906
908
912
914
916
918
922
924
926
928
1 라인 Φ-차이

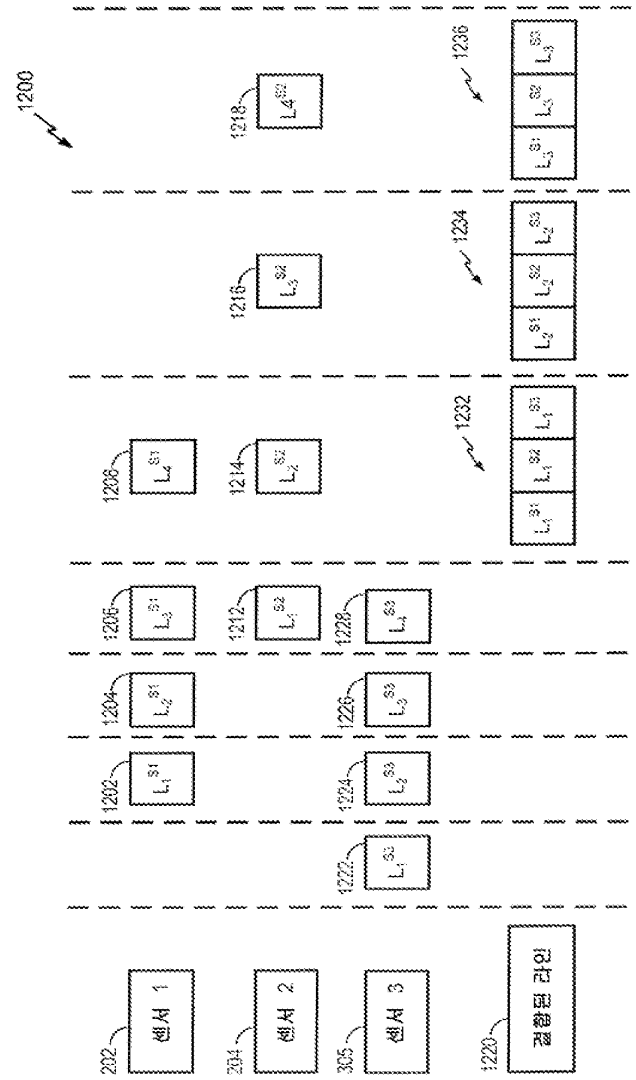
도면10


1000
202
센서 1
204
센서 2
305
센서 3
R G R G
G B G B
R G R G
1002
1004
1006
1012
1014
1016
1022
1024
1026
L1
L2
L3
1040
1050
1060
1020

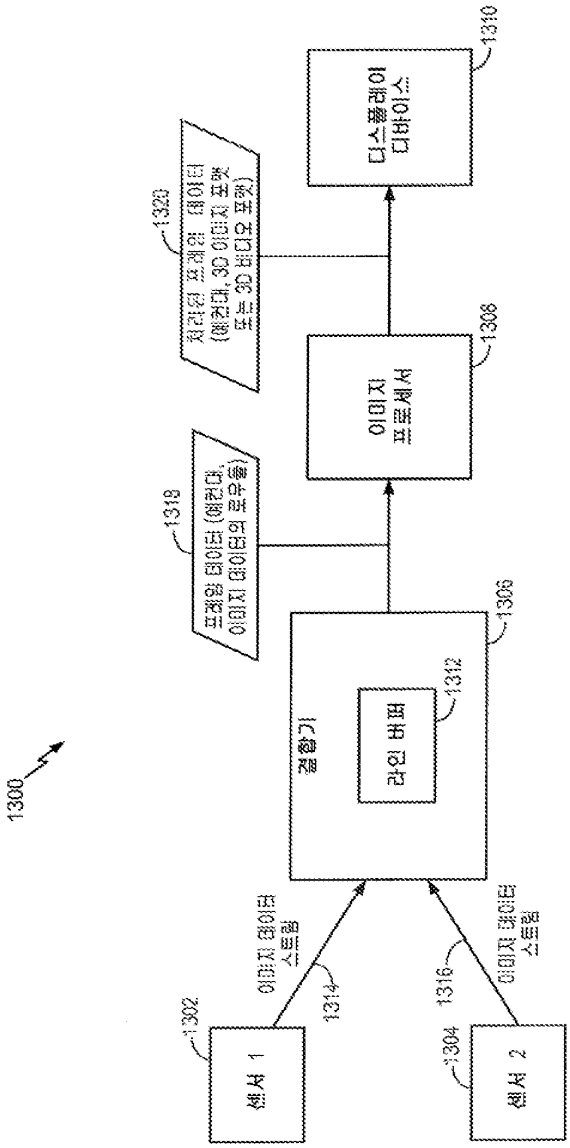
도면11


1100
1102
FV
LV
1104
셀서 1
1106
셀서 2
1108
셀서 3
1110
1112
결합된 FV
1114
LV/데이터
1116
LL
1118
1120
1122
1124
1130
1132
1134
1140
1142
1144
1150
1160
1170
1180
1182
시간

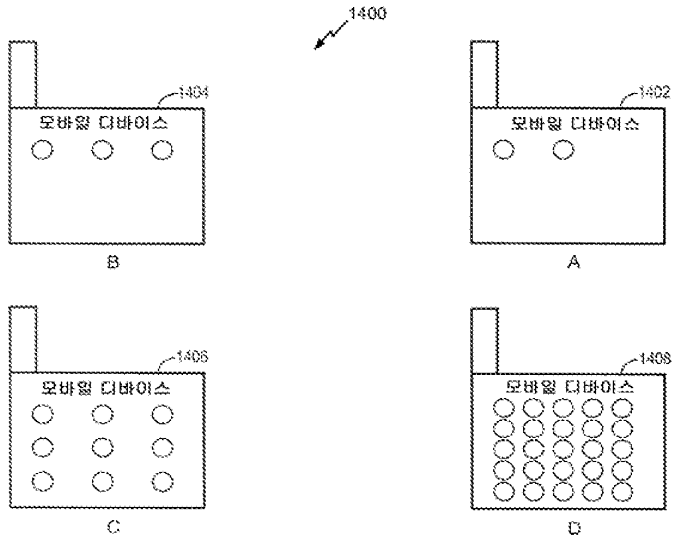
도면12


1200
센서 1
센서 2
센서 3
결합된 라인
202
204
205
1220
1202
1204
1206
1222
1224
1226
1228
1232
1234
1236
1212
1214
1216
1218
3 라인 Φ-차이

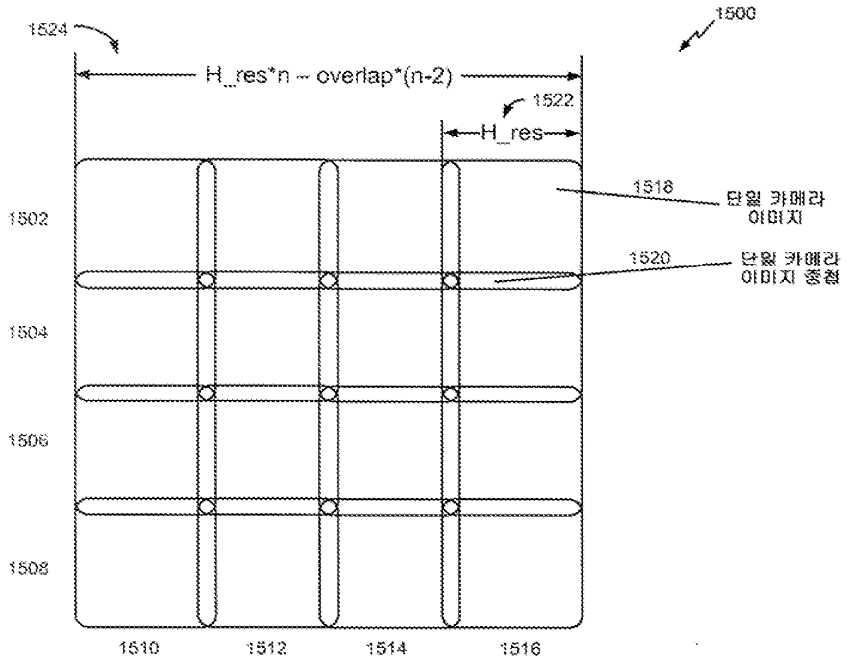
도면13


1300
센서 1
1302
센서 2
1304
이미지 데이터 스트림
1314
이미지 데이터 스트림
1316
결합기
1306
라인 버퍼
1312
프레임 데이터 (예컨대, 이미지 데이터의 모음들)
1318
이미지 프로세서
1308
처리된 프레임 데이터 (예컨대, 3D 이미지 포맷 또는 3D 비디오 포맷)
1320
디스플레이 디바이스
1310

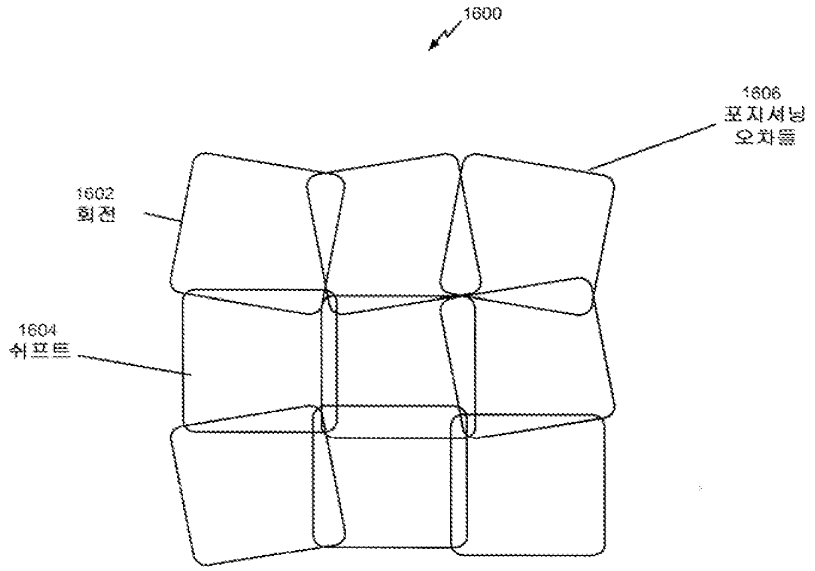
도면14


1400
1404
모바일 디바이스
B
1402
모바일 디바이스
A
1406
모바일 디바이스
C
1408
모바일 디바이스
D

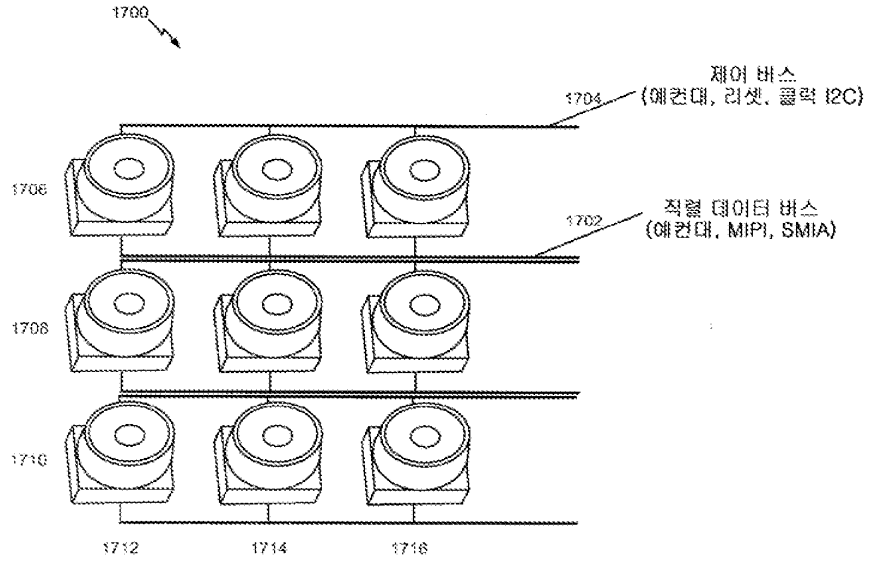
도면15


1500
1524
H_res*n ~ overlap*(n-2)
1522
H_res
1518
단일 카메라 이미지
1520
단일 카메라 이미지 중첩
1502
1504
1506
1508
1510
1512
1514
1516

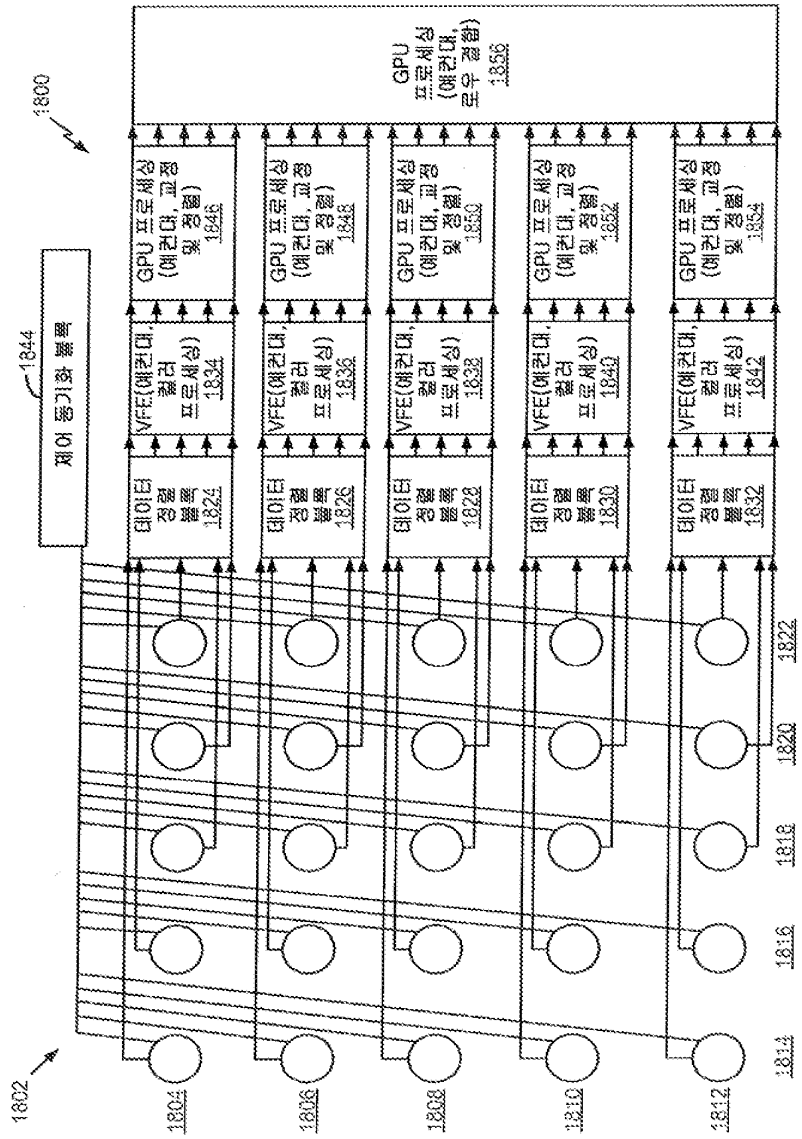
도면16


1600
1606
포지셔닝
오차들
1602
회전
1604
쉬프트

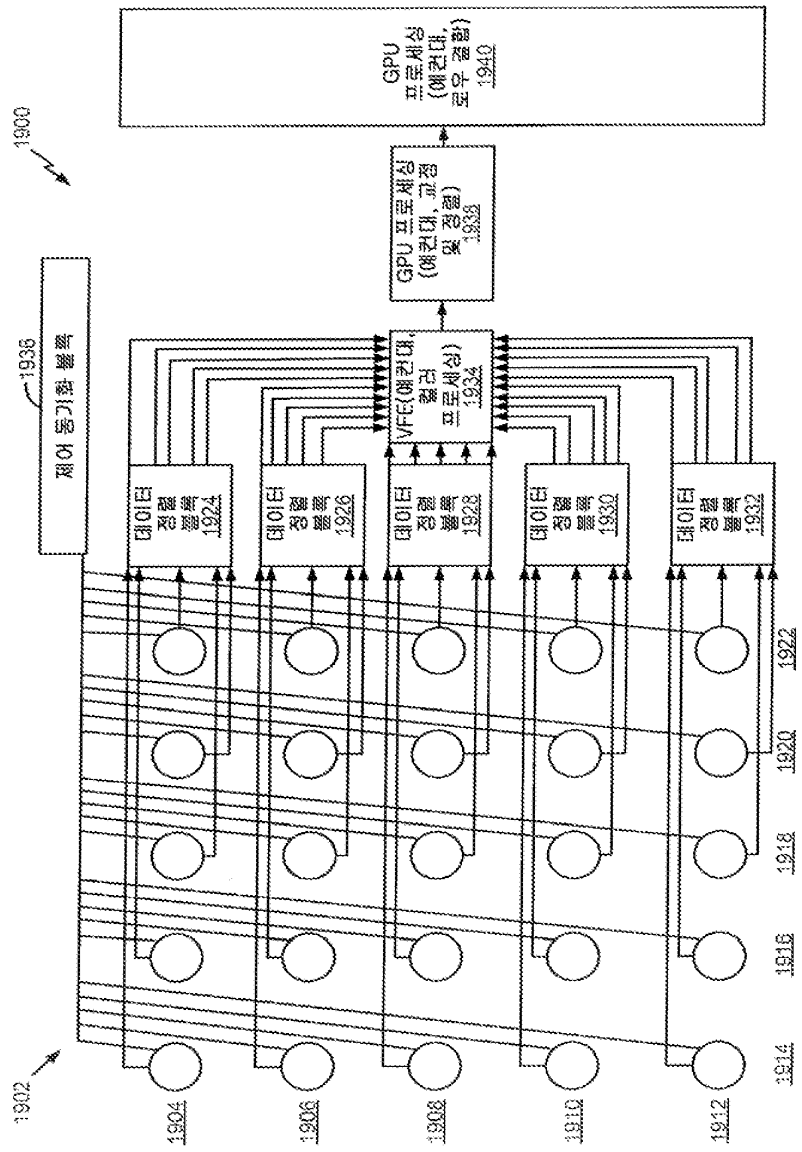
도면17


1700
제어 버스
(예컨대, 리셋, 클럭 I2C)
1704
1706
직렬 데이터 버스
(예컨대, MIPI, SMIA)
1702
1708
1710
1712
1714
1716

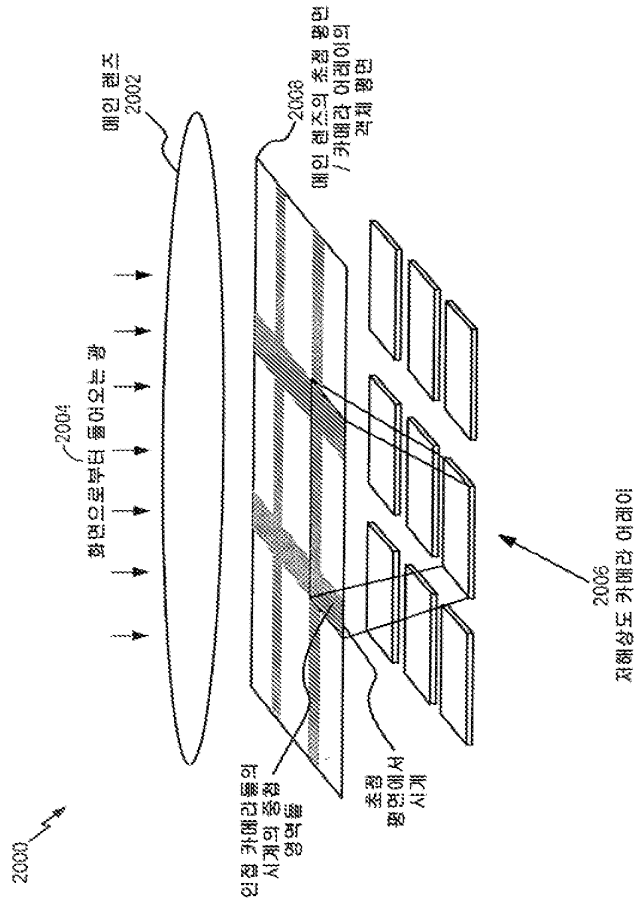
도면18


1800
GPU 프로세싱 (예컨대, 로우 결합) 1856
GPU 프로세싱 (예컨대, 프래그먼트 및 정점) 1846
GPU 프로세싱 (예컨대, 프래그먼트 및 정점) 1848
GPU 프로세싱 (예컨대, 프래그먼트 및 정점) 1850
GPU 프로세싱 (예컨대, 프래그먼트 및 정점) 1852
GPU 프로세싱 (예컨대, 프래그먼트 및 정점) 1854
VFE(예컨대, 컬러 프로세싱) 1834
VFE(예컨대, 컬러 프로세싱) 1836
VFE(예컨대, 컬러 프로세싱) 1838
VFE(예컨대, 컬러 프로세싱) 1840
VFE(예컨대, 컬러 프로세싱) 1842
데이터 정렬 블록 1824
데이터 정렬 블록 1826
데이터 정렬 블록 1822
데이터 정렬 블록 1830
데이터 정렬 블록 1832
제어 동기화 블록 1844
1802
1804
1806
1808
1810
1812
1814
1816
1818
1820
1822

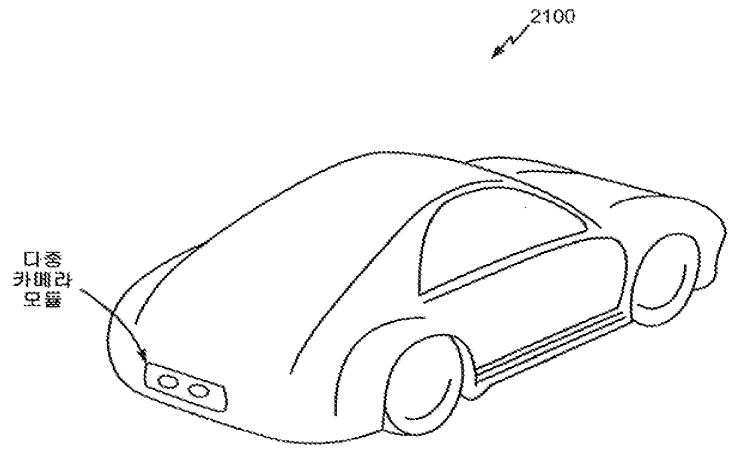
도면19


GPU
프로세싱
(예컨대,
로우 결합)
1940
1900
GPU 프로세싱
(예컨대, 교정
및 정합)
1938
1936
제어 동기화 블록
VFE(예컨대,
컬러
프로세싱)
1934
데이터
정렬 블록
1924
데이터
정렬 블록
1926
데이터
정렬 블록
1928
데이터
정렬 블록
1930
데이터
정렬 블록
1932
1922
1920
1918
1916
1914
1902
1904
1906
1908
1910
1912

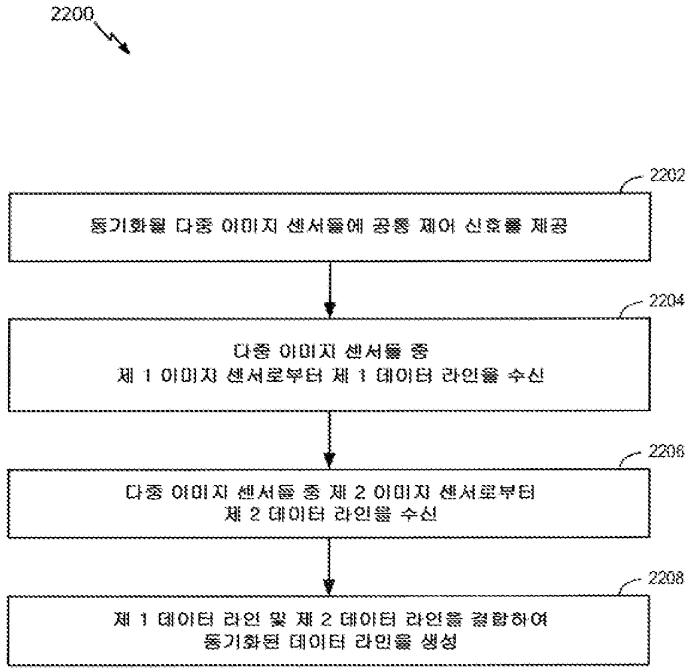
도면20


2000
메인 렌즈
2002
2004
렌즈로부터 들어오는 광
2006
자해상도 카메라 어레이
2008
메인 렌즈의 초점 평면
/ 카메라 어레이의
객체 평면
초점 평면에서
사계
인접 카메라들의
사계의 중첩
영역들

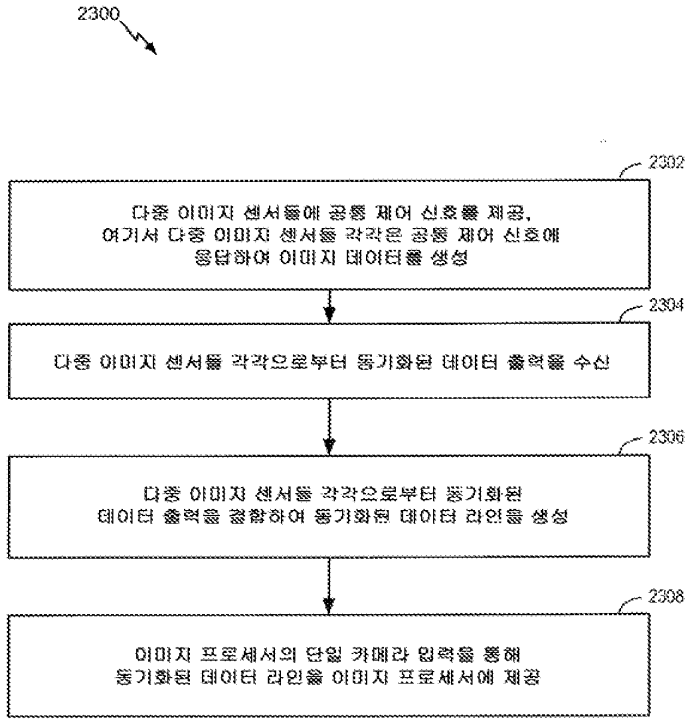
도면21


2100
다중
카메라
모듈

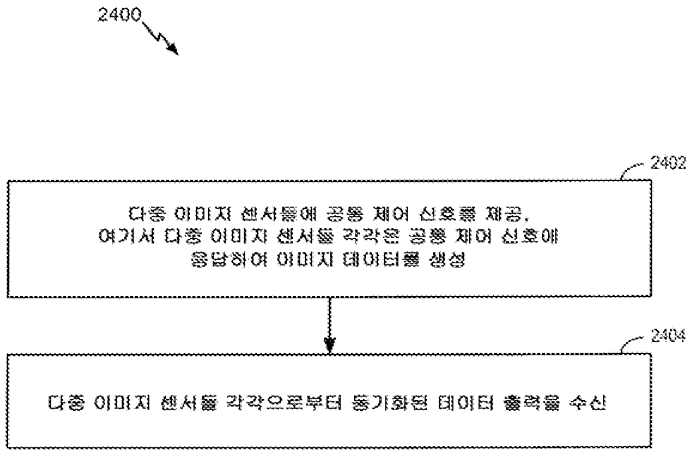
도면22


2200
2202
동기화될 다중 이미지 센서들에 공통 제어 신호를 제공
2204
다중 이미지 센서들 중
제 1 이미지 센서로부터 제 1 데이터 라인을 수신
2206
다중 이미지 센서들 중 제 2 이미지 센서로부터
제 2 데이터 라인을 수신
2208
제 1 데이터 라인 및 제 2 데이터 라인을 결합하여
동기화된 데이터 라인을 생성

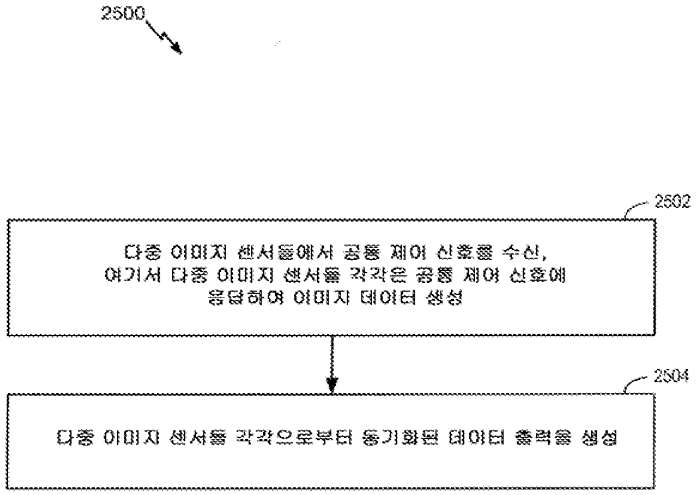
도면23


2300
2302
다중 이미지 센서들에 공통 제어 신호를 제공,
여기서 다중 이미지 센서들 각각은 공통 제어 신호에
응답하여 이미지 데이터를 생성
2304
다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신
2306
다중 이미지 센서들 각각으로부터 동기화된
데이터 출력을 결합하여 동기화된 데이터 라인을 생성
2308
이미지 프로세서의 단일 카메라 입력을 통해
동기화된 데이터 라인을 이미지 프로세서에 제공

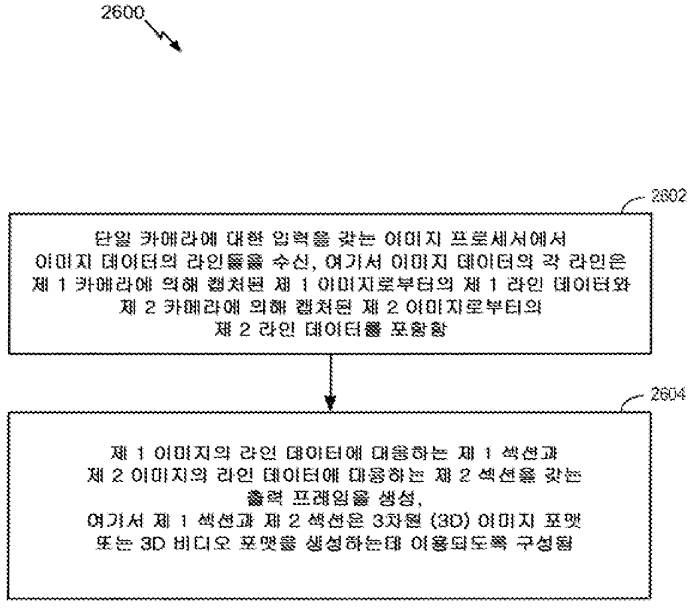
도면24


2400
2402
다중 이미지 센서들에 공통 제어 신호를 제공,
여기서 다중 이미지 센서들 각각은 공통 제어 신호에
응답하여 이미지 데이터를 생성
2404
다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 수신

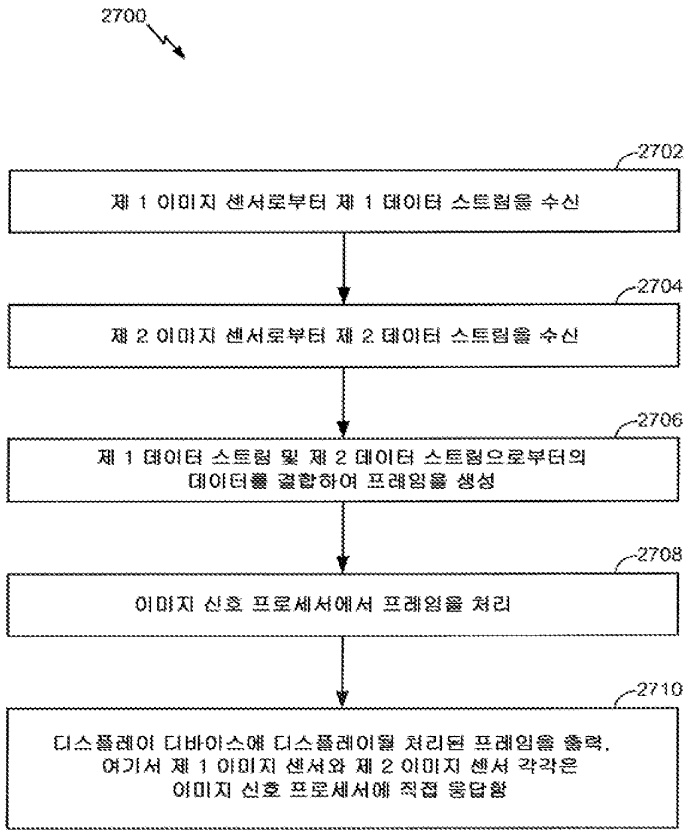
도면25


2500
2502
다중 이미지 센서들에서 공통 제어 신호를 수신,
여기서 다중 이미지 센서들 각각은 공통 제어 신호에
응답하여 이미지 데이터 생성
2504
다중 이미지 센서들 각각으로부터 동기화된 데이터 출력을 생성

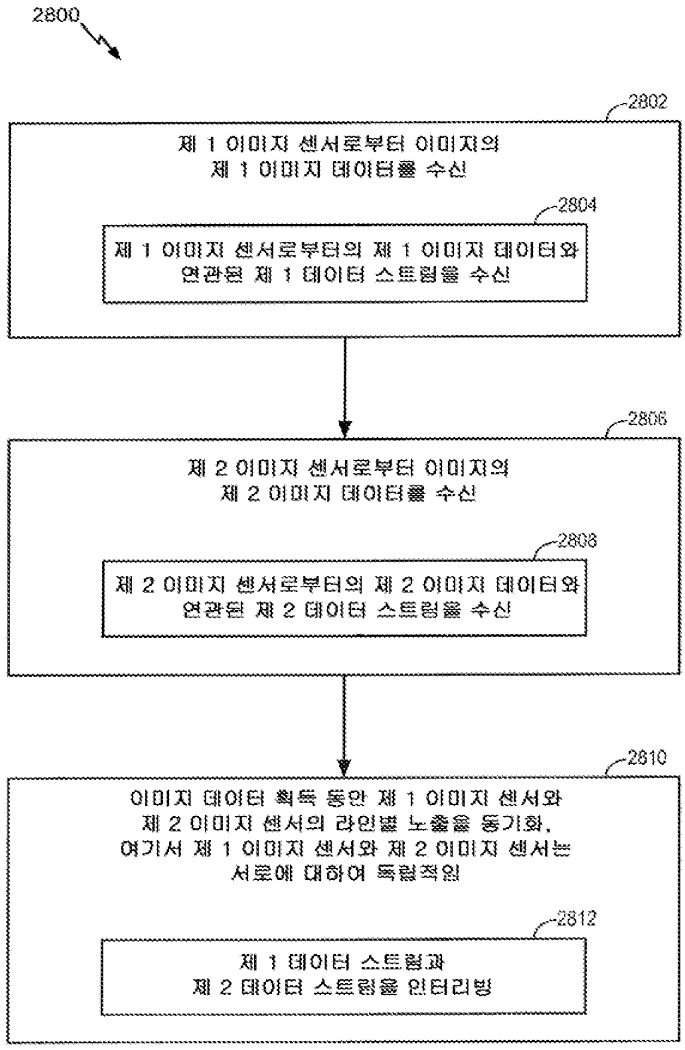
도면26


2600
2602
단일 카메라에 대한 입력을 갖는 이미지 프로세서에서
이미지 데이터의 라인들을 수신, 여기서 이미지 데이터의 각 라인은
제 1 카메라에 의해 캡처된 제 1 이미지로부터의 제 1 라인 데이터와
제 2 카메라에 의해 캡처된 제 2 이미지로부터의
제 2 라인 데이터를 포함함
2604
제 1 이미지의 라인 데이터에 대응하는 제 1 섹션과
제 2 이미지의 라인 데이터에 대응하는 제 2 섹션을 갖는
출력 프레임을 생성,
여기서 제 1 섹션과 제 2 섹션은 3차원 (3D) 이미지 포맷
또는 3D 비디오 포맷을 생성하는데 이용되도록 구성됨

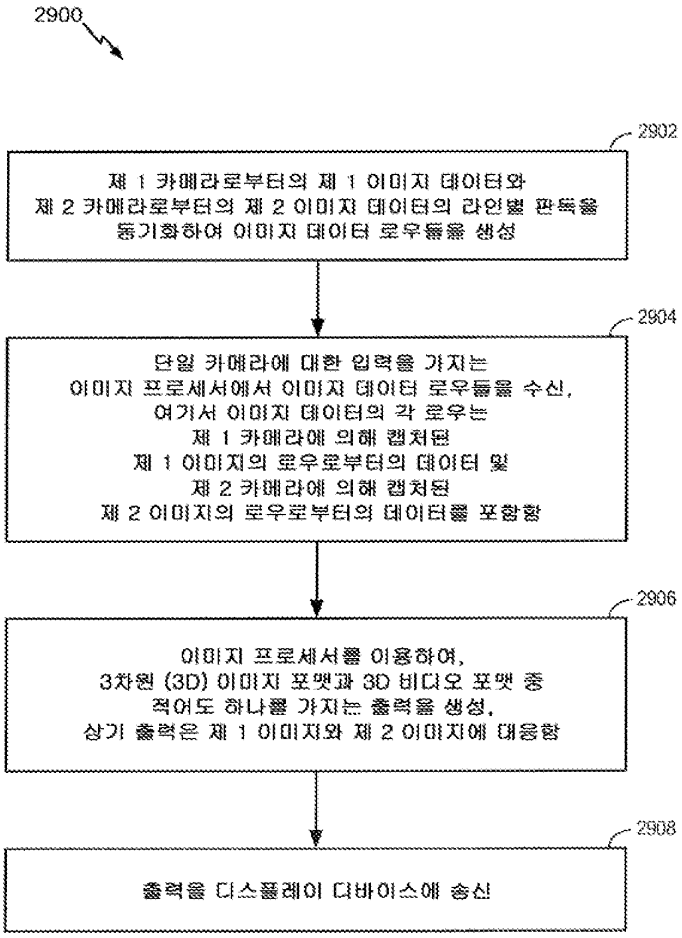
도면37


2700
2702
제 1 이미지 센서로부터 제 1 데이터 스트림을 수신
2704
제 2 이미지 센서로부터 제 2 데이터 스트림을 수신
2706
제 1 데이터 스트림 및 제 2 데이터 스트림으로부터의 데이터를 결합하여 프레임을 생성
2708
이미지 신호 프로세서에서 프레임을 처리
2710
디스플레이 디바이스에 디스플레이될 처리된 프레임을 출력, 여기서 제 1 이미지 센서와 제 2 이미지 센서 각각은 이미지 신호 프로세서에 직접 응답함

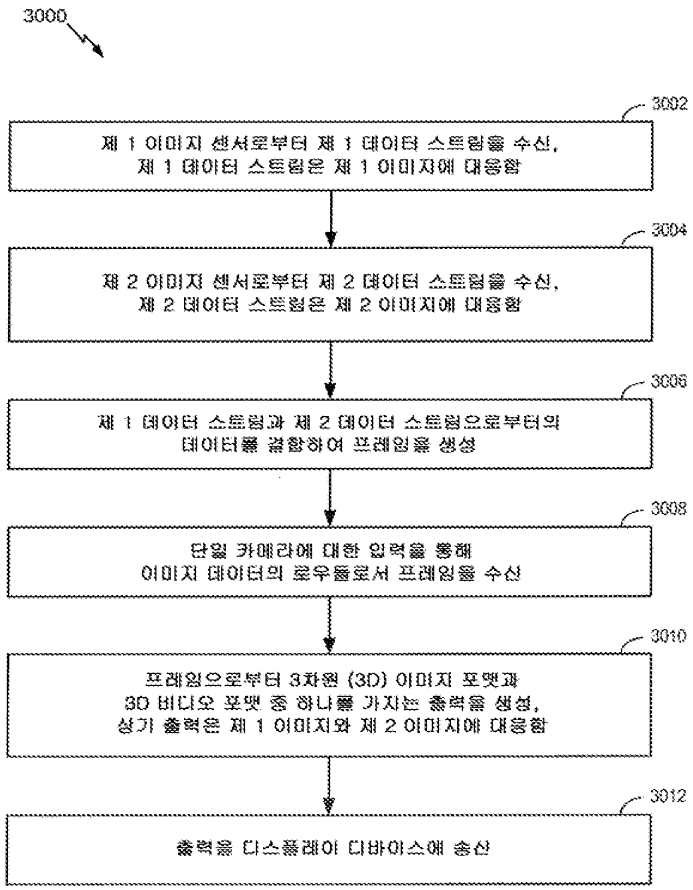
도면28


2800
2802
제 1 이미지 센서로부터 이미지의
제 1 이미지 데이터를 수신
2804
제 1 이미지 센서로부터의 제 1 이미지 데이터와
연관된 제 1 데이터 스트림을 수신
2806
제 2 이미지 센서로부터 이미지의
제 2 이미지 데이터를 수신
2808
제 2 이미지 센서로부터의 제 2 이미지 데이터와
연관된 제 2 데이터 스트림을 수신
2810
이미지 데이터 획득 동안 제 1 이미지 센서와
제 2 이미지 센서의 라인별 노출을 동기화,
여기서 제 1 이미지 센서와 제 2 이미지 센서는
서로에 대하여 독립적임
2812
제 1 데이터 스트림과
제 2 데이터 스트림을 인터리빙

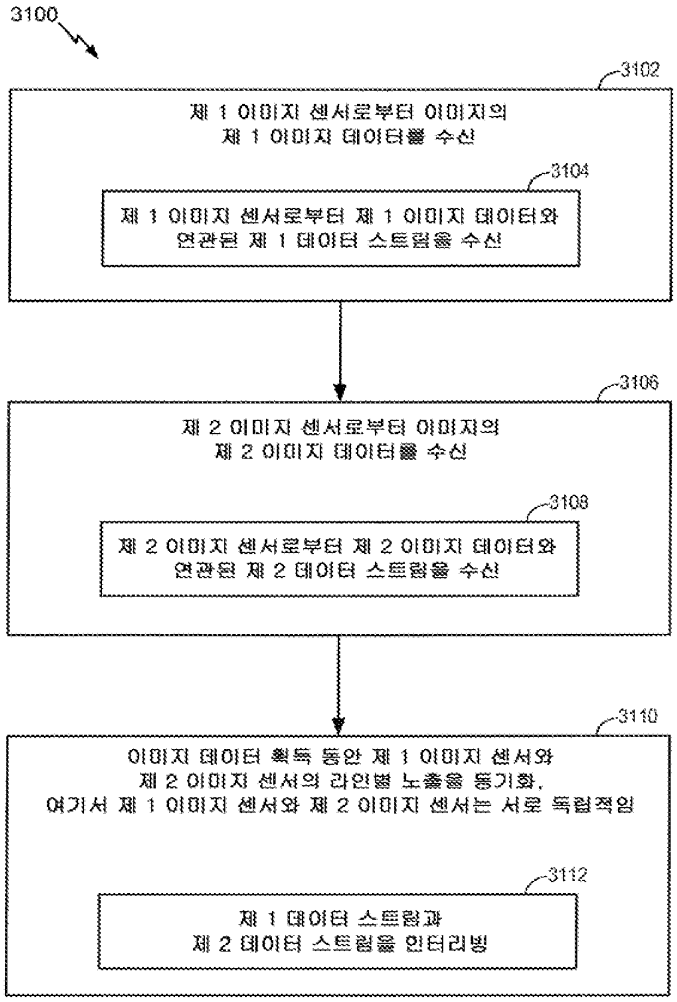
도면39


2900
2902
제 1 카메라로부터의 제 1 이미지 데이터와
제 2 카메라로부터의 제 2 이미지 데이터의 라인별 판독을
동기화하여 이미지 데이터 로우들을 생성
2904
단일 카메라에 대한 입력을 가지는
이미지 프로세서에서 이미지 데이터 로우들을 수신,
여기서 이미지 데이터의 각 로우는
제 1 카메라에 의해 캡처된
제 1 이미지의 로우로부터의 데이터 및
제 2 카메라에 의해 캡처된
제 2 이미지의 로우로부터의 데이터를 포함함
2906
이미지 프로세서를 이용하여,
3차원 (3D) 이미지 포맷과 3D 비디오 포맷 중
적어도 하나를 가지는 출력을 생성,
상기 출력은 제 1 이미지와 제 2 이미지에 대응함
2908
출력을 디스플레이 디바이스에 송신

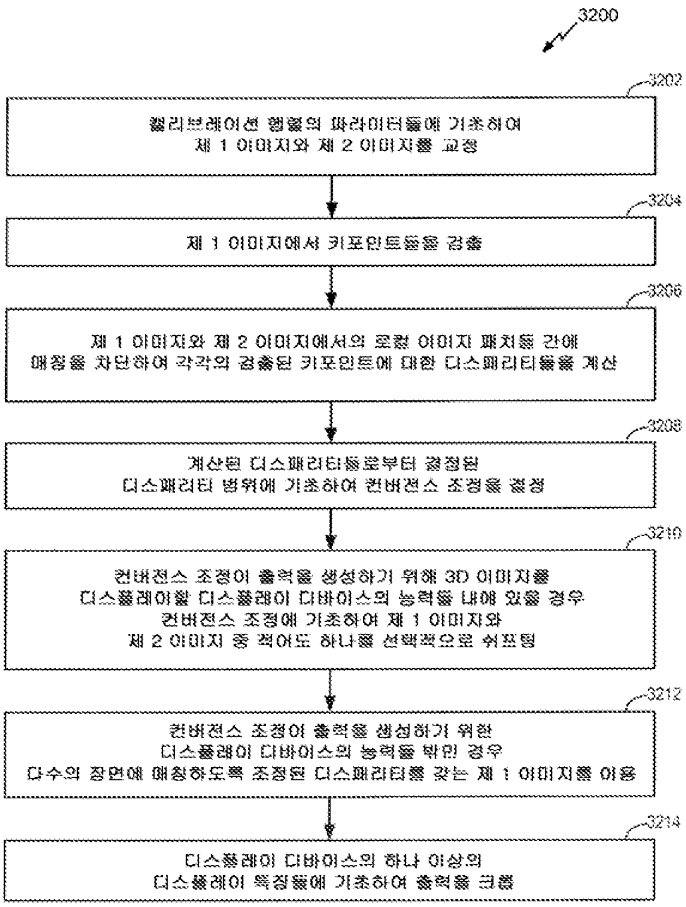
도면30


3000
3002
제 1 이미지 센서로부터 제 1 데이터 스트림을 수신,
제 1 데이터 스트림은 제 1 이미지에 대응함
3004
제 2 이미지 센서로부터 제 2 데이터 스트림을 수신,
제 2 데이터 스트림은 제 2 이미지에 대응함
3006
제 1 데이터 스트림과 제 2 데이터 스트림으로부터의
데이터를 결합하여 프레임을 생성
3008
단일 카메라에 대한 입력을 통해
이미지 데이터의 로우들로서 프레임을 수신
3010
프레임으로부터 3차원 (3D) 이미지 포맷과
3D 비디오 포맷 중 하나를 가지는 출력을 생성,
상기 출력은 제 1 이미지와 제 2 이미지에 대응함
3012
출력을 디스플레이 디바이스에 송신

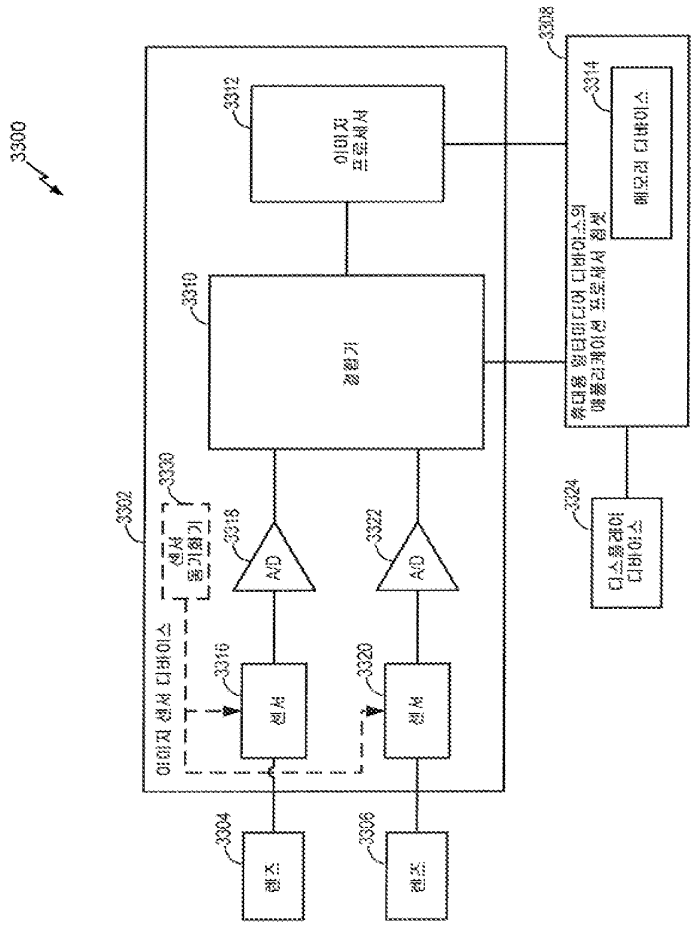
도면31


3100
3102
제 1 이미지 센서로부터 이미지의
제 1 이미지 데이터를 수신
3104
제 1 이미지 센서로부터 제 1 이미지 데이터와
연관된 제 1 데이터 스트림을 수신
3106
제 2 이미지 센서로부터 이미지의
제 2 이미지 데이터를 수신
3108
제 2 이미지 센서로부터 제 2 이미지 데이터와
연관된 제 2 데이터 스트림을 수신
3110
이미지 데이터 획득 동안 제 1 이미지 센서와
제 2 이미지 센서의 라인별 노출을 동기화,
여기서 제 1 이미지 센서와 제 2 이미지 센서는 서로 독립적임
3112
제 1 데이터 스트림과
제 2 데이터 스트림을 인터리빙

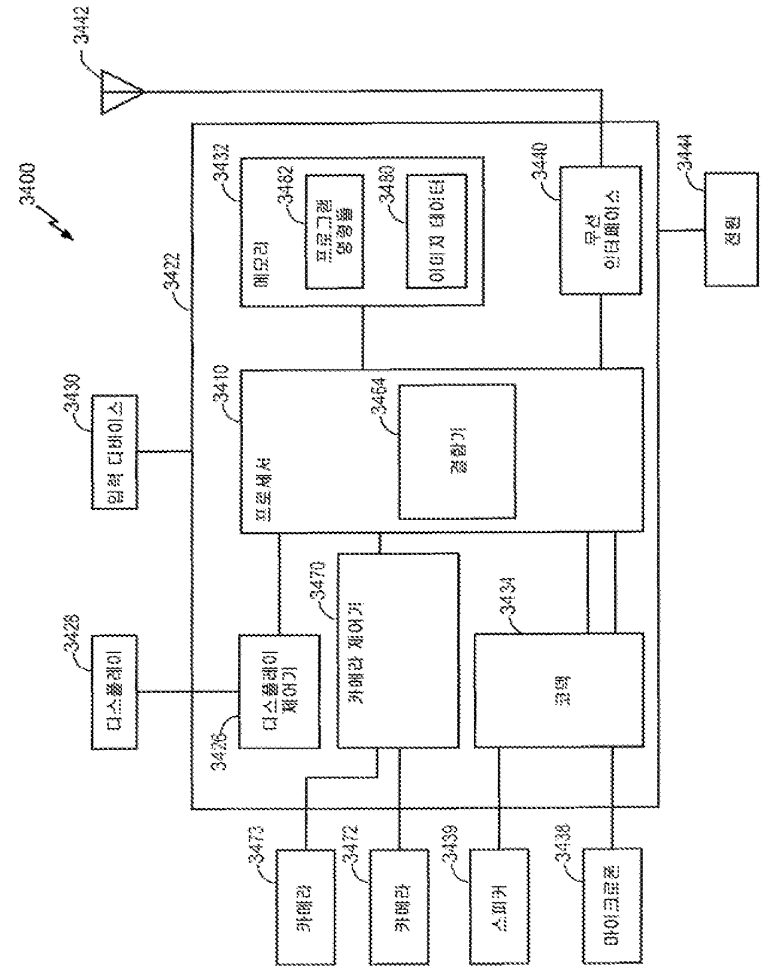
도면32


3200
3202
렌더브레이션 행렬의 파라미터들에 기초하여
제 1 이미지와 제 2 이미지를 교정
3204
제 1 이미지에서 키포인트들을 검출
3206
제 1 이미지와 제 2 이미지에서의 로컬 이미지 패치들 간에
매칭을 차단하여 각각의 검출된 키포인트에 대한 디스패리티들을 계산
3208
계산된 디스패리티들로부터 결정된
디스패리티 범위에 기초하여 컨버전스 조정을 결정
3210
컨버전스 조정이 출력을 생성하기 위해 3D 이미지를
디스플레이할 디스플레이 디바이스의 능력을 내에 있을 경우
컨버전스 조정에 기초하여 제 1 이미지와
제 2 이미지 중 적어도 하나를 선택적으로 쉬프팅
3212
컨버전스 조정이 출력을 생성하기 위한
디스플레이 디바이스의 능력을 밖인 경우
다수의 장면에 매칭하도록 조정된 디스패리티를 갖는 제 1 이미지를 이용
3214
디스플레이 디바이스의 하나 이상의
디스플레이 특징들에 기초하여 출력을 크롭

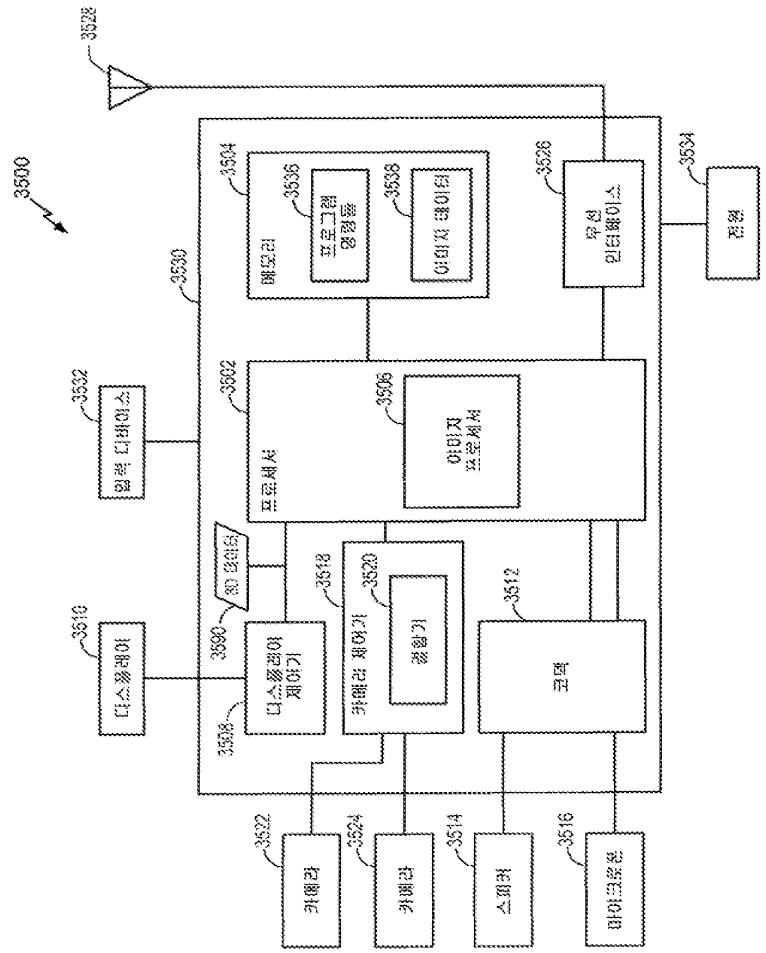
도면33


3300
3302
이미지 센서 디바이스
센서
동기화기
3330
3308
3312
이미지 프로세서
3314
메모리 디바이스
3310
동기기
3318
A/D
3322
A/D
3316
센서
3320
센서
3304
렌즈
3306
렌즈
3324
디스플레이 디바이스

도면34


3442
3400
3432
3482
프로그램 명령들
3480
이미지 데이터
메모리
3440
무선 인터페이스
3444
전원
3422
3430
입력 디바이스
3410
3464
프로세서
3428
디스플레이
3470
디스플레이 제어기
카메라 제어기
3434
3426
키패드
3473
카메라
3472
스피커
3439
마이크로폰
3438

도면35


3528
3500
3504
메모리
3536
프로그램 명령들
3538
이미지 데이터
3526
무선 인터페이스
3534
전원
3530
3532
입력 디바이스
3502
프로세서
3506
이미지 프로세서
3510
디스플레이
3590
제1 인터페이스
3508
디스플레이 제어기
3518
카메라 제어기
3520
콤팩기
3512
코덱
3522
카메라
3524
카메라
3514
스피커
3516
마이크로폰

Espacenet

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IMAGE RECORDING DEVICE AND METHOD FOR RECORDING AN IMAGE

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Abstract of KR101517704 (B1)

광학 소자가 개별 픽셀에 객체를 이미지화하는 이미지화 방향 또는 광학 소자에 의해 개별 픽셀에 이미지화되는 초점 깊이 영역 내의 횡적 이미지화 위치에 따라 픽셀의 샘플이 배열될 때, 그리고 (이와 같이 배열된) 픽셀의 샘플의 분포가 샘플의 전체 분포에 걸쳐 확장되는 균일 격자의 교차점에서 보간될 때, 다중 채널 광학 소자를 이용하는 경우, 한편으로는 하드웨어와 제조 비용간의 개선된 비율, 다른 한편으로는 화상 품질이 얻어진다. 이러한 방식으로, 전체 화상에 걸쳐 처리가 표준화되어, 서브영역간의 전이 문제가 방지된다.

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ABSTRACT KR101517704B1

When a sample of a pixel is arranged according to an imaging direction in which the optical element images an object in an individual pixel or a lateral imaging position within the depth-of-focus region in which an individual pixel is imaged by the optical element, and the sample of a pixel (so arranged) An improved ratio between hardware and manufacturing cost on the one hand and image quality on the other hand is obtained when using multi-channel optics when the distribution is interpolated at the intersection of a uniform grating that extends over the entire distribution of the sample. In this way, the processing is standardized over the entire image, and the problem of transition between subregions is prevented.

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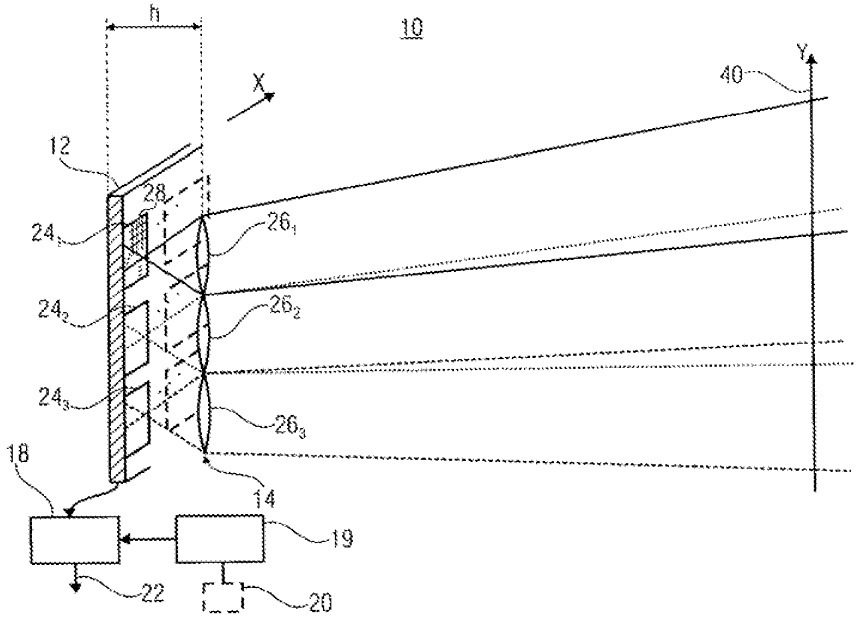
전체 청구항 수 : 총 16 항

(54) 발명의 명칭 **이미지를 기록하기 위한 이미지 기록 장치 및 방법**

(57) 요 약

광학 소자가 개별 픽셀에 객체를 이미지화하는 이미지화 방향 또는 광학 소자에 의해 개별 픽셀에 이미지화되는 초점 깊이 영역 내의 평적 이미지화 위치에 따라 픽셀의 샘플이 배열될 때, 그리고 (이와 같이 배열된) 픽셀의 샘플의 분포가 샘플의 전체 분포에 걸쳐 확장되는 균일 격자의 교차점에서 보간될 때, 다중 채널 광학 소자를 이용하는 경우, 한편으로는 하드웨어와 제조 비용간의 개선된 비율, 다른 한편으로는 화상 품질이 얻어진다. 이러한 방식으로, 전체 화상에 걸쳐 처리가 표준화되어, 서브영역간의 전이 문제가 방지된다.

대 표 도



특허청구의 범위

청구항 1

복수의 픽셀을 포함하고, 사진에서 픽셀 당 하나의 샘플을 검출하는 이미지 센서와,

상기 이미지 센서에 광학 이미지를 생성하는 광학 소자 - 상기 광학 소자는 중첩되는 입체각 범위를 개별적으로 이미지화(imaging)하여 상기 이미지 센서의 서브영역을 분리하는 다중 채널 광학 소자를 포함하며, 상기 이미지 센서의 각 픽셀은 상기 각 픽셀에 연관된 이미지화 값을 가지며, 상기 이미지화 값은 상기 광학 소자가 상기 개별 픽셀로 객체를 이미지화하는 이미지화 방향 또는 상기 광학 소자에 의해 상기 개별 픽셀로 이미지화되는 초점 깊이 영역 내의 횡적 이미지화 위치임 - 와,

화상 값의 어레이를 얻기 위해 상기 픽셀의 샘플의 전체 분포에 걸쳐 확장되는 균일 격자의 교차점에서 상기 픽셀의 이미지화 값에 따라 상기 픽셀의 샘플의 분포를 보간하는 보간기를 포함하는

화상 캡처 장치.

청구항 2

제 1 항에 있어서,

상기 다중 채널 광학 소자는, 상기 중첩되는 입체각 범위가 상기 중첩되는 입체각 범위 중 어느 하나보다 최대 120% 큰 전체 입체각 범위를 함께 커버하는

화상 캡처 장치.

청구항 3

제 1 항에 있어서,

상기 다중 채널 광학 소자는, 상기 중첩되는 입체각 범위가 상기 중첩되는 입체각 범위 중 어느 하나보다 적어도 4배 이상 큰 전체 입체각 범위를 함께 커버하는

화상 캡처 장치.

청구항 4

제 1 항 내지 제 3 항 중 어느 한 항에 있어서,

상기 광학 소자는, 상기 개별 이미지가 서로 다르지만, 정으로 변화없는 방식으로 각기 스펙트럼 필터링, 편광 필터링 또는 중성 농도(ND : neutral-density) 필터링되도록 구성되며, 상기 보간기는, 동일한 것에 대한 각 개별 이미지화가 동일하게 필터링되는 서브영역에 속하는 상기 픽셀의 샘플의 분포에 대해 개별적으로 보간을 수행하도록 구성되는

화상 캡처 장치.

청구항 5

제 4 항에 있어서,

동일한 것에 대한 각 개별 이미지화가 동일하게 필터링되는 서브 영역에 속하는 상기 픽셀의 상기 샘플의 상기 분포의 상기 개별 보간에 있어서, 상기 보간기는, 동일한 것에 대한 각 개별 이미지화가 상이하게 필터링되는 서브 영역에 속하는 픽셀의 상기 샘플의 상기 분포를 고려하는

화상 캡처 장치.

청구항 6

제 1 항 내지 제 3 항 중 어느 한 항에 있어서,

상기 이미지 센서의 상기 픽셀은 서로 상이한 스펙트럼, 편광 및/또는 중성 농도(ND : neutral-density) 감도를 포함하고, 상기 이미지 센서의 각 서브영역은 2개의 상이한 픽셀 그룹으로부터의 픽셀을 적어도 포함하고, 상기 보간기는 상기 픽셀 그룹에 대해 개별적으로 보간을 수행하도록 구성되는

화상 캡처 장치.

청구항 7

제 4 항 내지 제 6 항 중 어느 한 항에 있어서,

상기 보간기는 개별 필터링 동작을 위해 동일한 위치에서 동일한 공일 적자를 사용하는

화상 캡처 장치.

청구항 8

제 1 항 내지 제 7 항 중 어느 한 항에 있어서,

상기 이미지 센서의 사전 결정된 픽셀에 대해, 상기 이미지 센서 상의 상기 사전 결정된 픽셀에 관한 위치 정보를 이용한 계산에 의해, 또는 상기 사전 결정된 픽셀에 대한 기준을 이용한 룩업에 의해, 상기 사전 결정된 픽셀에 연관된 이미지화 값을 결정하는 연관기(associator)를 더 포함하는

화상 캡처 장치.

청구항 9

제 8 항에 있어서,

상기 사전에 대해, 근접 촬영과 원거리 촬영 사이를 적어도 구분하는 입력 인터페이스 및/또는 거리 추정기를 더 포함하되,

상기 연관기는, 근접 촬영의 경우 상기 이미지화 값이 상기 초점 깊이 영역 내의 횡적 이미지화 위치가 되도록 시차 효과를 고려하면서 상기 결정을 수행하고, 원거리 촬영의 경우 상기 이미지화 값이 이미지화 방향이 되도록 시차 효과를 무시한 채 상기 결정을 수행하는

화상 캡처 장치.

청구항 10

제 8 항 또는 제 9 항에 있어서,

상기 사전에 대해, 촬영 거리를 결정하는 입력 인터페이스 및/또는 거리 추정기를 더 포함하되, 상기 연관기는 상기 촬영 거리에 따라 상기 결정을 수행하는

화상 캡처 장치.

청구항 11

제 8 항 또는 제 9 항에 있어서,

상기 화상 캡처 장치는 상기 화상 값의 어레이 내의 상기 픽셀과 상기 이미지화 값의 연관에 의해 상기 광학 소자의 배향이 상쇄되도록 구성되는

화상 캡처 장치.

청구항 12

제 1 내지 제 11 항 중 어느 한 항에 있어서,

상기 다중 채널 광학 소자는 복수의 마이크로렌즈를 포함하고, 상기 이미지 센서의 각 픽셀과 개별 이미지화 값의 상기 연관은, 상기 다중 채널 광학 소자의 상기 마이크로 렌즈의 광축의 방향, 상기 마이크로렌즈 중 상기 픽셀의 픽셀 좌표, 및 상기 마이크로렌즈의 왜곡에 의존하는

화상 캡처 장치.

청구항 13

제 1 항 내지 제 12 항 중 어느 한 항에 있어서,

상기 보간기는 각 교차점에 대해 상기 샘플의 분포 중 최근접 이웃을 검색하고, 상기 개별 교차점과 상기 최근접 이웃에 연관된 상기 이미지화 값 사이의 상기 거리의 반비례 또는 상기 거리의 제곱의 반비례에 해당하는 가중치로 상기 샘플에 걸쳐 가중 평균을 수행하는

화상 캡처 장치.

청구항 14

제 1 항 내지 제 13 항 중 어느 한 항에 있어서,

상기 다중 채널 광학 소자는 마이크로렌즈의 어레이를 포함하고, 상기 이미지 센서로부터의 상기 광학 소자의 거리는 상기 마이크로렌즈의 초점 거리와 같거나 크며, 상기 마이크로렌즈의 정점으로부터의 평균 거리는 상기 이미지 센서의 서브영역의 중심간 거리에 비해 확장되는

화상 캡처 장치.

청구항 15

다수의 픽셀을 포함하고, 사진에서 픽셀당 하나의 샘플을 검출하는 이미지 센서와, 상기 이미지 센서에 광학 이미지를 생성하는 광학 소자에 의해 화상을 캡처하는 방법 - 상기 광학 소자는 중첩되는 입체각을 개별적으로 이미지화하여 상기 이미지 센서의 서브영역을 분리하는 다중 채널 광학 소자를 포함함 - 으로서,

상기 광학 소자가 개별 픽셀로 객체를 이미지화하는 이미지화 방향 또는 상기 광학 소자에 의해 상기 개별 픽셀로 이미지화되는 초점 깊이 영역 내의 횡적 이미지화 위치인 이미지화 값을 상기 이미지 센서의 각 픽셀과 연관하는 단계와,

화상 값 어레이를 얻도록 상기 픽셀의 샘플의 상기 전체 분포에 걸쳐 확장되는 균일 격자의 교차점에서 상기 픽셀의 이미지화 값에 따라 상기 픽셀의 샘플의 분포를 보간하는 단계를 포함하는

화상 캡처 방법.

청구항 16

컴퓨터 상에서 실행될 때, 청구항 15의 화상 캡처 방법을 수행하는 프로그램 코드를 포함하는

컴퓨터 프로그램.

명 세 서

기 술 분 야

[0001] 본 발명은 화상 캡처 장치 및 화상 캡처 방법에 관한 것이다.

배 경 기 술

[0002] 이동 전화 카메라 분야 및 자동차 부품(automotive engineering) 분야와 같은 여러 분야에서, 카메라 모듈의 소형화 및 그 제조 비용의 저감은 중요한 목표이다. 모든 면에서, 모듈 크기는 화소 크기에 비례한다. 이것은 또한 광축에 따른 길이에도 적용되어, 상대적으로 작은 화소는 주어진 전체 화소수에 대한 센서 크기를 감소시키고, 상대적으로 작은 센서는 주어진 시야에 대해 초점 길이를 보다 짧게 할 수 있다. 카메라 모듈의 광축에 따른 허용 확장은 주로 광학 시스템의 초점 길에 의해 제한된다.

[0003] 본 출원의 겸눈에 착안하면, 다중 채널 이미지화 시스템(multi-channel imaging system)은 소형화 및 비용 저감의 두가지 측면 모두에서 개선을 보장한다. 대략 몇 밀리미터 확장된 단일 스택(single stack)의 렌즈 대신에, 다중 채널 이미지화 시스템 내의 광학 시스템은 마이크로렌즈 어레이로 구성된다. 이들 마이크로렌즈 어레이에 의해 생성된 마이크로화상(micropicture)은 광학적으로 또는 전기적으로 단일 화상으로 합쳐진다. 전체 시스템의 특정한 사전정의된 시야에 대해, 그러한 다중 채널 이미지화 시스템의 마이크로렌즈의 초점 길이는 단채널 시스템의 초점 길이의 단지 일부이며, 그에 따라 광축에 따른 설계 높이(design height)는 감소되고, 초점 깊이는 현저히 증가된다. 각 마이크로화상은 시야의 작은 부분만을 커버하기 때문에, 광학 시스템은 단순하게 구성될 수 있다(종종, 채널당 하나의 렌즈와 몇개의 조리개로 충분함). 마이크로렌즈는 대략 몇백 마이크로미터(㎛)의 직경과 몇십 마이크로미터 범위의 정점 높이(vertex height)를 갖기 때문에, 웨이퍼 접합 배열(wafer bond arrangement)에서 비용 효율이 높게, 그리고 고정밀도로 생산될 수 있다.

[0004] 그러나, 카메라, 이동 전화 등과 같은 애플리케이션에 대해 충분한 해상도를 얻어야한다는 과제를 여전히 갖고 있다. 비교적 측 방향으로 평행한 각 개별 채널의 광학 경로에도 불구하고, 개별 영상 채널 상의 개별 부분 화상이 만나는 스티칭(stitching)을 복잡하게 하는 광학 왜곡이 각 채널에 대해 발생한다. 만일 이미지 센서의 서브영역의 프레임 어레이가 단지 함께 스티치되어 전체 픽셀 어레이를 형성하는 그런 경화성을 가지고, 마이크로렌즈 어레이와 이미지 센서의 인접된 서브영역을 서로 배열하려고 하면, 이것은 제조 허용 범위와 이미지 센서와 마이크로렌즈 어레이의 어셈블리에서의 허용 범위에 대한 요구가 커진다는 것을 의미한다. 브루크너, 두파레, 단베르그, 라이텐 및 브라우너의 "Driving Microoptical Imaging System towards Miniature Camera Application, Micro-Optic 2010, Processing of SPIE, vol.7716"에서, 전체 화상을 형성하기 위해 다중 채널 이미지화 시스템의 부분 화상을 조합하는 알고리즘이 설명되고, 이것은 몇몇 스테이지에서 효과를 거두었다. 마이크로화상은 초기에 한정되고 이어서 등화되며, 그결과 시차를 고려하면서 재배열됨으로써 마이크로화상은 함께 결합되어 전체 화상을 형성한다. 서브픽셀 정확도로 등화가 수행된다. 그래서 얻어진 개별 픽셀 클라우드는 각각의 경우에 등화되는 부분 화상을 생성하기 위해 보간이 이루어지고, 화상 정보는 정수 픽셀 위치로 맵핑된다. 상기 부분 화상은 최종적으로 짜맞춰져, 픽셀을 재배열하거나 또는 등화된 부분 화상의 중첩 영역에서 픽셀을 재배열하거나 픽셀을 간삽하여전체 화상을 형성한다. 거기에 개시된 이 방안이 부분 화상의 개별 처리의 특일지로 인한 상기 문제를 감소시키더라도, 생성된 전체 화상내에서, 특히 부분 화상의 중첩 영역을 따라 인공 산물(artifact)이 발생한다.

[0005] 전체 시야가 커진 다중 채널 이미지화 시스템과 관련하여 상술한 바와 유사한 문제가 다른 출원에서 발생할 수도 있다. "Scene independent Method for Information in lenslet Array Images"라는 발명의 명칭을 가진 US2001/013807A1호는, 예를 들어, 렌즈가 거의 동일한 방향으로 향하고 동일한 이미지 조리개 각도를 가져야 하는 마이크로렌즈 어레이를 설명한다. 그러나, 개별 마이크로렌즈의 시선 방향은 매우 작은 차이만 있다. 특히, 그 특허는 어떻게 개별 부분 화상의 시선 방향에서의 차이가 결정될 수 있는지를 설명한다. 이점에 있어서, 상기 특허는 그중에서도 어떻게 부분 화상이 다른 것에 대해 매우 정확하게 배치될 수 있는지에 대해 설명한다. 그러나, 프레임의 잠재적인 왜곡은 보상되지 않는다.

발명의 내용

해결하려는 과제

[0006] 본 발명의 목적은, 화상 캡처 장치 및 화상 캡처 방법을 제공하여, 촬영(photographing)에 다중 채널 광학 소자가 이용될 때, 제조 및 하드웨어면에서 상대적으로 저렴한 비용으로 전체 화상의 만족스러운 품질을 얻을 수 있는 것이다.

과제의 해결 수단

[0007] 이 목적은 청구항 1에서 청구된 바와 같은 화상 캡처 장치 및 청구항 15에서 청구된 바와 같은 방법에 의해 달성된다.

[0008] 본 발명의 일 실시예에 따라, 화상 캡처 장치는, 복수의 픽셀을 구비하고 사진에서 픽셀 당 하나의 샘플을 검출하도록 구성되는 이미지 센서와, 이미지 센서에 광학 이미지를 생성하는 광학 소자를 포함하며, 상기 광학 소자는 중첩되는 입체각 범위를 개별적으로 형성하여 이미지 센서의 서브영역을 분리하는 다중 채널 광학 소자를 구비한다. 이미지 센서의 각 픽셀은 그와 연관된 이미지 값을 갖고, 이미지 값은 광학 소자가 객체를 개별 픽셀로 이미지화하는 이미지 방향 또는 광학 소자에 의해 개별 픽셀로 이미지화되는 초점 깊이 영역 내의 횡적 이미지화 위치이다. 최종적으로, 화상 캡처 장치는 화상 값의 어레이를 획득하기 위해 픽셀의 샘플의 전체 분포를 가로질러 확장되는 균일 격자(regular grid)의 교차점에서 그 이미지 값에 따라 픽셀의 샘플의 분포를 보간하는 보간기를 구비한다.

발명의 효과

[0009] 본 발명의 발견은, 광학 소자가 개별 픽셀로 객체를 이미지화하는 이미지화 방향 또는 광학 소자에 의해 개별 픽셀에 이미지화되는 초점 깊이 영역 내의 횡적 이미지화 위치에 따라 픽셀의 샘플이 배열될 때, 그리고 (이와 같이 배열된) 픽셀의 샘플의 분포가 샘플의 전체 분포에 걸쳐 확장되는 균일 격자의 교차점에서 보간될 때, 다중 채널 광학 소자를 이용하는 경우, 한편으로는 하드웨어와 제조 비용간의 개선된 비율, 다른 한편으로는 화상 품질이 얻어질 수 있다. 이러한 방식으로, 전체 화상에 걸쳐 처리가 표준화되어, 서브영역간의 전이 문제가 방지된다.

[0010] 본 출원의 바람직한 실시예는 종속 청구항의 주제이다.

도면의 간단한 설명

[0011] 이하, 첨부된 도면을 참조하여 본 출원의 바람직한 실시예를 더욱 상세히 설명한다.

도 1은 본 출원의 일 실시예에 따른 화상 캡처 장치의 개략도,

도 2는 본 출원의 다른 조금 더 상세한 실시예에 따른 화상 캡처 장치의 개략도,

도 3a는 이미지화 값으로서 초점 깊이 영역에서의 횡적 이미지화 위치가 이용되는 본 출원의 일 실시예에 따른, 그 이미지화 값(imaging value)에 따른 픽셀 분포의 개략도,

도 3b는 이미지화 값으로서 광학 소자가 개별 픽셀에 이미지화 하는 이미지 방향이 이용되는 본 발명의 일 실시예에 따른, 이미지화 값에 따른 픽셀 분포의 개략도,

도 4는 일 실시예에 따른 이미지 센서 및 마이크로렌즈 어레이로 구성된 배열의 단면도,

도 5a 및 도 5b는 개별 픽셀의 시야 및 시선 방향을 도시하는 개략도,

도 6은 일 실시예에 따른 해곡을 포함하는 서브영역 내의 픽셀의 시선 방향을 나타내는 공간뷰(spatial view),

도 7은 일 실시예에 따른 픽셀 도트 플라우드 및 중첩된 레귤러 그리드(superimposed regular grid)의 개략도.

도 8은 시차 효과(parallax effect)를 잘못 무시하여 야기되는 에러를 나타내는 두 촬영 상황(situations)의 개략도이다.

발명을 실시하기 위한 구체적인 내용

[0012] 도 1은 본 발명의 일 실시예에 따른 화상 캡처 장치이다. 도 1의 화상 캡처 장치는 일반적으로 참조 번호 '10'으로 표시되고, 예를 들어 다수의 픽셀(도 2까지는 도시되지 않음)을 갖는 이미지 센서(12)와, 이미지센서(12)에 광학 이미지를 생성하는 광학 소자(14)를 구비하며, 광학 소자는 중첩 입체각 범위(16_1~16_3)를 개별적으로 이미지화(imaging)하여 이미지 센서의 서브영역(subarea)(이것도 도 2까지는 도시되지 않음)을 분리하는 다중 채널 광학 소자를 구비한다. 도 1의 이미지 캡처 장치(10)는 보간기(18)를 더 구비하고, 연관기(19) 및 사용자 입력 인터페이스 및/또는 거리계(20)와 같은 추가 구성 요소를 (옵션으로) 더 구비한다.

[0013] 이미지 센서(12)는 보간기(18)에 접속되고, 밝기 값과 같은 샘플을 픽셀당 검출하여, 그것을 보간기(18)에 출력하도록 구성된다. 옵션의 입력 인터페이스 및/또는 옵션의 거리계(20)는 연관기를 통해 보간기(18)에 옵션으로 접속된다. 옵션의 입력 인터페이스 또는 거리계(20)를 통해 연관기(19)와 입력하여, 보다 상세히 후술될 보간에서, 중첩 입체각 범위(16_1~16_3)에 의해 형성된 전체 시야 내에 위치하고 이미지 센서(12)의 개별 소영역에 이미지화 되는 장면(scene)의 객체에 의해 나타나는 거리를 보간기(18)가 고려하는 것이 가능하다. 보간기(18)는 화상 캡처 장치(10)의 출력단(22)에서 화상 값의 해상 형태로 소망하는 화상을 출력한다.

[0014] 도 1의 화상 캡처 장치(10)의 설계는 상술했기 때문에, 이하 그 작동 모드에 대해 보다 상세히 설명한다. 도 1과 동일한 구성 요소가 도시되지만 본 출원의 일 실시예에 따라 더욱 상세한 레벨을 갖는 도 2도 예시로 참조한다.

[0015] 이미 상술한 바와 같이, 광학 소자(14)는 이미지 센서(12)의 소영역(24_1-24_3, 24_3)을 분리하기 위해 중첩하는 입체각 범위(16_1~16_3)를 개별적으로 이미지화하는 다중 채널 광학 소자를 구비한다. 도 1 및 도 2에 도시된 바와 같이, 멀티채널 광학 소자는 마이크로렌즈(26_1~26_3)의 렌즈 어레이일 수 있으며, 그 각각은 시야, 또는 입체각 범위(16_1~16_3)를 갖는 해당 채널을 형성하기 위해 서브영역(24_1, 24_2, 23_3) 중 하나와 연관된다. 도 1 및 도 2의 예인 경우에, 다중 채널 광학 소자는 개별적으로 보이는 서로 중첩된 입체각 범위보다 명확하게(예를 들어, 중첩된 입체각 범위(16_1~16_3)의 각각보다 4배) 큰 전체 입체각 범위를 중첩된 입체각 범위(16_1~16_3)가 함께 커버하도록 구성된다. 그렇게 함으로써, 본 출원의 상세한 설명의 도입부에서 미리 언급한 바와 같이, 본질적으로 이미지 센서(12)로부터 광학 소자(14)의 거리에 해당하고, 마이크로렌즈의 초점 길이와 같거나 약간 큰 설계 높이 h는 감소될 수 있다. 마이크로렌즈(26_1~26_3)의 중심간 거리(center-to-center distance) 또는 마이크로렌즈(26_1~26_3)의 정점(vertices)의 평균 거리가 이미지 센서(12)의 서브영역(24_1~24_3)의 중심간 거리 또는 반복 거리에 비해서 커진다는 점에서, 전체 시야각이 확실히 전체적으로 커진다. 이런 방식으로, 화상 캡처 장치의 소망하는 전체 시야 범위는 설계 높이 h로부터 분리된다. 한편, 전체 시야 범위가 개별 시야 범위(16_1~16_3)로 세분화됨으로 인하여, 개별 광학 소자를 구비하는 설계에 비해 설계 높이 h가 감소될 수 있고, 설계 높이 h의 감소량은 서브영역의 수가 증가되는 만큼 증가된다. 그러나, 실제로는 렌즈간의 요구되는 거리 또는 보다 작은 서브영역에 관한 렌즈의 크기로 인하여, 개별 채널로의 세분화는 제한될 수 있다. 예를 들어, 채널의 수는 4~10000개 사이이다.

[0016] 작동 모드를 설명하기 전에, 다음 실시예에서 설명되는 시나리오와 달리, 마이크로렌즈(26_1~26_3)의 반복 거리가 서브영역(24_1~24_3)의 평균 반복 거리보다 작게(즉, 입체각 범위가 본질적으로 완전히 중첩되게) 설정되는 것도 가능하다는 점에 최종적으로 주목해야 한다. 예를 들어, 전체 입체각 범위는 기껏해야 중첩된 개별 입체각 범위 중 어느 하나보다 120% 큰 정도로 작을 수 있다.

[0017] 상술한 바와 같이, 이미지 센서(12)는 다수의 픽셀(28)을 구비한다. 특히, 서브영역(24_1~24_3)의 각각은 다수의 상기 픽셀(28)을 구비한다. 예를 들어, 각 서브영역(24_1~24_3)은 32개 이상의 픽셀을 구비한다. 도 4를 참조하여 보다 상세히 후술하는 바와 같이, 이미지 센서(12)는 단일 칩 이미지 센서일 수 있으며, 예를 들어, 여기서 서브영역(24_1~24_3)은 결합하여 형성되고, 여기서 상기 서브영역(24_1~24_3)간의 간격은 광학 중복기, 열 및/

또는 행 디코더 등과 같은, 픽셀(28)의 감광 영역을 제어하는 제어 회로부를 수용하는 데 이용될 수 있다.

[0018] 개별적인 입체각 영역(16_1~16_9)이 광학 소자(14), 특히 마이크로 렌즈(26_1~26_9)에 관한 배열에 의해 서브영역(24_1~24_9)과 연관되는 것과 마찬가지로, 각 픽셀(28)도 당연히 개별 입체각 범위를 갖고, 그 개별 입체각 범위는 그것과 연관된 시선 방향 및/또는 이미지화 방향보다 확실히 작고, 상기 방향은 예를 들어 픽셀의 개별적인 입체각 범위를 중심으로 확장된다. 도 5 및 도 5b를 참조하여 연관성을 보다 상세하게 추출한다. 이미지화 방향 및/또는 시선 방향의 모든 이미지화 각도 및/또는 시선 각도는, 예를 들어, 광학 소자(14)의 광축 또는 이미지 센서(12)의 감광성 표면 영역의 표면 법선에 관해서 결정된다. 이런 방식으로, 도 3b에 도시된 바와 같은 평면, 즉 2개의 축을 가로지르는 평면 내에 픽셀(28)을 배열하는 것이 가능하고, 그 중 축(30)은 픽셀(28)의 열 방향(x)으로 개별 픽셀의 이미지화 방향의 편차 ϑ가 늘어가고, 축(32)은 예를 들어 축(x)에 수직인 행 방향(y)으로 광학축에 대한 이미지화 방향의 각도 편차가 늘어간다(나중의 각도는 ϑ에 의해 지시됨). 축이 가급적 동일하게 크기 조정되거나 등방성인 점을 주목해야 한다. 도 3b는 이렇게 가로지르는(spanned) 평면 내에 픽셀이 어떻게 그 이미지화 방향을 따라 배열되는지를 나타낸다. 가장자리(34)는 예를 들어 서브영역(24_1)의 픽셀(28)의 위치(도트로 표시됨)를 둘러싼다. 가장 자리(34)의 루선감은 모양은 마이크로 렌즈의 왜곡이 (φ, ϑ) 평면 내의 서브영역(24_1)의 픽셀(28)의 루선 형상 분포를 초래한다는 점을 나타낸다. 명확히 하기 위해, 도 3b는 다른 서브영역(24_2~24_9)의 픽셀(28)은 도시하지 않고 그 가장자리(36, 38)만을 도시하며, 개별적인 루분 픽셀의 에지(edge)는 흐리게 했다. 또한, 도 3b는 예를 들어 x 방향에서 서브영역(24_1~24_9)에 인접하여 배치될 수 있고, 도 2에서 파선으로 표시된 서브 영역의 픽셀 위치를 도시한다.

[0019] 화상 캡처 장치(10)에 의해 캡처된 장면이 충분히 멀어져 있는 경우, 상술한 바와 같이 각 픽셀(28)에 연관된 시선 방향을 고려하는 것만으로 충분할 것이다. 화상 영역(24_1~24_9) 및 연관된 마이크로렌즈가 서로 횡으로 상쇄(offset)되어 발생하는 시차 효과(parallax effect)는 간격이 큰 경우에 영향이 없다. 이것은 보다 짧은 간격과는 다르다. 예를 들어, 도 2가 이 초점 깊이 영역을 도시하는 것과 마찬가지로, 도 1은 광학 소자(14)의 광축에 수직으로 확장되는 면으로서 초점 깊이 영역(40)을 도시한다. 캡처된 장면이 몇개의 채널로 분할되어 광학 소자(14)의 초점 깊이가 매우 높은 것을 다시 한번 주목해야한다. 이런 방식으로, 마이크로렌즈(26_1~26_9)가 매우 큰 초점 깊이 범위(즉, 광학 소자(14)로부터의 거리의 매우 큰 범위) 내의 객체를 이미지화 하는 것도 가능하다. 예를 들어, 이미지 센서(12)의 감광성 영역으로부터 마이크로렌즈(26_1~26_9)의 초점 깊이와 같거나 약간 더 큰 거리에 마이크로렌즈(26_1~26_9)를 배치할 수 있다.

[0020] 각 픽셀(28)이 그것과 연관된 이미지화 방향을 가질 수 있는 것과 마찬가지로, 각 픽셀은 그것과 연관된(즉, 광학 소자(14)에 의해 개별 픽셀(28)에 대해 이미지화되는) 횡적으로 확장되는 초점 깊이 영역(40) 내의 횡적 이미지화 위치를 가질 수도 있다. 도 3a에 도시된 바와 같이, 방향 x에서의 직교 좌표와 방향 y에서의 직교 좌표에 의해 점쳐지는 평면 내에 그 횡적 이미지화 위치에 따라 픽셀(28)을 배열할 수 있다. 도 3b에서와 같이, 도 3a는 단지 서브영역(24_1)에 대한 픽셀(28)의 위치를 도트에 의해 개별적으로 나타내거만, 실선은 전반적으로 서브영역(24_1~24_9)의 픽셀의 위치의 클라우드(cloud)의 위치 및/또는 확장을 나타내고, 파선은 도 2에서 파선에 의해 표시된 잠재적인 추가 서브영역의 픽셀의 위치를 나타낸다. 도 3a에서, 또한, 가장자리선의 루선 형상의 구현은 광학 소자(14)의 단일 채널 광학 소자가 왜곡을 야기할 수 있다는 점을 나타낸다.

[0021] 상술한 바와 같이, 이미지 센서(12) 및 광학 소자(14)는 서로 동거리에 배열된다. 물론, 초점 깊이 범위를 조절할 수 있도록 이미지 센서(12)와 광학 소자(14) 사이의 거리를 다양하게 조정하는 것도 가능하지만, 상술한 바와 같이 다중 채널 광학 소자 및 마이크로렌즈의 (크기가 감소된) 조리개의 활용으로 인해, 초점 깊이 범위는 대부분의 경우 어떠한 재조정이 필요하지 않을 정도로 충분히 크다. 아직 시차가 문제가 되지 않는 거리에 배열된 객체의 화상을 캡처하도록 화상 캡처 장치(10)가 설계된 경우, 서브영역(24_1~24_9)의 개별 픽셀(28)과 이미지화 방향의 연관(도 3b에 도시됨)이 고정되는 것도 가능할 것이다. 이 경우, 거기에 연관기(19)가 반드시 필요한 것은 아니다. 오히려, 연관은 보간기(18)의 기능을 수행하는 프로그램 코드 내에서 일관되게 프로그래밍되거나, 하드웨어에 내장될 수 있다. 대신에, 연관기(19)는 룩업 테이블의 형태로 메모리로서 제공될 수 있다. 각 사진에 대한 개별 픽셀(19)의 이미지화 방향을 제산출하는 연산부로서 연관기(19)를 구현하는 것도 가능할

것이다.

[0022] 물론, 도 1의 화상 캡처 장치(10)는 대략 1/2미터의 근접 범위와 같이 특정한 근접 범위 내의 객체를 캡처하는 데만 적용되는 것도 가능할 것이다. 이 경우, 도 3a에 따른 상술한 연관이 보간기(18) 내에 고정적으로 탑재될 수 있고, 연관기(19)는 생략할 수 있다. 그러나, 도 3b의 연관과 관련하여 상술한 바와 같은 대안도 당연히 가능할 것이다.

[0023] 예를 들어 적절한 교정 객체를 캡처함으로써(화상 캡처 장치의 후속하는 어셈블리(assembly)에 의해) 도 3b 및 도 3a에 따른 연관이 결정될 수 있다. 대신에, 초점 깊이 영역(40)의 이미지화 방향 및/또는 횡적 이미지화 위치의 연관의 결정은, 화상 캡처 장치(10)의 설계 파라미터 및/또는 특히 광학 소자(14)의 이미지 센서(12)의 설계 파라미터와 그 상호 연관 위치를 이용한 산출에 의해 결정될 수 있다. 두 대안 모두에 대하여, 광학 소자(14)에 의해 야기된 왜곡을 고려하는 것도 가능할 것이다.

[0024] 물론, 서브영역간 또는 조리개간의 횡적인 상쇄로 인해 시차 효과가 영향을 미치는 사진과 그렇지 않은 사진 둘 다에 대해 화상 캡처 장치(10)가 제공되는 것도 가능할 것이다. 이 경우, 연관이 도 3b에 따라(즉, 원거리 촬영(long-distance shot)에 대해) 수행되는 것인지 또는 도 3a에 따라(즉, 근접 촬영(close-up shot)에 대해) 수행되는 것인지를 연관기(19)에 명시하기 위해, 사용자 입력 인터페이스(20)가 사용자에 의해 사용될 수 있다. 거리계(20)에 의한 명시(specification) 역시 가능하며, 상기 거리계는 실시간 측정 등에 의해 또는 상관 관계와 같이 서브영역 내에 존재하는 그 자신의 정보를 분석하는 것에 의해 거리를 결정할 수 있다. 도 3b 및 도 3a에 따른 연관간의 전이는 급격할 필요가 없다. 오히려, 광학 소자(14)로부터의 장면의 거리가 증가함 만큼 시차 구간은 계속해서 사라진다. 따라서, 연관기(19)가 입력 인터페이스/거리계(20)로부터 캡처될 객체의 거리의 지시(indication)를 획득하고, 거리의 지시에 의해 검색하거나 또는 거리의 지시를 이용하여 산출함으로써, 시차 구간을 고려하면서 그에 따라 연관을 조정하는 것도 가능할 것이다.

[0025] 보간기(18)는 도 3b 및/또는 도 3a에 따른 평면 내의 모든 픽셀(28)의 공통 도트 플라우드로부터 픽셀의 어레이(즉, 화상 값의 균일한 격자(즉, 소망하는 화상))를 생성한다. 이를 위해, 보간기(18)는 서브영역의 모든 개별 도트 플라우드의 조합에 걸쳐 균일 격자(42)를 중첩시키고(즉, 픽셀을 갖는 전체 프레임이 이미지값에 따라 배열됨), 도 3a 및 도 3b에 따른 평면 내의 위치에서(즉, 균일 격자(42)의 교차점의 위치에서) 픽셀의 샘플 사이를 보간한다. 균일 격자가 노드보다 많은 교차점(즉, 픽셀(28)보다 많은 교차점)을 구비하는 것이 가능하다는 점에 주목해야 한다. 그러나, 소망하는 화상 화상 어레이에 기여하는 균일 격자(42)의 교차점은 모든 픽셀의 공유량 내에 있어야 하며, 그것은 그렇지 않을 경우 거기에 연관된 부정확성을 포함하는 외삽법(extrapolation)이 요구될 수 있기 때문이다. 보간 방법의 예를 하기에 제시한다. 그러나, 제공될 수 있는 다수의 가능한 보간 방법이 있다. 어쨌든, 이미지값은 균일 격자의 격자 간격보다 적어도 16배 큰 최소 단위를 갖는 스칼라 정확도(scalar accuracy)로 표현하는 것이 바람직하다. 한편, 도 3a 또는 도 3b에 따른 공간(room) 내의 보간기(18)는 거기에서 발생한 구성 요소들을 제 1 비트 정확도(first bit accuracy)로 처리할 수 있고, 그와 관련하여 격자(42)의 교차점은 적어도 16배의 최소 단위의 간격을 갖는다. 따라서, 예를 들어, 도트 프레임의 중첩 영역 또는 개별 픽셀 도트 플라우드에서 조차 격자점 당 한번의 보간만 수행되고, 개별 중첩 영역 내에서 중첩되는 모든 프레임이 상기 보간에 동일하게 참여한다는 사실을 반영 하는 하나의 단계에서 그리고 동일한 방식으로 모든 프레임에 대해 보간이 일어날 수 있다. 이미지값을 재조정하거나 조작할 필요가 없다. 일단 그들이 결정되면, 그들은, 예를 들어 픽셀의 밝 밀도값이 개별 보간값과 결합되는 가중값으로만, 특히, 후술하는 바와 같이, 현재 보간이 일어나는 고려되는 교차 격자점과 개별 포워 픽셀 사이의 간격의 적정한 측정과 동일한 가중값으로만, 그들이 고려된다.

[0026] 상술한 설명은 픽셀(28)이 상이한 감도 반응을 나타낼 가능성을 언급하지 않았다. 그 감도는 예를 들어 입사광의 편광에 비해 또는 (중립) 감도에 비해 다를 수 있다. 이 경우, 균일 화상 어레이를 얻기 위해 보간기(18)가 상술한 바와 같이 도 3a 및/또는 도 3b에 따른 평면 내에 동일한 감도 특성을 갖는 픽셀을 배열하고, 별도로 이 감도 특성에 대해 그 위에 격자(42)를 각기 중첩시킬 수 있을 것이다. 그래서, 이 방안은 모든 감도 특성에 대해 및/또는 모든 감도 특성의 픽셀과 별도의 각 감도 특성에 대해 수행될 것이다. 후술하는 바와 같이, 이 경우에 상이한 감도 특성을 갖는 픽셀이 고려된다는 점에서 동일한 감도 특성을 갖는 픽셀의 개별적인 부분 분포의 보간이 개선되는 것이 가능하다. 방금 설명된 방식으로, 컬러 화상을 얻을 수 있다. 이 방안의 효과는, 격자(42)가 도 3a 및/또는 도 3b에 따른 평면 내의 모든 감도 특성에 대해 정확히 동일한 위치에 배치되어, 공유되는 컬러 화상 어레이의 위치에 관한 모든 색상 성분이 정확히 동일한 위치를 나타내는 데 있다. 서브픽셀 셀(subpixel cell)의 구성이 상이한 위치에서 획적으로 샘플링되므로, 컬러 화상 센서로 적은 동상의 컬러 사진을

가지고는, 그 경우가 아니다. 화상 캡처 장치(10)의 서브영역(24_1~24_9)에서, 이것도 그 경우이지만, 보간에 의해, 개별 감도 특성의 픽셀 또는 서브클라우드가 정확히 동일한 위치에서 보간된다. 방금 설명된 바와 같이, 만일 보간을 개선하기 위해 다른 감도 특성을 갖는 픽셀이 추가로 이용되면, 훨씬 더 좋은 화상 품질이 얻어질 것이다.

[0027] 그러나, 화상 캡처 장치(10)에서, 개별적으로 도시된 각 채널은 균일하게 필터링(예를 들어 스펙트럼 필터링, 중성 농도 필터링, 또는 편광 필터링)되지만, 상이한 채널은 상이한 필터 특성을 갖는 것도 가능하다. 이 경우, 각 필터 특성을 위해, 이 필터 특성에 속하는 채널이 화상 캡처 장치(10)의 전체 시야를 커버하도록 입체각 범위가 제공될 수 있고, 그래서 이들 모든 필터 특성을 위한 도 3a 및/또는 도 3b에 따른 전체 화상 클라우드가 얻어진다. 다시, 이 경우에, 이러한 방식으로 컬러 화상과 같은 다중 성분 화상 정보를 구비하는 균일한 화상 어레이를 얻기 위해, 보간기(18)는 상이한 필터 특성을 위한 이들 픽셀 또는 서브클라우드 각각에 대해 균일 격자(42)의 격자 교차점에서 따로 보간을 수행할 수 있다.

[0028] 본 출원에 따른 실시예의 작동 모드 및 구조를 대략 설명했기 때문에, 하기에는 상술한 개별 구성요소를 구성하는 가능성을 다룬다. 후술하는 설명으로부터 보는 바와 같이, 이미지 센서(12)는 CMOS 이미지 센서일 수 있고, 예를 들어 여기에서 서브영역(24_1~24_9)은 기판 또는 칩 상에 공동으로 집적된다. 웨이퍼 본딩 또는 플랑에 의해, 멀티채널 광학 소자는 칩 자신에 직접 집적되거나, 또는 서브영역(24_1~24_9)과 조리개 사이의 광학적 투명성(transparency)을 보장하지만 개별 채널의 광학적 상호 분리를 보장하는 반투명층 배열에 의해 기판의 표면으로부터 떨어져서 집적될 수 있다.

[0029] 보간기(18)는 그 위에 집적된 이미지 센서(12)도 구비하는 동일 칩 또는 기판 상에 집적될 수 있다. 보간기(18)는 프로세서 상에서 실행되는 프로그래밍 가능한 회로 로직 또는 컴퓨터 프로그램일 수 있다. 그러나 특히, 보간기(18)는 이미지 센서(12)에 집속된 컴퓨터일 수도 있다.

[0030] 연관기(19)는 비휘발성 메모리(예를 들어, EEPROM 등)일 수 있다. 화상 입력 인터페이스(20)는 예를 들어 제 1 토글 위치, 제 2 토글 위치 및 비토글 위치를 갖는 토글 스위치일 수 있다(앞의 두 위치는 원거리 촬영(long-distance shot)이나 근접 촬영(close-up shot)을 트리거할 수 있고, 끝에 말한 위치는 아이들 또는 무정의(don't-care) 상태일 것이다). 주동 위치에 따라, 연관기는 예를 들어 도 3b 또는 도 3a에 따른 연관을 수행할 것이다. 그러나, 사용자 입력 인터페이스(20)는 그래픽 유저 인터페이스 내의 조절 가능한 바(adjustable bar)와 같이 기타 상식 가변형 사용자 인터페이스 상의 회전 절인 것도 가능할 것이다. 방금 설명한 경우에 있어서, 연관기(19)는 초점 깊이 영역(40)의 형적 이미지화 위치의 연관을 산출하는 것과 동일하게 이용하기 위하여, 연속 또는 준연속의 거리의 지시만을 아루어지는 입력을 이용할 수도 있다.

[0031] 그러나, 상술한 바와 같이, 거리 센서(20)가 이용될 수도 있다. 이 거리 센서는 캡처되는 장면의 거리를 실행시간 측정 등과 같은 임의의 방식으로 측정할 수 있지만, 예를 들어 그들 자신의 개별 부분 화상의 화상 정보로부터의 추정에 의해서도 측정할 수 있다. 따라서, 이렇게 얻어진 거리 측정은 거의 양자화된 상태에서 상술한 바와 같이 연관 사양을 조절하는 연관기(19)에 의해 이용될 수 있다.

[0032] 본 출원의 몇몇 실시예를 이미 상술했으므로, 아마 상기 실시예를 구현하는 데 이용될 수 있는 몇몇 세부 구현을 하기에 제공한다.

[0033] 이와 관련해서, 상술한 무언가는 처음에 다룬 말로 한목될 것이다. 상술한 바와 같이, 광학 소자(14)는 예를 들어 센서(12) 상의 $M \times N$ 비중첩 마이크로화상을 생성한다. 마이크로채널 광학 소자의 개별 채널은 예를 들어 개별 마이크로렌즈(26_1~26_9)를 구비한다. 각 마이크로렌즈는, 먼저 상술했고 후술되는 바와 같이, 객체 공간(object room)으로부터 센서까지 입체각 범위(16_1~16_9)를 이미지화한다(이 간소화는 마이크로렌즈 반복 거리에 비해 그 거리가 큰 객체에만 적용함). 도 1의 44에서 도시된 바와 같이 개별 채널의 입체각 범위(16_1~16_9) 또는 시야는 분리되는 것이 아니라 서로 중첩된다.

[0034] 마이크로화상(24_1~24_9)(이 마이크로 화상은 연관된 마이크로렌즈(26_1~26_9)에 의해 조사된 영역 내에 차례로 배치됨) 내의 각 픽셀(28)은 같은 것에 대해 통합되는 작은 입체각을 "본다(see)". 도 5a는 이 관련 서브영역(24_1)의 매우 간소화한 도면을 예시적으로 제공한다. 마이크로렌즈의 서브영역(24_1)(명확하게 하기 위해 도 5a에서 도시 생략함) 내의 서로 인접한 픽셀(28) 중 단 하나를 바라보는 입체각(46)은 어떠한 공백도 없이 인접해 있다. 물론, 픽셀(28)의 제한된 충전율로 인해, 영역(46)은 어떠한 공백도 없이 서로 인접하지 않는 것이 가능

하다. 그러나, 간소화하기 위해, 픽셀(28)의 값이 개별적인 입체각(46)의 중앙에서 빔의 방향으로 개별 픽셀(28) 상에 입사되는 복사 휘도의 측정량을 나타낸다고 상정할 수 있다. 그래서 이것은 개별 픽셀(28)의 상술한 시선 방향(48)을 나타내고, 도 5b에 도시된다.

[0035] 제조 비용을 감소시키기 위하여, 마이크로렌즈가 왜곡으로부터 자유로울 수 없을 수도 있다. 따라서, 픽셀은 도 3a 및 도 3b에 따라 동일한 방식으로 공간을 스캔하지 않는다(예를 들어, 그래서 도 3b에서 픽셀의 시선 방향으로부터 형성된 격자는 균일하지 않다. 또한, 다중 채널 광학 소자의 각 마이크로렌즈(26_1~26_5)는 도 6에서 영역(24_1)의 채널에 대한 예로서 도시된 고유의 왜곡 형태를 가질 수 있다.

[0036] 그러나, 상술한 바와 같이, 화상 캡처 장치(10)가 마이크로 화상으로부터 균일한, 만족스러운 공유 화상을 생성하는 것이 가능하다.

[0037] 픽셀로부터의 방사 휘도(radiance)의 측정값, 즉 개별 픽셀(28)의 샘플은 도 3a 또는 도 3b에 따라 평면 내에 구획된다. 측정값의 좌표는, 예를 들어, 연관된 마이크로렌즈(26_1~26_5) 또는 각 채널의 시선 방향 또는 광축 방향으로부터, 각 마이크로렌즈 아래의 각 픽셀의 픽셀 좌표로부터, 그리고 각 마이크로렌즈의 방향으로부터 비롯되고, 각도 단위, 또는 초점 깊이면(focal-depth plane)에 관한 직교 플롯(Cartesian plot)으로 나타낼 수 있다. 왜곡의 정확한 형상은 광학 소자(14)의 광학 설계로부터 결정될 수 있지만, 센서(12)와 예를 들어 집속 광학 소자(14)로 이루어지는 특정한 물리적 시스템에 대해 측정될 수도 있다.

[0038] 어떤 방식으로, 각 마이크로렌즈 또는 이미지 센서의 각 서브영역은 도 3a 및 도 3b에 따른 평면 내에 작은 도트 클라우드(dot cloud)를 생성한다. 도트 클라우드 내의 각 (매단히 작은) 도트는 각 초점 깊이면 내의 특정 시선 방향 또는 확적 형성 위치에 대한 방사 휘도의 측정값을 나타낸다. 도트 사이의 방사 휘도는 서로에 도트는 것으로 상정될 수 있다.

[0039] 인접 마이크로렌즈(도 3a 및 도 3b에서 단지 외부 크기에 관해 지시되는 가장 자리(34)를 가짐)의 도트 클라우드는 서로 침범한다. 마이크로렌즈 시스템의 광학적 설계는, 도트 클라우드의 도트가 일치하지는 않지만 가능한한 균일하게 평면 내에 분포되도록, 즉 개별 채널의 픽셀 도트 서브클라우드가 서로 교차하는 영역(그러한 중첩 영역은 도 3b에서 50으로 지시됨) 내에도 분포되도록 구성될 수 있다.

[0040] 그 다음, 보간기(18)는 상술한 바와 같이 균일한 직교 격자(42)에 의해 얻어진 전체 도트 클라우드를 중첩시킨다. 직교 격자의 교차 도트에 존재하는 방사 휘도는 기존 측정값으로부터 결정되거나 보간된다. 예를 들어, 각 교차점에 관해, n개의 최근접 이웃이 결정되고, 그들의 방사 휘도값은 가중 평균하는 데 이용된다. 각 픽셀 밀도값의 가중 또는 표준은 예를 들어 간격의 역 또는 간격의 제곱의 역에 의해 결과를 얻을 수 있다.

[0041] 최근접 이웃은 예를 들어 도트 클라우드의 모든 도트를 훑어서(browsing) 결정할 수 있다. 도트가 소위 빈(bin)이라 하는 여러 영역으로 사전에 분할된 경우, 이것은 검색을 가속시킬 수 있다. 첫번째 대안은 클라우드의 픽셀간의 삼각 분할(이상적으로 델로네 삼각 분할(Delaunay triangulation))을 포함하는 것이다. 델로네 삼각 분할 내의 임의의 도트의 최근접 이웃을 찾는 것이 비교적 빠르다. 특히, 의사 코드에 의해 묘사된 다음 알고리즘은 도트 클라우드를 생성하고 보간하는 데 이용될 수 있다.

```
// Erzeuge Punktwolke
für jede Farbe
    PunktWolke(Farbe).init()
     für jedes Mikrobild
          für jeden Bildpunkt in Mikrobild
                falls (FarbevonBildpunkt(Bildpunkt) =  Farbe)
                       BlickRichtung = BerechneBlickRichtungdesPixels
                       (Mikrolinse, PositionInLinse(Bildpunkt))
                       PunktWolke(Farbe).Hinzufügen(BlickRichtung,
                       StrahldichteVonBildpunkt(Bildpunkt))
                  Ende falls
          Ende für
     Ende für
Ende für
// Ergebnis: drei Bildwolken mit Strahldichteinformationen


// Interpolation
InterpoliertesBild.init()
für jede Farbe
    für x = 0 bis BildBreite
      für y = 0 bis BildHöhe
        Nachbarn = PunktWolke(Farbe).findeNächstenNachbarn(x,y)
        für jeden Nachbarn in Nachbarn
            Gewicht = BerechneNorm(Nachbar, x,y)
            InterpoliertesBild(Farbe,x,y)+=     Gewichtung     *     Nach-
            bar.Strahldichte;
        Ende für
      Ende für
    Ende für
Ende für
// Ergebnis: Interpoliertes Bild
```

[0042]

[0043] 상기 의사 코드를 설명하기 위해, 도 7과 관련하여 위 도면을 다시 한번 간략하게 참조한다. 도트 클라우드 생성 프로그램 코드 내의 첫번째 루프는 픽셀의 개별 색상을 통과한다. 따라서, 전체 클라우드는 각 색상에 대해 생성된다. 두번째 루프는 모든 마이크로화상(24_1~24_5)을 통과한다. 세번째 루프(즉, 가장 안쪽의 것)는 현재 마이크로화상(24_1~24_5) 내의 모든 픽셀(28)을 통과한다. 가장 안쪽의 이프 질의(if query)에 의해, 현재 검색된 픽셀이 현재 색상을 갖는지의 여부와 같이 검증이 이루어진다. 만일 그렇다면, 특히 개별 채널 및/또는 개별 마이크로렌즈에 대한 참고(reference)와 마이크로 화상 내의 픽셀 위치를 이용하여 그 시선 방향이 산출되고, 현재 검색된 픽셀의 방사 휘도는 도 3a 및/또는 도 3b에 따른 평면 내의 해당 위치에서 구해된다. 이 예의 경우, 시선 방향(즉, 도 3b에 따른 평면)이 기준으로서 이용된다.

[0044] 두번째 프로그램 부분은 실제 보간을 다룬다. 가장 바깥쪽 루프는 개별 색상을 다시 통과한다. 각 색상에 대해, 균일한 직교 격자(42)(즉, 그 교차점(52))는 한차례 순환된다. "pictureWidth"과 "pctureHeight"는 출력단(22)에서 나중에 출력될 소망하는 전체 화상의 화상 높이 및 화상 너비를 가리킨다. 해당하는 2개의 루프에 이어서, 이 격자점(52)에 대해 이웃이 처음에 결정된다. 예로서 도 7에 도시된 바와 같이, 격자(42)의 교차점(52)의 4개의 최근접 이웃은 예를 들어, 1~4에 의해 지시되는 픽셀일 것이다. 상기 최근접 이웃 픽셀 전체에 걸쳐 가장 안쪽의 루프 사이클은, 현재 교차점(52)의 위치에서 보간값을 얻기 위해, 상기 픽셀의 각각에 대해 현재 격자점(52)으로부터의 적절한 거리 표준에 따른 가중을 산출하고, 상기 픽셀 이웃의 방사 휘도의 합(그에 따라 상기 합은 가중됨)을 형성한다. 이러한 방식으로, 교차 격자점(52) 전체에 대해 보간값이 (특히, 모든 색상에 대해) 결정되어, 다중 성분 색상값이 각 격자 교차점(52)에 대한 각 격자(42)에 대해 얻어진다.

[0045] 이전 설명에 대한 몇개의 대체예를 하기에 설명한다. 상술한 바와 같이, 각 채널은 개별적으로 필터링될 수 있다. 그러나, 이미지 센서(12)가 베이어 패턴(Bayer pattern)과 같은 적절한 컬러 필터 어레이에 의해 커버되는 것도 가능하다. 이런 방식으로, 전체 화상의 분광 복사량(spectral radiance)은 몇개(일반적으로 3개)의 파장 대역에 대해 측정될 수 있다. 당연히, 단일 대역 내의 측정점의 밀도는 감소된다. 베이어 패턴에서, 녹색용 2개, 적색 및 청색용 4개 로 나뉜다. 상술한 바와 같이, 예를 들어 색상 채널당 하나의 도트 클라우드가 생성될 것이다. 최종 화상의 녹색 채널은 녹색 도트 클라우드 내의 해당 보간으로부터 얻어진다. 그것이 적색 및 청색에 대해서 유사하게 적용된다. 채널들은 함께 최종 컬러 화상을 생산한다.

[0046] 개선된 점으로서, 녹색 채널로부터의 측정점이 적색 및 청색 채널을 보간하는 데 이용되는 것이 가능하고, 그 반대도 가능하다.

[0047] 또한 이미 상술한 바와 같이, 시차 효과는, 이미지 처리될 객체의 거리가 마이크로렌즈 반복 거리에 비해 크지 않으면, 시차 무간이 무시될 정도인지에 따라 간소화가 더이상 적용되지 않게 한다. 픽셀의 시선 방향(48)에

더하여, 이미지 센서 상의 그의 위치도 이 경우에 관련이 있다. 이것을 설명하기 위해, 객체가 원거리에 정확하게 배열되고(즉, 객체가 이미지 센서(12)로부터 충분히 멀리 떨어지고), 여기에서 캡처될 객체가 상기 원거리에 배치된다(즉, 도 3b에 따른 관찰이 이용된다)고 상정될 수도 있는 경우가 위에 도시되고, 객체가 원거리에 배치되어 있다고 상정하더라도 그것이 가깝게 배치된 경우가 아래 부분에 도시된 도 8을 개략적으로 참조한다. 54는 각각의 경우에 객체가 시선 방향(48)에 당는 위치에서 객체의 샘플 지점 A~V가 최종 화상 내에 어떻게 재배열되는지를 나타낸다. 도시된 바와 같이, 최종 화상 내에 객체가 정확히 배치된 경우에 객체 상의 일련의 지점 A~V가 유지되는 반면, 잘못 배치된(즉, 이미지 센서(12)에 너무 가까운) 경우에 일련의 객체 지점은 뒤죽박죽 된다.

[0048] 따라서, 상기 실시예가 채용되는 경우, 보간기(18)는 어떠한 끊김없이 단축스러운 고해상도 이미지를 구성할 수 있다. 화상 캡처 장치가 명시된 바와 같이 움직이는 한 및/또는 상술한 조정 가능성이 이용되는 한, 객체 상의 인접 지점의 측정값은 최종 화상에서 거기 계속해서 인접된다. 또 다른 한편, 이미지된 내의 측정 지점의 배열의 객체 거리가 고려되어야 할 수 있다. 가장 간단한 경우, 고정된 객체 거리가 상정될 수 있다. 상술한 바와 같이, 상술한 바와 같이 측정 지점의 거리 추정 및/또는 측정 그리고 측정점의 해당 처리도 실현 가능한 것이다.

[0049] 상술한 설명은 보다 작은 시야각을 갖고 서로 중첩되는 몇개의 채널로 구획함으로써 시야가 확대된 화상 캡처 장치에 관해 주로 언급했다. 본 출원은 또한 다른 출원에 대해서도 실현 가능하며, 여기서, 예를 들어 본질적으로 중첩되는 단일 채널 시야를 갖는 상이한 시야각으로부터 장면이 보인다.

[0050] 상기 실시예에 있어서, 사용된 다중 채널 광학 소자는 처프된(chirped) 마이크로렌즈 어레이(즉, 해당 기판의 중앙 위치에 대하여 확장 방식으로 배치되거나 또는 상이한 방식으로 상배되는, 평적 위치를 그의 렌즈 정점이 구비하는 마이크로 렌즈 어레이)일 수 있다. 예를 들면, 도 4는 이미지 센서(12)와 마이크로렌즈 어레이(14) 사이에 고정 거리를 갖는 고정 배열의 가능한 예를 나타낸다. 이미지 센서(12)는 예를 들어 CMOS 이미지 센서, 또는 어떤 다른 반도체 센서이다. 채널 분리 및 미광(stray light) 흡수를 위한 엠브레인 영역(66, 68)을 사이에 두고 몇개의 유리 기판(60, 62, 64)이 기판(12) 상에 배열된다. 최상부 유리 기판(60) 상에 마이크로렌즈(26_1~26_5)가 형성된다. 도시된 바와 같이, 마이크로렌즈의 정점 반목 거리가 서브영역(24_1~24_5)의 중심 반복 거리보다 크고, 그것은 전체 시야가 확산 및/또는 개별 채널의 중앙 시선 방향(70_1~70_5)의 발산(divergence)을 야기한다. 도 4에 따른 설계의 예는, 예를 들어 개별 카메라(즉, 이미지 센서 및 마이크로렌즈 어레이의 개별 조합)의 절단 공정(dicing)이 후속되는 웨이퍼 접합 배열로 생산될 수 있다.

[0051] 플렌옵틱 카메라(plenoptic camera)의 범주 내에서, 상기 실시예는 주요한 광학 소자를 상술한 실시예에서의 마이크로렌즈 어레이에 부가하는 데 이용될 수 있다.

[0052] 상기 실시예에 관해서, 상술한 마이크로렌즈 어레이의 채널은 서로 동일할 수도 있고, 또는 측면 방향이나 형도를 가로질러 상이하거나 처핑된(chirped) 수 있다. 결국, 채널은 개별 렌즈에 의해 이미지화되거나, 예로서 도 4에 도시된 바와 같이, 렌즈 시스템에 의해 이미지화될 수 있다. 마이크로렌즈 어레이 대신에 이미지화용 조리개를 이용하는 것도 가능하고, 또는 양자의 조합도 가능하다. 두 경우 모두, 하나의 클라우드가 각 픽셀의 시선 방향을 결정하여, 상술한 보간이 수행될 수 있는 도트 클라우드(dot cloud)로 이어질 수 있다.

[0053] 상기 실시예에서, 시차 정정(parallax correction) 뿐만 아니라 프레임의 반전(inversion) 및 그 등화(equalization)가 결과적으로 또는 본질적으로 하나의 단계에서 수행되어, 처리를 가속시킨다. 한 단계에서 전체 화상을 형성하도록 화상 정보가 조합되고, 중간 보간 단계가 생략되어, 화질이 개선되고 아티팩트(artifact)가 감소되기 때문에, 전체 화상의 품질이 더욱 개선된다. 상기 실시예는 필터를 구비하는 센서에 적합하다. 각 마이크로렌즈 아래의 컬러 필터 어레이를 이용하거나, 또는 각 마이크로렌즈의 아래에 정확히 한 필터의 필터를 배치할 수 있다. 빙금 말한 필터는 RGB 컬러 필터일 수 있고, 또한 RGB+그레이나 RGB+시안과 같은 추가 색상이 이용될 수도 있다. 적광 필터 또는 다양한 농도의 그레이 및/또는 중성 농도 필터(ND(neutral density) filter)가 이용될 수도 있다.

[0054] 따라서, 컬러 사진을 찍을 수 있다. 또한, 다중 분광 이미지화 영역 내의 추가 분광 화상, 편광 정보, 더 큰 동적 범위 등과 같은 부가 정보를 갖는 화상의 사진을 찍을 수 있다.

[0055] 상술한 예에 의하면, 서로에 관한 부분 화상을 전체적으로 기록할 뿐만 아니라 다른 것에 관해 화상의 각 픽셀을 기록하는 것도 가능해질 수도 있다. 마이크로 화상의 해독은 본질적으로 자동으로 균형이 무너진다. 따라서, 다양한 마이크로화상이 상이하게 왜곡될 수도 있어, 광학 시스템에 의해 제한된 요건이 확실히 감소된다.

광학 소자(14)는 설계가 보다 간단해질 수 있고 보다 작거나 보다 평평해질 수 있으며, 제조 허용 범위(manufacturing tolerance)는 보다 커질 수 있고, 이 모든 것은 결과적으로 상기 실시예의 제조 비용을 감소시키고 설계 크기를 줄일 수도 있다.

[0056] 상기 실시예는 이동 전화, 화상 회의 시스템과 같은 다양한 분야의 애플리케이션, 의료 애플리케이션 분야, 로봇 공학, 기계 시각(machine-vision) 애플리케이션, 차량 카메라 및 원격 감지, 특히 다중 분광 이미징 분야의 카메라 시스템에 채용될 수 있다. 시스템의 관점에서, 상술한 실시예는 다중 조리개(multi-aperture) 이미지화 시스템을 구비하는 카메라 및 카메라 어레이(즉 넷 개의 카메라를 구비하는 시스템)에 의해 적용될 수 있다. 한편, 상술한 채널 각각은 명확히 하나의 카메라로 개별적으로 형성될 수 있으며, 이 경우, 상술한 이미지 센서(12)는 그 자체가 각기 서브영역(24_1~24_4)을 형성할 카메라의 개별 칩으로 분리(break down)되고, 광학 소자(14)는 카메라의 개별 렌즈로 분리될 것이다.

[0057] 비록 장치와 관련하여 몇개의 형태를 설명했지만, 상기 형태는 해당하는 방법의 기술을 나타내는 것으로도 이해되는 것이며, 그래서 장치의 블록 또는 구성요소는 해당하는 방법 단계 또는 방법 단계의 특징으로서 이해될 수도 있다. 거기에 유추하면, 방법 단계 또는 그와 관련하여 설명된 형태도 해당 장치의 해당 블록 또는 세부 내용 또는 특징을 나타낸다

[0058] 특정 구현 요건에 따르면, 본 발명의 실시예는 하드웨어 또는 소프트웨어로 구현될 수 있다. 예를 들어 플로피 디스크, DVD, 블루레이 디스크, CD, ROM, PROM, EPROM, EEPROM 또는 플래시 메모리, 하드 디스크 또는 기타 자기 또는 광학 메모리와 같은 디지털 저장 매체를 이용하여 구현(implementation)이 수행되며, 디지털 저장 매체는 그 위에 저장되어 각각의 방법이 수행되도록 프로그래밍 가능한 컴퓨터 시스템과 협력 또는 설질적으로 협력할 수 있는 전기적으로 판독 가능한 제어 신호를 구비한다. 따라서, 디지털 저장 매체는 컴퓨터로 판독될 수 있다. 본 발명에 따른 몇몇 실시예는, 본 명세서에서 설명된 방법 중 어느 하나를 수행하도록 프로그래밍 가능한 컴퓨터 시스템과 협력할 수 있는 전기적으로 판독 가능한 제어 신호를 갖는 데이터 캐리어를 구비한다.

[0059] 일반적으로, 본 발명의 실시예는 컴퓨터 프로그램 제품이 컴퓨터 상에서 실행될 때 본 방법 중 하나를 수행하도록 작동하는 프로그램 코드를 구비하는 컴퓨터 프로그램 제품으로서 구현될 수 있다. 프로그램 코드는 또한 예를 들어 기계 판독 가능한 캐리어에 저장될 수 있다.

[0060] 다른 실시예는 본 명세서에서 설명된 방법 중 어느 하나를 수행하는 컴퓨터 프로그램을 구비하되, 상기 컴퓨터 프로그램은 기계 판독 가능 캐리어 상에 저장된다.

[0061] 환언, 본 창의적인 방법의 실시예는 컴퓨터 프로그램이 컴퓨터 상에서 실행될 때 본 명세서에서 설명된 방법 중 하나를 수행하는 프로그램 코드를 구비하는 컴퓨터 프로그램이다. 본 창의적인 방법의 또 다른 실시예는 본 명세서에서 설명된 방법 중 하나를 수행하는 컴퓨터 프로그램이 그 위에 저장된 데이터 캐리어(또는 디지털 저장 매체 또는 컴퓨터 판독 가능한 매체)이다.

[0062] 본 창의적인 방법의 또 다른 실시예는 본 명세서에서 설명된 방법 중 하나를 수행하는 컴퓨터 프로그램을 나타내는 데이터 스트림 또는 일련의 신호이다. 데이터 스트림 또는 일련의 신호는 예를 들어 데이터 통신 링크(예를 들어, 인터넷)를 통해 전송되도록 구성될 수 있다.

[0063] 또 다른 실시예는 처리 수단, 예를 들어, 본 명세서에서 설명된 방법 중 하나를 수행하도록 구성되거나 또는 적용된 컴퓨터 또는 컴퓨터 프로그래밍 가능한 로직 디바이스를 구비한다.

[0064] 또 다른 실시예는 그 위에 설치되어 본 명세서에서 설명한 방법 중 하나을 수행하는 컴퓨터 프로그램을 갖는 컴퓨터를 포함한다.

[0065] 몇몇 실시예에서, 프로그래밍 가능한 로직 디바이스(예를 들어, FPGA(field-programmable gate array))는 본 명세서에서 설명한 방법의 일부 또는 모든 기능을 수행하는 데 이용될 수 있다. 몇몇 실시예에서, FPGA는 본 명세서에서 설명한 방법 중 하나를 수행하는 마이크로프로세서와 협력할 수 있다. 일반적으로, 몇몇 실시예에서 본 방법은 임의의 하드웨어 디바이스에 의해 수행된다. 이것은 컴퓨터 프로세서(CPU)와 같이 일반적으로 적용될 수 있는 하드웨어이거나 또는 본 방법에 특화된 하드웨어(예를 들어, ASIC)일 수 있다.

[0066] 상술한 실시예는 단지 본 발명의 원리를 예시한 것이다. 본 명세서에서 설명된 배열과 세부 내용의 수정 및 변형은 당업자에게 명확한 것으로 이해되는 것이다. 따라서, 실시예의 기술 및 설명에 의해 본 명세서에서 제공하는 특정한 세부 내용보다는 이하의 청구범위의 범주에 의해서만 본 발명이 제한되어야 한다.

부호의 설명

[0067] 10 : 화상 캡처 장치 12 : 이미지 센서

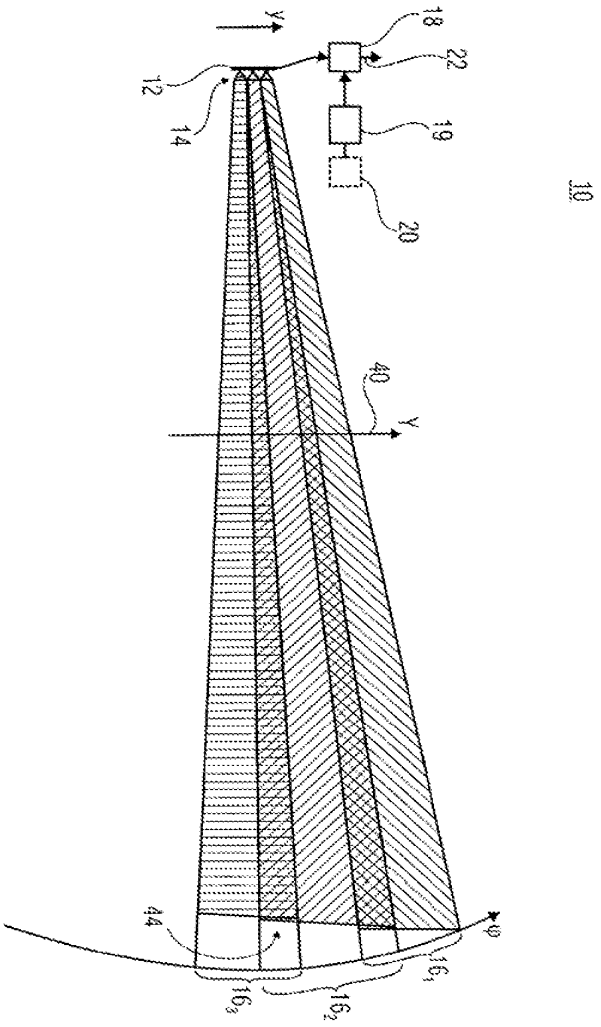
14 : 광학 소자 16_1 ~ 16_3 : 입체각 범위

18 : 보간기(interpolator) 19 : 연관기(associator)

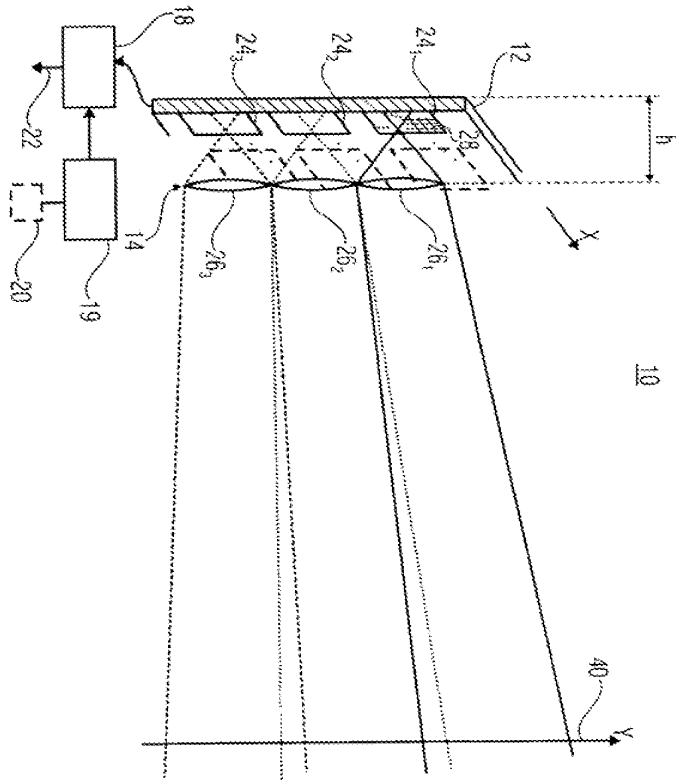
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도면

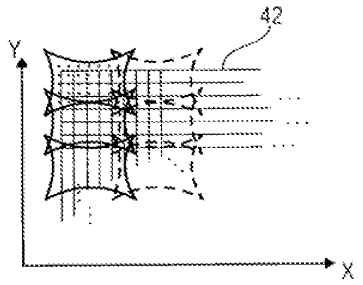
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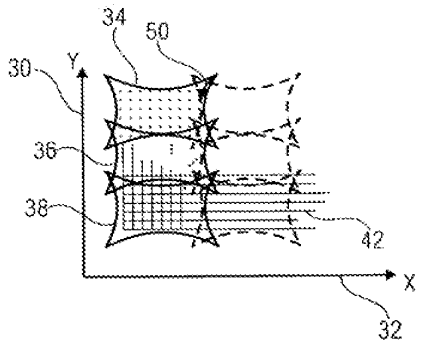
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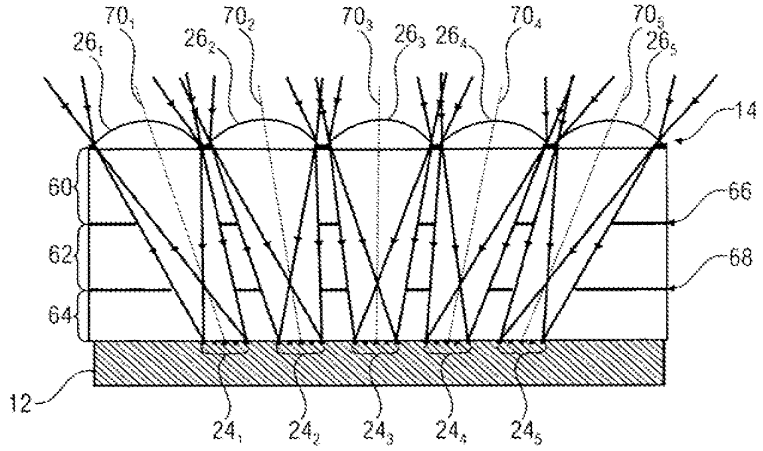
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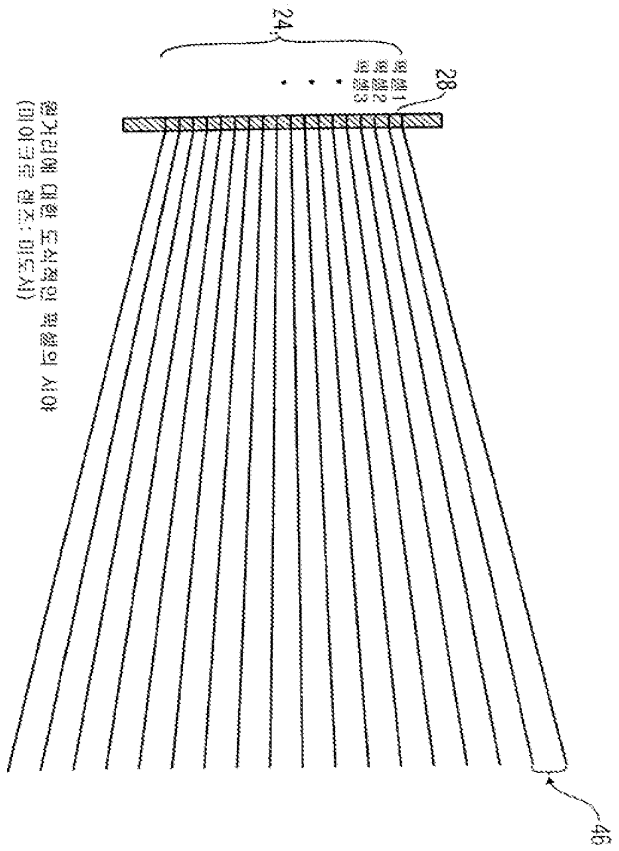
도면3b


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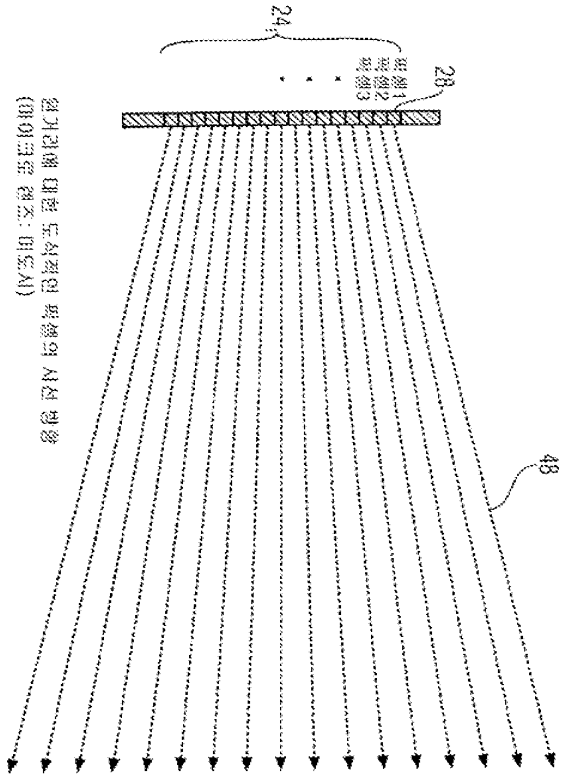
도면4


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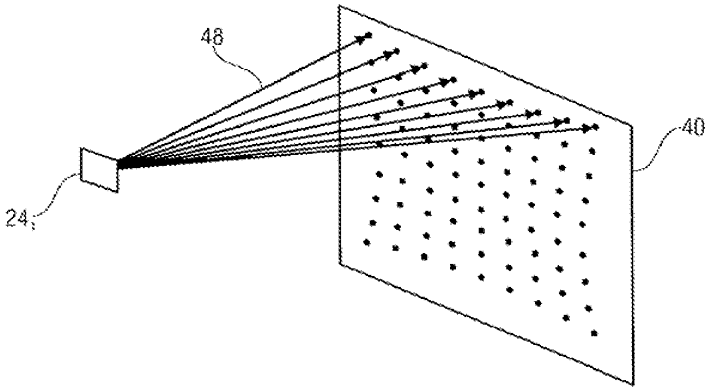
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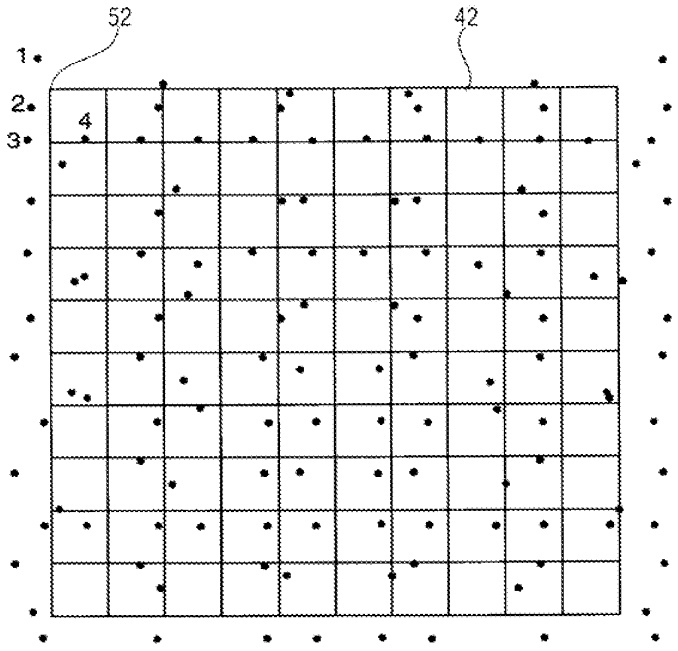
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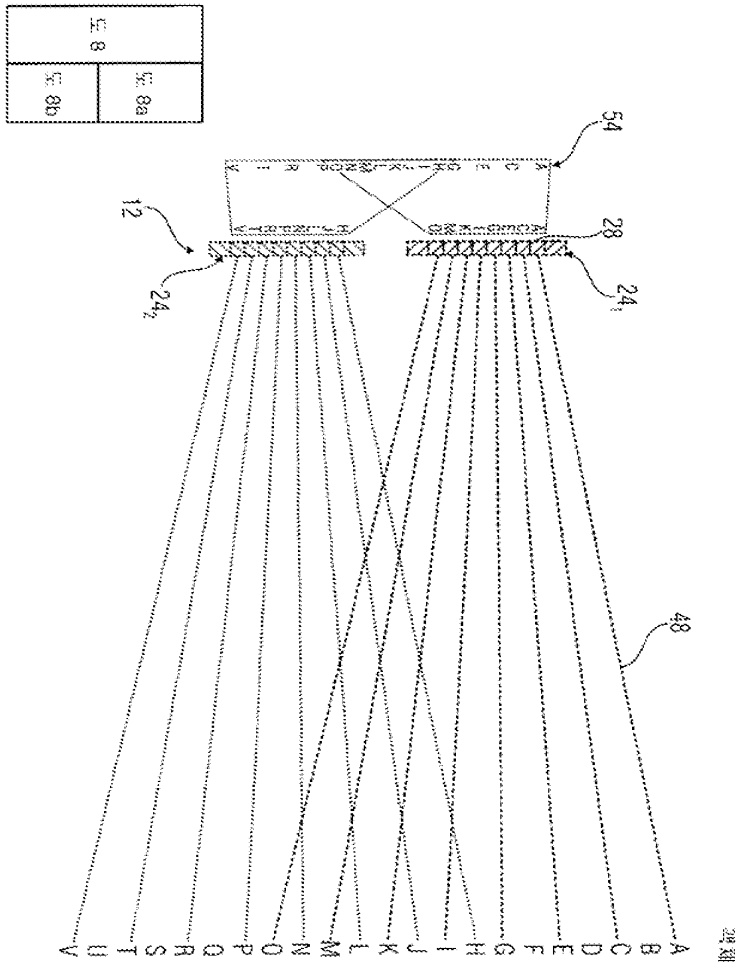
도면6



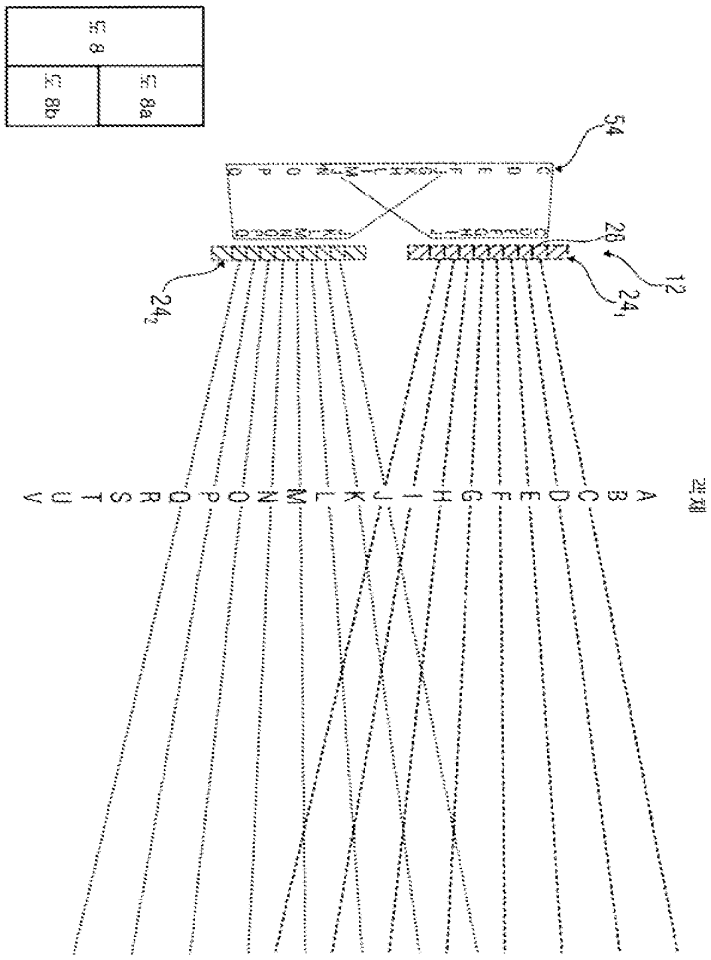
도면7



도면8a



도면8b



Espacenet

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MULTI-CAMERA SYSTEM USING FOLDED OPTICS

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Applicant(s): QUALCOMM INC [US] ± (퀄컴 인코포레이티드)

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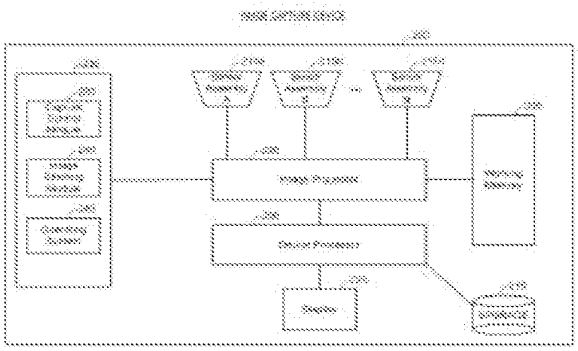
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Priority number(s): US201261716339P 20121019 ; US201313837098 20130315 ; WO2013US64381 20131010

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Abstract not available for KR20150072439 (A)
Abstract of corresponding document: US2014111650 (A1)

Described herein are methods and devices that employ a plurality of image sensors to capture a target image of a scene. As described, positioning at least one reflective or refractive surface near the plurality of image sensors enables the sensors to capture together an image of wider field of view and longer focal length than any sensor could capture individually by using the reflective or refractive surface to guide a portion of the image



scene to each sensor. The different portions of the scene captured by the sensors may overlap, and may be aligned and cropped to generate the target image.

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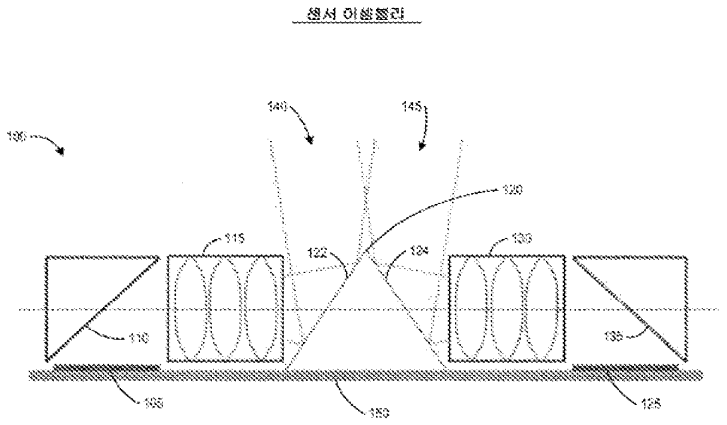
전체 청구항 수 : 총 21 항

(54) 발명의 명칭 **폴드형 광학계를 이용한 다중-카메라 시스템**

(57) 요 약

본 명세서에서는 장면의 타겟 이미지를 캡처하기 위해 복수의 이미지 센서들을 채용하는 방법들 및 디바이스들이 기술된다. 기술된 바와 같이, 복수의 이미지 센서들 부근에 적어도 하나의 반사 또는 굴절 면을 포지셔닝시키는 것은 센서들이, 각 센서로 이미지 장면의 일부분을 가이드하기 위해 반사 또는 굴절 면을 이용함으로써 임의의 센서가 개별적으로 캡처하는 것보다 더 긴 초점 길이 및 더 넓은 시야의 이미지들을 함께 캡처하는 것을 가능하게 한다. 센서들에 의해 캡처된 장면의 상이한 부분들은 오버랩될 수도 있고, 정렬 및 코로케이팅되어 타겟 이미지를 생성할 수도 있다.

대 표 도



(52) CPC특허분류
H04N 5/2254 (2013.01)
H04N 5/23296 (2013.01)
H04N 7/18 (2013.01)

명 세 서

청구범위

청구항 1

장면의 타겟 이미지를 캡처하기 위한 이미지 캡처 시스템으로서,

복수의 이미지 센서들로서, 상기 복수의 이미지 센서들의 각각은 복수의 시야들 (fields of view) 중 하나를 가지고, 상기 복수의 시야들의 각각은 상기 장면의 실질적으로 상이한 부분을 포함하는, 상기 복수의 이미지 센서들;

복수의 렌즈 어셈블리들로서, 각 렌즈 어셈블리는 상기 복수의 이미지 센서들 중의 하나에 대응하는, 상기 복수의 렌즈 어셈블리들;

상기 장면의 적어도 일부분을 포함하는 광을 상기 복수의 렌즈 어셈블리들 중의 적어도 하나를 통과하도록 지향시키도록 포지셔닝된 주변;

복수의 부면들로서, 상기 부면들의 각각은 상기 복수의 렌즈 어셈블리들 중의 하나로부터의 상기 광의 적어도 일부분을 상기 복수의 이미지 센서들 중의 하나로 지향시키고, 상기 복수의 이미지 센서들의 각각은 복수의 부분 이미지들 중 하나를 캡처하며, 상기 복수의 부분 이미지들의 각각은 상기 복수의 시야들 중 하나에 대응하는, 상기 복수의 부면들; 및

상기 복수의 부분 이미지들을 상기 타겟 이미지로 어셈블링하도록 구성된 프로세싱 모듈을 포함하는, 이미지 캡처 시스템.

청구항 2

제 1 항에 있어서,

실질적으로 평평한 기판을 더 포함하는, 이미지 캡처 시스템.

청구항 3

제 2 항에 있어서,

상기 복수의 이미지 센서들은 상기 기판 상에서 서로에 대해 인접하여 측방으로 배치되는, 이미지 캡처 시스템.

청구항 4

제 2 항에 있어서,

상기 복수의 이미지 센서들은 상기 기판 상에서 2 열들로 배열되고, 상기 주변은 상기 2 열들 사이에 포지셔닝되는, 이미지 캡처 시스템.

청구항 5

제 2 항에 있어서,

상기 복수의 이미지 센서들은 상기 기판 상에서 상기 주변 주위로 원형으로 배열되는, 이미지 캡처 시스템.

청구항 6

제 1 항에 있어서,

상기 주변은 상기 광을 반사시키도록 구성된 프리즘을 포함하는, 이미지 캡처 시스템.

청구항 7

제 6 항에 있어서,

상기 프리즘은 복수의 면들을 포함하고, 상기 복수의 면들의 각각은 상기 복수의 시야들 중 하나를 포함하는 광

의 일부분을 상기 복수의 렌즈 어셈블리들 중의 하나를 향해 반사시키는, 이미지 캡처 시스템.

청구항 8

제 1 항에 있어서,

상기 주변은 거울을 포함하는, 이미지 캡처 시스템.

청구항 9

제 1 항에 있어서,

상기 주변은 복수의 반사 면들을 포함하고, 상기 복수의 반사 면들의 각각은 상기 복수의 시야들 중 하나를 포함하는 광의 일부분을 상기 복수의 렌즈 어셈블리들 중의 하나를 향해 반사시키는, 이미지 캡처 시스템.

청구항 10

제 1 항에 있어서,

상기 복수의 부면들 각각은 반사 면을 포함하는, 이미지 캡처 시스템.

청구항 11

장면의 타겟 이미지를 캡처하는 방법으로서,

복수의 이미지 센서들을 제공하는 단계로서, 상기 복수의 이미지 센서들의 각각은 복수의 시야들 중 하나를 가지고, 상기 복수의 시야들의 각각은 상기 장면의 실질적으로 상이한 부분을 포함하는, 상기 복수의 이미지 센서들을 제공하는 단계;

복수의 렌즈 어셈블리들을 제공하는 단계로서, 각 렌즈 어셈블리는 상기 복수의 이미지 센서들 중의 하나에 대응하는, 상기 복수의 렌즈 어셈블리들을 제공하는 단계;

상기 장면의 적어도 일부분을 포함하는 광을 적어도 하나의 주변을 이용하여 상기 복수의 렌즈 어셈블리들의 각각을 향해 지향시키는 단계;

상기 복수의 렌즈 어셈블리들의 각각으로부터의 상기 광을 복수의 부면들을 이용하여 상기 복수의 이미지 센서들 중의 대응하는 이미지 센서를 향해 지향시키는 단계;

복수의 부분 이미지들을 캡처하는 단계로서, 상기 복수의 부분 이미지들의 각각은 상기 복수의 이미지 센서들 중의 하나에 의해 캡처되고 상기 복수의 시야들 중 하나에 대응하는, 상기 복수의 부분 이미지들을 캡처하는 단계; 및

상기 복수의 부분 이미지들을 상기 타겟 이미지로 어셈블링하는 단계를 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 12

제 11 항에 있어서,

상기 복수의 부분 이미지들을 상기 타겟 이미지로 어셈블링하는 단계는,

상기 복수의 부분 이미지들을 결합 이미지로 결합하는 단계; 및

상기 타겟 이미지를 생성하기 위해 원하는 에스펙트 비에 따라 상기 결합 이미지를 크로핑 (cropping) 하는 단계를 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 13

제 11 항에 있어서,

상기 복수의 부분 이미지들을 상기 타겟 이미지로 어셈블링하는 단계는,

상기 복수의 부분 이미지들에서 적어도 하나의 오버랩 영역을 결정하는 단계; 및

상기 적어도 하나의 오버랩 영역에 적어도 부분적으로 기초하여 상기 복수의 부분 이미지들을 정렬시킴으로써

상기 장면을 포함하는 정렬된 이미지를 생성하는 단계를 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 14

제 13 항에 있어서,

상기 타겟 이미지를 생성하기 위해 원하는 에스펙트 비에 따라 상기 정렬된 이미지를 프로핑하는 단계를 더 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 15

제 11 항에 있어서,

상기 복수의 렌즈 어셈블리들을 이용하여 상기 복수의 부분 이미지들을 포커싱하는 단계를 더 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 16

제 11 항에 있어서,

상기 장면의 적어도 일부분을 포함하는 광을 상기 복수의 렌즈 어셈블리들의 각각을 향해 지향시키는 단계는, 적어도 하나의 반사 면을 이용하여 상기 광을 반사시키는 단계를 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 17

제 16 항에 있어서,

상기 적어도 하나의 반사 면을 이용하여 상기 광을 반사시키는 단계는, 상기 복수의 시야들 중 하나를 포함하는 상기 광의 일부분을 복수의 반사 면들을 이용하여 상기 복수의 렌즈 어셈블리들의 각각을 향해 반사시키는 단계를 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 18

제 11 항에 있어서,

상기 장면의 적어도 일부분을 포함하는 광을 상기 복수의 렌즈 어셈블리들의 각각을 향해 지향시키는 단계는, 적어도 하나의 프리즘을 이용하여 상기 광을 굴절시키는 단계를 포함하는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 19

제 18 항에 있어서,

상기 적어도 하나의 프리즘을 이용하여 상기 광을 굴절시키는 단계는, 상기 광을 상기 프리즘의 복수의 면들을 통해 굴절시키는 단계를 포함하고,

상기 복수의 시야들의 각각의 시야를 포함하는 상기 광의 일부분은 상기 복수의 렌즈 어셈블리들 중의 하나를 향해 상기 복수의 면들 중의 하나를 통해 굴절되는, 장면의 타겟 이미지를 캡처하는 방법.

청구항 20

명령들을 포함하는 비-일시적 컴퓨터 판독가능 매체로서,

상기 명령들은 프로세서에 의해 실행될 때,

복수의 이미지 센서들을 이용하여 타겟 이미지 장면의 복수의 부분들의 이미지 데이터를 캡처하는 단계로서, 상기 복수의 이미지 센서들의 각각은, 상기 장면의 적어도 일부분을 포함하는 광을 적어도 하나의 주면으로부터 복수의 렌즈 어셈블리들 중의 하나를 통과하도록 지향시킨 다음 그 광을 복수의 부면들 중 하나에서 반사시킴으로써 결정된 복수의 실질적으로 상이한 시야들 중 하나를 가지고, 상기 타겟 이미지의 상기 복수의 부분들의 각각은 상기 복수의 시야들 중 하나에 대응하며, 제 1 시야 및 제 2 시야는 상기 장면을 포함하는 광을 제 1 및 제 2 이미지 센서들을 향해 반사 또는 굴절시키도록 구성된 적어도 하나의 면에 적어도 부분적으로 기초하여 결

정되는, 상기 복수의 이미지 센서들을 이용하여 타겟 이미지 장면의 복수의 부분들의 이미지 데이터를 캡처하는 단계; 및

상기 타겟 이미지의 상기 복수의 부분들을 상기 타겟 이미지로 결합하는 단계

를 포함하는 방법을 수행하는, 비-일시적 컴퓨터 판독가능 매체.

청구항 21

장면의 타겟 이미지를 캡처하기 위한 이미지 캡처 시스템으로서,

타겟 이미지 장면의 적어도 일부분을 포함하는 광을 재지향시키는 수단;

복수의 부분 이미지들을 포거상하는 수단으로서, 상기 복수의 부분 이미지들의 각각은 상기 장면의 실질적으로 상이한 부분을 각각 포함하는 복수의 시야들 중 하나에 대응하는, 상기 복수의 부분 이미지들을 포거상하는 수단;

상기 복수의 부분 이미지들을 캡처하는 수단; 및

상기 복수의 부분 이미지들을 상기 타겟 이미지로 결합하는 수단을 포함하는, 이미지 캡처 시스템.

발명의 설명

기 술 분 야

[0001] 본 개시물은 다중-카메라 어레이를 포함하는 이미징 시스템들 및 방법들에 관한 것이다. 특히, 본 개시물은 이미지 품질을 유지 또는 향상시키면서 저-프로필 이미징 시스템들 및 모바일 디바이스들을 가능하게 하는 시스템들 및 방법들에 관한 것이다.

배 경 기 술

[0002] 모바일 전화기들 및 태블릿 컴퓨팅 디바이스들과 같은 많은 모바일 디바이스들은 스틸 및/또는 비디오 이미지들을 캡처하기 위해 사용자에 의해 작동될 수도 있는 카메라들을 포함한다. 모바일 디바이스들은 통상적으로 비교적 작도록 설계되기 때문에, 카메라 또는 이미징 시스템들을 저-프로필 모바일 디바이스들 유지하기 위해 가능한 한 얇게 설계하는 것이 중요해질 수 있다. 다양한 종래의 디바이스들에서, 모바일 디바이스들의 두께는, 이미징 센서를 그것의 측면으로 돌리고 광선들을 그 센서로 꺾게 하기 위해 반사 디바이스들을 이용함으로써 가능한 한 작게 유지된다. 하지만, 이 특별한 솔루션 (solution) 은, 이미징 센서의 폭 및 픽셀 피치가 카메라의 최고 해상도를 결정할 수도 있기 때문에, 매우 권고하지는 않다.

[0003] 다른 종래의 디바이스들에서, 모바일 디바이스의 두께는 이미징 시스템의 초점 길이를 짧게 함으로써 가능한 한 작게 유지된다. 하지만, 시스템의 초점 길이가 가능한 한 짧도록 설계되는 경우에 여러 문제점들이 발생할 수 있다. 예를 들어, 초점 길이와 시스템의 시야는 역의 관계가 있기 때문에, 초점 길이를 짧게 하는 것은, 이미지가 자연스러운 이미지로부터 예컨대 약 60 도 이상의 시야로 자연스럽지 못한 넓은 시야 이미지로 바뀔 수도 있을 정도로 시야를 증가시킬 수도 있다. 또한, 초점 길이가 감소함에 따라 렌즈 롤-오프 (roll-off), 예컨대, 이미지의 중앙에 비해 이미지의 에지 부근에서의 광 또는 휘도의 손실이 증가할 수도 있다. 따라서, 모바일 디바이스들에서의 이미징 시스템들의 초점 길이가 감소됨에 따라, 이미지 품질은 바람직하지 않은 렌즈 롤-오프로 인해 열화될 수도 있다.

[0004] 또한, 다양한 모바일 디바이스들에서의 이미징 시스템들의 변조 전달 함수 (modulation transfer function; MTF) 는 이미지의 중앙에 비해 이미지의 에지 부근에서 보다 낮은 해상도를 생성할 수도 있고, 이는 MTF 롤-오프로서 거칭될 수도 있다. MTF 롤-오프는 또한 초점 길이에 대해 역의 관계일 수도 있기 때문에, 모바일 디바이스들에서의 감소된 초점 길이는 이미지의 에지들에서의 해상도를 감소시킬 수도 있다. 또한, 보다 짧은 초점 길이들은 렌즈의 주 광선의 입사각을 증가시킬 수도 있고, 이는 또한 픽셀들 사이의 증가된 광 및 전기적 크로스토크 (crosstalk) 및 더 낮은 센서 MTF 성능을 포함하는 바람직하지 않은 아티팩트들 (artifacts) 을 생성할 수 있다. 따라서, 이미지 품질을 유지하면서 모바일 디바이스들에서의 이미징 시스템들의 두께를 감소시키는 것이 어로울 수 있다.

발명의 내용

바람직한 실시예의 상세한 설명

[0005] 본 명세서에서 기술된 폴드형 (folded) 광학 센서 어레이들 및 이미지 캡처 기술들은 초점 길이 (focal length)를 짧게 하는 것 또는 센서 어레이의 시야 (field of view)에 걸쳐 이미지의 해상도를 감소시키는 것 없이 저-프로필 (low-profile) 이미지 캡처 (capture) 디바이스들의 형성을 허용한다. 주 및 부 면을 이용하여 어레이에서 각 센서를 향해 광을 재지향시킴으로써, 그리고, 주 및 부 면들 사이에서 입사 광 (incoming light)을 포커싱하기 위해 사용되는 렌즈 어셈블리들을 포지셔닝 (positioning) 시킴으로써, 센서 어레이는 렌즈 어셈블리들에 대해 직교하는 평평한 기판 (flat substrate) 상에 포지셔닝될 수도 있다. 보다 긴 초점 길이는 광학 줌과 같은 특징들을 구현하는 것, 및 보다 많은 광학 엘리먼트들을 부가하는 것과 같이, 전통적인 모바일 카메라에 의해 통상적으로 부여되는 보다 많은 공간을 필요로하는 보다 복잡한 광학들을 통합하는 것을 가능하게 한다. 카메라의 각도 해상도를 지칭하고 카메라가 얼마나 잘 멀리 떨어진 곳의 물체들을 해상하는지를 결의하는 카메라 예류덕 (acuity)는 초점 길이에 비례하고 따라서 보다 긴 카메라들로부터 직접 혜택이 있다.

[0006] 실시형태들의 일부는 타겟 이미지를 포함하는 입사 광을 어레이에서의 센서들에 의한 캡처를 위해 다수의 부분들로 분할하기 위해 예를 들어 다수의 면들을 갖는 중앙 거울을 채용할 수도 있다. 다른 실시형태들은 다수의 면들 (facets)을 갖는 프리즘을 채용할 수도 있고, 여기서, 각 면은 타겟 이미지를 포함하는 광의 일부분을 어레이에서의 센서를 향해 지향시킨다. 분할 광 (split light)의 각 부분은 렌즈 어셈블리를 통과하여 센서 바로 위 또는 아래에 포지셔닝된 면에서 반사되어, 각 센서가 이미지의 일부분을 캡처할 수도 있다. 몇몇 상황들에서, 어레이에서의 각 센서는 어레이에서의 이웃하는 (neighboring) 센서들에 의해 캡처된 부분들과 약간 오버랩 (overlap)되는 이미지의 부분을 캡처할 수도 있고, 이들 부분들은 예를 들어 이미지 스티칭 (image stitching) 기법들에 의해 타겟 이미지로 어셈블링될 수도 있다.

[0007] 일 실시형태에 따르면, 이미지 캡처 시스템은, 복수의 이미지 센서들로서, 복수의 이미지 센서들의 각각은 복수의 시야들 (fields of view) 중 하나를 가지고, 복수의 시야들의 각각은 장면 (scene)의 실질적으로 (substantially) 상이한 부분을 포함하는, 상기 복수의 이미지 센서들; 복수의 렌즈 어셈블리들로서, 각 렌즈 어셈블리는 복수의 이미지 센서들 중의 하나에 대응하는, 상기 복수의 렌즈 어셈블리들; 장면의 적어도 일부분을 포함하는 광을 복수의 렌즈 어셈블리들 중 적어도 하나를 통과하도록 지향 (direct)시키도록 포지셔닝된 주 면 (primary surface); 복수의 부면들 (secondary surfaces) 로서, 부면들의 각각은 광의 적어도 일부분을 복수의 렌즈 어셈블리들 중의 하나로부터 복수의 이미지 센서들 중의 하나로 지향시키고, 복수의 이미지 센서들의 각각은 복수의 부분 이미지들 중 하나를 캡처하며, 복수의 부분 이미지들의 각각은 복수의 시야들 중 하나에 대응하는, 상기 복수의 부면들; 및 복수의 부분 이미지들을 타겟 이미지로 어셈블링하도록 구성된 프로세싱 모듈을 포함한다.

[0008] 이미지 캡처 시스템은 선택적으로 광학적 기판을 더 포함할 수도 있다. 복수의 이미지 센서들, 복수의 렌즈 어셈블리들, 주면 및 부면들은 다양한 적합한 구성들로 기판 상에 탑재될 수도 있다. 주면은 하나 이상의 반사 면을 포함할 수도 있고, 일부 실시형태들에서는 타겟 이미지 장면을 포함하는 입사광을 재지향 (redirect)시키도록 구성된 하나 이상의 면들을 포함하는 프리즘일 수도 있다.

[0009] 다른 실시형태에 따르면, 타겟 이미지 장면을 캡처하는 방법이 제공되고, 이 방법은, 복수의 이미지 센서들을 제공하는 단계로서, 복수의 이미지 센서들의 각각은 복수의 시야들 중 하나를 가지고, 복수의 시야들의 각각은 장면의 실질적으로 상이한 부분을 포함하는, 상기 복수의 이미지 센서들을 제공하는 단계; 복수의 렌즈 어셈블리들을 제공하는 단계로서, 각 렌즈 어셈블리는 복수의 이미지 센서들 중의 하나에 대응하는, 상기 복수의 렌즈 어셈블리들을 제공하는 단계; 장면의 적어도 일부분을 포함하는 광을 적어도 하나의 주면을 이용하여 복수의 렌즈 어셈블리들의 각각을 향해 지향시키는 단계; 복수의 렌즈 어셈블리들의 각각으로부터의 광을 복수의 부면들을 이용하여 복수의 이미지 센서들 중의 대응하는 이미지 센서를 향해 지향시키는 단계; 복수의 부분 이미지들을 캡처하는 단계로서, 복수의 부분 이미지들의 각각은 복수의 이미지 센서들 중의 하나에 의해 캡처되고 복수의 시야들 중 하나에 대응하는, 상기 복수의 부분 이미지들을 캡처하는 단계; 및 복수의 부분 이미지들을 타겟 이미지로 어셈블링 (assembling)하는 단계를 포함한다.

도면의 간단한 설명

[0010] 이미지 캡처의 다양한 양태들이 첨부 도면들에서 제한적 방식이 아닌 예시적인 방식으로 도시된다.

도 1a 는 폴드형 광학 센서 어셈블리의 일 실시형태의 횡단 측면도를 나타낸다.

도 1b 는 도 1a 의 폴드형 광학 센서 어셈블리의 투영된 시야들의 일 실시형태의 상면도를 나타낸다.

도 2 는 이미지 캡처 디바이스의 하나의 실시형태의 블록도를 나타낸다.

도 3a 는 폴드형 광학 센서 어레이의 일 실시형태의 블록도를 나타낸다.

도 3b 는 도 3a 의 폴드형 광학 센서 어레이의 일 실시형태의 투시도를 나타낸다.

도 3c 는 도 3a 및 도 3b 의 폴드형 광학 센서 어레이의 투영된 시야들의 하나의 실시형태의 개략도를 나타낸다.

도 4 는 폴드형 광학 센서 어셈블리의 컴포넌트들의 각도 관계를 보여주는 폴드형 광학 센서 어셈블리의 하나의 실시형태의 횡단 측면도를 나타낸다.

도 5a 는 폴드형 광학 센서 어레이의 다른 실시형태의 투시도를 나타낸다.

도 5b 는 폴드형 광학 센서 어레이의 또 다른 실시형태의 투시도를 나타낸다.

도 5c 는 도 5a 및 도 5b 의 폴드형 광학 센서 어레이들의 투영된 시야들의 일 실시형태의 개략도를 나타낸다.

도 6a 는 폴드형 광학 센서 어레이의 다른 실시형태의 투시도를 나타낸다.

도 6b 는 도 6a 의 폴드형 광학 센서 어레이의 투영된 시야들의 일 실시형태의 개략도를 나타낸다.

도 7 은 캐스케이드된 폴드형 광학 센서 어레이의 일 실시형태의 블록도를 나타낸다.

도 8 은 폴드형 광학 센서 어셈블리의 다른 실시형태의 횡단 측면도를 나타낸다.

도 9 는 폴드형 광학 이미지 캡처 프로세스의 일 실시형태를 나타낸다.

발명을 실시하기 위한 구체적인 내용

[0011] 본 명세서에서 개시된 구현형태들은 모바일 이미징 애플리케이션들 (mobile imaging applications) 을 위한 시스템들, 방법들 및 장치들을 제공한다. 예를 들어, 본 명세서에서 설명된 바와 같이, 이미지 품질을 유지 또는 향상시키면서 모바일 디바이스들의 폼 팩터 (form factor) 를 감소시키는 것이 바람직할 수 있다. 본 명세서에서 개시된 구현형태들은 이미징 시스템의 시야에 걸쳐 다수의 이미징 센서들 및/또는 다수의 렌즈들을 채용함으로써 이미지 시스템들의 두께를 감소시키기 위해 모바일 디바이스들에서 이용될 수 있다. 다양한 구현들에서, 카메라들 및/또는 이미징 센서들의 어레이는 하나 이상의 반사 면들에 인접 (adjacent) 하여 제공될 수도 있다. 센서들의 어레이는 다수의, 중첩하는 (overlapping) 이미지들을 캡처할 수 있고, 이는 함께 스티치되어 높은 이미지 품질 및 해상도 (resolution) 를 유지하면서 단일 이미지를 형성할 수 있다. 다수의 센서들을 기판 상에서 측방으로 (laterally) 어떠 배치하거나 그 외에 시스템에서 서로 인접하게 배치함으로써, 이미징 시스템의 전체 높이 또는 두께가 감소될 수 있다. 다양한 구현들에서, 개시된 시스템들은 비교적 긴 광학 경로 길이들을 포함하는 소형 폼드형 광학 시스템들일 수도 있다. 초점 길이를 설정적인 방식으로 감소시키지 않음으로써, 감소된 높이의 이미징 시스템을 여전히 유지하면서 상기 설명된 이미지 품질에서의 감소들이 최소화될 수 있다.

[0012] 개시된 개념들의 많은 다른 구현형태들이 가능하다는 것을 이해하여야 한다. 다양한 이점들은 개시된 구현형태들로 달성될 수 있다. 예를 들어, 이미징 시스템을 포함하는 모바일 디바이스의 전체 두께는 모바일 디바이스들에서 사용되는 종래의 이미징 시스템들에 비해 감소될 수 있다. 또한, 센서 어레이의 시야에 걸친 이미지의 해상도가 향상될 수 있고, (예컨대, 해상도가 에지들에서 감소할 수도 있는) 전통적인 카메라들에서 발견되는 해상도에서의 롤-오프를 최소화할 수 있다. 또한, 시스템의 시야에 걸친 다중 렌즈들의 사용은 전체 시야에 걸친 총 유효 해상도를 증가시킬 수 있다. 또한, 다중 렌즈들의 사용은 카메라의 초점 길이를 증가시키고 따라서 카메라의 에퓨티를 증가시킬 수도 있다.

[0013] 다양한 배열들에서, 각 카메라의 시야는 포스트-프로세싱 (post-processing) 후에 초점을 조정하기 위한 능력을 가능하게 하는 것과 같은 특정 목적들을 달성하기 위해 오버랩될 수도 있다. 또한, 하이 다이내믹 레인지 카메라들은 2 개의 동시적 이미지들을 캡처하고 그 다음 그들을 함께 병합 (merge) 하도록 구현될 수 있다. 또한, 렌즈들과 어레이에서의 각 카메라의 센서 사이의 초점 길이를 변화시킴으로써 오토포커스 애플리케이션이 구현될 수 있다. 본 명세서에서 설명된 바와 같이, 다양한 다른 이점들 및 구현형태들이 달성될 수 있다.

[0014] 당해 기술 분야에서 통상의 지식을 가진 자 (이하, '통상의 기술자' 라 함) 는, 이들 실시형태들이 하드웨어, 소프트웨어, 펌웨어, 또는 이들의 임의의 조합으로 구현될 수도 있다는 것을 인식할 것이다. 통상의 기술자는, 정보 및 신호들이 여러 상이한 기술들 및 기법들의 임의의 것을 이용하여 표현될 수도 있다는 것을 이해할 것이다. 예를 들어, 상기 설명 전체를 통해 언급될 수도 있는 데이터, 명령들, 커맨드들, 정보, 신호들, 비트들, 심볼들, 및 칩들은 전압들, 전류들, 전자기파들, 자기 필드들 또는 입자들, 광학 필드들 또는 입자들, 또는 이들의 임의의 조합에 의해 표현될 수도 있다.

[0015] 이하의 설명에서, 특정 상세들은 예들의 완전한 이해를 제공하기 위해 주어진다. 하지만, 통상의 기술자는 예들이 이들 특정 상세들 없이도 실시될 수도 있다는 것을 이해할 것이다. 예를 들어, 전기적 컴포넌트들/디바이스들은 불필요한 상세에서 예들을 모호하게 하지 않도록 블록도들로 보여질 수도 있다. 다른 경우들에서, 이러한 컴포넌트들, 다른 구조들 및 기법들은 예들을 추가적으로 설명하기 위해 상세하게 보여질 수도 있다.

[0016] 예들은 플로우차트, 흐름도, 유한 상태도, 구조도, 또는 블록도로서 묘사되는 프로세스로서 설명될 수도 있다는 것을 또한 유의한다. 비록 플로우차트가 동작들을 순차적인 프로세스로서 설명할 수도 있지만, 많은 동작들은 병행하여 또는 동시에 수행될 수 있고 프로세스는 반복될 수 있다. 또한, 동작들의 순서는 재배열될 수도 있다. 프로세스는 그것의 동작들이 완료될 때 종결된다. 프로세스는 방법, 함수, 절차, 서브루틴, 서브프로그램 등에 대응할 수도 있다. 프로세스가 소프트웨어 함수에 대응하는 경우, 그것의 종결은 함수의 호출 함수 또는 메인 함수로의 복귀에 대응한다.

[0017] 이제 도 1a 및 도 1b 를 참조하면, 예시적인 플드형 광학 다중-센서 어셈블리 (100) 가 이제 보다 자세히 설명될 것이다. 도 1a 에서 보는 바와 같이, 센서 어셈블리 (100) 는 이미지 센서들 (105, 125), 반사 면들 (110, 135), 렌즈 어셈블리들 (115, 130), 중앙 반사 면 (120) 을 포함하고, 이들 모두는 기판 (150) 에 탑재된다.

[0018] 이미지 센서들 (105, 125) 은, 어떤 실시형태들에서, 전하 결합형 디바이스 (CCD), 상보형 금속 산화물 반도체 센서 (CMOS), 또는 광을 수용하고 수용된 이미지에 응답하여 이미지 데이터를 생성하는 임의의 다른 이미지 감지 디바이스를 포함할 수도 있다. 이미지 센서들 (105, 125) 은 정지 사진의 이미지 데이터를 획득할 수도 있고, 또한 캡처된 비디오 스트림에서의 모션에 관한 정보를 제공할 수도 있다. 센서들 (105 및 125) 은 개별 센서들일 수도 있고, 또는, 3x1 어레이와 같은 센서들의 어레이를 나타낼 수도 있다. 하지만, 통상의 기술자에 의해 이해될 바와 같이, 임의의 적합한 센서들의 어레이가 개시된 구현형태들에서 사용될 수도 있다.

[0019] 센서들 (105, 125) 은 도 1a 에서 도시된 바와 같이 기판 (150) 상에 탑재될 수도 있다. 일부 실시형태들에서, 모든 센서들은 평행한 기판 (150) 에 탑재됨으로써 하나의 평면 상에 있을 수도 있다. 기판 (150) 은 임의의 적합한 실질적으로 평평한 재료일 수도 있다. 중앙 반사 면 (120) 및 렌즈 어셈블리들 (115, 130) 역시 기판 (150) 상에 탑재될 수도 있다. 센서 어레이 또는 어레이들, 복수의 렌즈 어셈블리들, 및 복수의 주 및 부 반사 또는 굴절 면들을 탑재하기 위한 다수의 구성들이 가능하다.

[0020] 일부 실시형태들에서, 중앙 반사 면 (120) 은 타겟 이미지 장면으로부터의 광을 센서들 (105, 125) 을 향해 재지향시키도록 이용될 수도 있다. 중앙 반사 면 (120) 은 거울 또는 복수의 거울들일 수도 있고, 평평할 수도 있고 또는 입사 광을 이미지 센서들 (105, 125) 로 적절하게 재지향시키기 위해 필요한 형상으로 될 수도 있다. 예를 들어, 일부 실시형태들에서, 중앙 반사 면 (120) 은 입사 광선들을 렌즈 어셈블리들 (115, 130) 을 통과하여 센서들 (105, 125) 로 반사시키기 위한 사이즈 및 형상의 거울일 수도 있다. 중앙 반사 면 (120) 은 타겟 이미지를 포함하는 광을 다수의 부분들로 분할하고 각 부분을 상이한 센서에 지향시킬 수도 있다. 예를 들어, 중앙 반사 면 (120) 의 제 1 측 (122) 은 제 1 시야 (140) 에 대응하는 광의 일부분을 좌측 센서 (105) 를 향해 보낼 수도 있는 한편, 제 2 측 (124) 은 제 2 시야 (145) 에 대응하는 광의 제 2 부분을 우측 센서 (125) 를 향해 보낸다. 이미지 센서들의 시야들이 함께 적어도 타겟 이미지를 커버한다는 것을 이해하여야 한다.

[0021] 수용 센서들이 복수의 센서들의 어레이의 각각인 일부 실시형태들에서, 중앙 반사 면은 타겟 이미지 장면의 상이한 부분을 센서들의 각각으로 보내도록 서로에 대해 각도를 가진 다수의 반사 면들로 이루어질 수도 있다. 어레이에서의 각 센서는 실질적으로 상이한 시야를 가질 수도 있고, 일부 실시형태들에서, 시야들은 오버랩할 수도 있다. 중앙 반사 면의 어떤 실시형태들은 렌즈 시스템을 설계할 때 자유도 (degree of freedom) 를 증가시키기 위해 복잡한 비-평면형 면들을 가질 수도 있다. 또한, 비록 중앙 면이 반사 면으로서 논의되지만, 다른 실시형태들에서, 중앙 면은 굴절형일 수도 있다. 예를 들어, 중앙 면은 복수의 면들로 구성된 프리즘

일 수도 있고, 여기서, 각 면은 광면을 포함하는 광의 일부분을 센서들 중의 하나를 향해 지향시킨다.

[0022] 중앙 반사 면 (120) 에서 반사된 후에, 광은 렌즈 어셈블리들 (115, 130) 을 통과할 수도 있다. 하나 이상의 렌즈 어셈블리들 (115, 130) 은 중앙 반사 면 (120) 과 센서들 (105, 125) 및 반사 면들 (110, 135) 사이에 제공될 수도 있다. 렌즈 어셈블리들 (115, 130) 은 각 센서를 향해 지향되는 타겟 이미지의 부분을 포커싱하기 위해 이용될 수도 있다.

[0023] 일부 실시형태들에서, 각 렌즈 어셈블리는 하나 이상의 렌즈들 및 렌즈를 하우징 (housing) 을 통해 복수의 상이한 렌즈 포지션들 (positions) 중에서 이동시키기 위한 액추에이터 (actuator) 를 포함할 수도 있다. 액추에이터는 보이스 코일 모터 (VCM), 마이크로-전자 기계 시스템 (MEMS), 또는 형상 메모리 합금 (SMA) 일 수도 있다. 렌즈 어셈블리는 액추에이터를 제어하기 위한 렌즈 드라이버 (lens driver) 를 더 포함할 수도 있다.

[0024] 전통적인 오토 포커스 기법들은 렌즈들 (115, 130) 과 각 센서 어셈블리의 대응하는 센서 (105, 125) 사이의 초점 길이를 변경함으로써 구현될 수도 있다. 일부 실시형태들에서, 이것은 렌즈 배럴 (barrel) 을 이동시킴으로써 달성될 수도 있다. 다른 실시형태들은 렌즈 어셈블리에 대한 거울의 각도를 조정함으로써 또는 중앙 거울을 위 또는 아래로 이동시킴으로써 초점을 조정할 수도 있다. 어떤 실시형태들은 각 센서에 대해 측면 거울들을 이동시킴으로써 초점을 조정할 수도 있다. 이러한 실시형태들은 어셈블리가 각 센서의 초점을 개별적으로 조정하는 것을 허용할 수도 있다. 또한, 일부 실시형태들에 대해, 예를 들어 전체 어셈블리에 대해 액체 렌즈와 같은 렌즈를 배치함으로써, 전체 어셈블리의 초점을 한번에 변경하도록 하는 것이 가능하다. 어떤 구현형태들에서, 카메라 어레이의 초점 포인트를 변화시키기 위해 계산적인 사진촬영술이 이용될 수도 있다.

[0025] 반사 면들 (110 및 135) 과 같은, 다수의 측면 반사 면들이 센서들과 대향하여 중앙 거울 (120) 주위에 제공될 수 있다. 렌즈 어셈블리들을 통과한 후에, 측면 반사 면들 (110, 135) 은 광을 평행한 센서들 (105, 125) 을 향해 아래로 반사시킬 수 있다. 묘사된 바와 같이, 센서 (105) 는 반사 면 (110) 아래에 포지셔닝될 수도 있고, 센서 (125) 는 반사 면 (135) 아래에 포지셔닝될 수도 있다. 하지만, 다른 실시형태들에서, 센서들은 측면 반사 면들 위에 있을 수도 있고, 측면 반사 면들은 광을 위로 반사시키도록 구성될 수도 있다. 각 렌즈 어셈블리로부터의 광이 센서들을 향해 재지향되는 측면 반사 면들 및 센서들의 다른 적합한 구성들이 가능하다. 어떤 실시형태들은 측면 반사 면들 (110, 135) 의 이동이 연관된 센서의 초점 또는 시야를 변화시키는 것을 가능하게 할 수도 있다.

[0026] 도 1b 에서 도시된 바와 같이, 각 센서의 시야 (140, 145) 는 그 센서와 연관된 중앙 거울 (120) 의 면에 의해 대상 공간으로 방향이 돌려질 수도 있다. 각 카메라의 시야가 대상 필드 상의 상이한 로케이션들로 조향될 수 있도록 어레이에서의 프리즘들을 이동 및/또는 거울들을 경사시키기 위해 기계적인 방법들이 채용될 수도 있다. 이것은, 예를 들어, 하이 다이내믹 레인지 카메라를 구현하기 위해, 카메라 시스템의 해상도를 증가시키기 위해, 또는 플렌옵틱스 (plenoptics) 카메라 시스템을 구현하기 위해, 이용될 수도 있다. 각 센서의 (또는 각 3x1 어레이의) 시야는 대상 공간으로 투영될 수도 있고, 각 센서는 그 센서의 시야에 따라 타겟 장면의 일부분을 포함하는 부분 이미지를 캡처할 수도 있다. 일부 실시형태들에서, 대향 센서 어레이들 (105, 125) 에 대한 시야들 (140, 145) 은 소정 양 (150) 만큼 오버랩될 수도 있다. 오버랩 (150) 을 감소시키고 단일 이미지를 형성하기 위해, 아래 설명되는 스티칭 프로세스가 2 개의 대향하는 센서 어레이들 (105, 125) 로부터의 이미지들을 결합하기 위해 이용될 수도 있다. 스티칭 프로세스의 어떤 실시형태들은 부분 이미지들을 함께 스티칭함에 있어 공통적인 포인트들을 식별하기 위해 오버랩 (150) 을 채용할 수도 있다. 충첩하는 이미지들을 함께 스티칭한 후에, 스티칭된 이미지는 최종 이미지를 형성하기 위해 원하는 애스펙트 비 (aspect ratio), 예컨대 4:3 또는 1:1 로 프로젝팅될 수도 있다.

[0027] 도 2 는 하나 이상의 이미지 센서 어셈블리들 (215a-n) 에 연결된 이미지 프로세서 (220) 를 포함하는 컴포넌트들의 셋트를 갖는 디바이스 (200) 의 하이 레벨 블록도를 나타낸다. 이미지 프로세서 (220) 는 또한 작업 메모리 (205), 메모리 (230), 및 디바이스 프로세서 (250) 와 통신하고, 디바이스 프로세서 (250) 는 다시 스토리지 (storage) (210) 및 전자 디스플레이 (225) 와 통신한다.

[0028] 디바이스 (200) 는 셀 전화기, 디지털 카메라, 태블릿 컴퓨터, PDA 등일 수도 있다. 본 명세서에서 기술된 것과 같은 감소된 두께의 이미징 시스템이 이점들을 제공할 수 있을 많은 휴대용 컴퓨팅 디바이스들이 존재한다. 디바이스 (200) 는 또한 정지형 컴퓨팅 디바이스 또는 얇은 이미징 시스템이 유리할 임의의 디바이스일 수도 있다. 디바이스 (200) 상의 사용자에 대해 복수의 애플리케이션들이 이용가능할 수도 있다. 이들 애플리케이션들은 전통적인 사진 및 비디오 애플리케이션들, 하이 다이내믹 레인지 이미징 (high

dynamic range imaging), 파노라믹 포토 및 비디오, 또는 3D 이미지들 또는 3D 비디오와 같은 입체적 이미징을 포함할 수도 있다.

[0029] 이미지 캡처 디바이스 (200) 는 외부 이미지들을 캡처하기 위한 이미지 센서 어셈블리들 (215a-n) 을 포함한다. 이미지 센서 어셈블리들 (215a-n) 은, 도 1a 에 대해 상기 논의된 바와 같이, 센서, 렌즈 어셈블리, 및 타겟 이미지의 일부분을 각 센서로 재지향시키기 위한 주 및 부 반사 또는 굴절 면을 각각 포함할 수도 있다. 일반적으로, N 개의 이미지 센서 어셈블리들 (215a-n) 이 사용될 수도 있고, 여기서, N ≥ 2 이다. 따라서, 타겟 이미지는 N 개의 부분들로 분할될 수도 있고, 여기서, N 센서 어셈블리들의 각 센서는 그 센서의 시야에 따라 타겟 이미지의 하나의 부분을 캡처한다. 하지만, 일부 실시형태들은 오직 하나의 이미지 센서 어셈블리만을 채용할 수도 있고, 이미지 센서 어셈블리들 (215a-n) 은 본 명세서에서 설명된 폴드형 광학 이미징 디바이스의 구현을 위해 적합한 임의의 수의 이미지 센서 어셈블리들을 포함할 수도 있다는 것을 이해할 것이다. 센서들의 수는, 도 4 에 대해 이하 더 자세히 논의되는 바와 같이 시스템의 보다 낮은 z-높이를 달성하기 위해, 또는, 포스트-프로세싱 후에 이미지의 포커스를 조정하는 능력을 가능하게 할 수도 있는, 플렌옵틱스 카메라의 것과 유사한 중첩하는 시야들을 가지는 것과 같은 다른 목적들의 필요성들을 충족시키기 위해, 증가될 수도 있다. 다른 실시형태들은 2 개의 동시적인 이미지들을 캡처하고 그 다음 그들을 함께 병합하는 능력을 가능하게 하는 하이 다이내믹 레인지 카메라들에 적합한 시야 중첩 구성을 가질 수도 있다. 이미지 센서 어셈블리들 (215a-n) 은 캡처된 이미지를 이미지 프로세서 (220) 에 전송하기 위해 카메라 프로세서 (220) 에 커플링될 수도 있다.

[0030] 이미지 프로세서 (220) 는, 이하 보다 자세히 설명될 바와 같이, 고품질의 스티칭된 이미지를 산출하기 위해 타겟 이미지의 N 개의 부분들을 포함하는 수신된 이미지 데이터에 대해 다양한 프로세싱 동작들을 수행하도록 구성될 수도 있다. 프로세서 (220) 는 범용 프로세싱 유닛 또는 이미징 애플리케이션들 (imaging applications) 을 위해 특별히 설계된 프로세서일 수도 있다. 이미징 프로세싱 동작들의 예들은 크로핑 (cropping), (예를 들어 상이한 해상도로의) 스케일링 (scaling), 이미지 스티칭, 이미지 포맷 변환, 컬러 보간, 컬러 프로세싱, 이미지 필터링 (예컨대, 공간 이미지 필터링), 렌즈 아티팩트 또는 결함 보정 등을 포함한다. 프로세서 (220) 는 일부 실시형태들에서 복수의 프로세서들을 포함할 수도 있다. 어떤 실시형태들은 각각의 이미지 센서에 대해 전용되는 프로세서를 가질 수도 있다. 프로세서 (220) 는 하나 이상의 전용 이미지 신호 프로세서들 (ISPs) 또는 프로세서의 소프트웨어 구현일 수도 있다.

[0031] 도시된 바와 같이, 이미지 프로세서 (220) 는 메모리 (230) 및 작업 메모리 (205) 에 접속된다. 예시된 실시형태에서, 메모리 (230) 는 캡처 제어 모듈 (235), 이미지 스티칭 모듈 (240), 및 오퍼레이팅 시스템 (245) 을 저장한다. 이들 모듈들은 다양한 이미지 프로세싱 및 디바이스 관리 태스크들 (tasks) 을 수행하도록 디바이스 프로세서 (250) 의 이미지 프로세서 (220) 를 구성하는 명령들을 포함한다. 작업 메모리 (205) 는 메모리 (230) 의 모듈들에 포함된 프로세서 명령들의 작업 셋트를 저장하기 위해 이미지 프로세서 (220) 에 의해 이용될 수도 있다. 대안적으로, 작업 메모리 (205) 는 또한, 디바이스 (200) 의 동작 동안 생성된 동적 데이터를 저장하기 위해 이미지 프로세서 (220) 에 의해 이용될 수도 있다.

[0032] 상기 언급된 바와 같이, 이미지 프로세서 (220) 는 메모리들에 저장된 수개의 모듈들에 의해 구성된다. 캡처 제어 모듈 (235) 은 이미징 센서 어셈블리들 (215a-n) 의 포커스 포지션을 조정하도록 이미지 프로세서 (220) 를 구성하는 명령들을 포함할 수도 있다. 캡처 제어 모듈 (235) 은 디바이스 (200) 의 전체 이미지 캡처 기능들을 제어하는 명령들을 더 포함할 수도 있다. 예를 들어, 캡처 제어 모듈 (235) 은 이미징 센서 어셈블리들 (215a-n) 을 이용하여 타겟 이미지 장면의 로 (raw) 이미지 데이터를 캡처하도록 이미지 프로세서 (220) 를 구성하기 위한 서브루틴들을 호출하는 명령들을 포함할 수도 있다. 캡처 제어 모듈 (235) 은 그 다음, 센서 어셈블리들 (215a-n) 에 의해 캡처된 N 개의 부분 이미지들에 대해 스티칭 기법을 수행하고 스티칭되고 크로핑된 타겟 이미지를 이미징 프로세서 (220) 로 출력하기 위해 이미지 스티칭 모듈 (240) 을 호출할 수도 있다. 캡처 제어 모듈 (235) 은 또한, 캡처될 장면의 프리뷰 (preview) 이미지를 출력하기 위해 로 이미지 데이터에 대해 스티칭 동작을 수행하기 위해, 그리고, 소정 시간 간격들로 또는 로 이미지 데이터에서의 장면이 변경될 때 프리뷰 이미지를 업데이트하기 위해 이미지 스티칭 모듈 (240) 을 호출할 수도 있다.

[0033] 이미지 스티칭 모듈 (240) 은 캡처된 이미지 데이터에 대해 스티칭 및 크로핑 기법들을 수행하도록 이미지 프로세서 (220) 를 구성하는 명령들을 포함할 수도 있다. 예를 들어, N 개의 센서들 (215a-n) 의 각각은 각 센서의 시야에 따른 타겟 이미지의 부분을 포함하는 부분 이미지를 캡처할 수도 있다. 시야들은 도 1b 에 대해 상기 설명되고 도 3c, 도 4c, 도 5b 및 도 6b 에 대해 이하 설명되는 바와 같이, 오버랩 영역들을 공유할 수도 있다. 단일 타겟 이미지를 출력하기 위해, 이미지 스티칭 모듈 (240) 은 고해상도 타겟 이미지를 생성하

기 위해 다수의 N 개의 부분 이미지들을 결합하도록 이미지 프로세서 (220) 를 구성할 수도 있다. 타겟 이미지 생성은 종래의 이미지 스티칭 기법들을 통해 발생할 수도 있다. 이미지 스티칭의 예들은, 참조에 의해 그 전체가 본원에 통합되는, 미국 특허 출원 번호 제 11/623,050 호 (문서 번호 060170) 에서 발견될 수 있다.

[0034] 예를 들어, 이미지 스티칭 모듈 (240) 은 N 개의 부분 이미지들의 서로에 대한 회전 및 정렬을 결정하기 위해 피처들 (features) 을 매칭 (matching) 시키기 위해 N 개의 부분 이미지들의 에지들을 따라 오버랩 영역들을 비교하기 위한 명령들을 포함할 수도 있다. 각 센서의 시야의 형상 및/또는 부분 이미지들의 최종으로 인해, 결합된 이미지는 불규칙한 형상을 형성할 수도 있다. 따라서, N 개의 부분 이미지들을 정렬 및 결합한 후에, 이미지 스티칭 모듈 (240) 은 예컨대 4:3 직사각형 또는 1:1 정사각형과 같은 원하는 형상 및 에스펙트비로 결합된 이미지를 크로핑하도록 이미지 프로세서 (220) 를 구성하는 서브루틴들을 호출할 수도 있다. 크로핑된 이미지는 스토리지 (210) 에의 저장을 위해 또는 디스플레이 (225) 상에서의 표시를 위해 디바이스 프로세서 (250) 로 전송될 수도 있다.

[0035] 오퍼레이팅 시스템 모듈 (245) 은 디바이스 (200) 의 프로세싱 자원 및 작업 메모리 (205) 를 관리하도록 이미지 프로세서 (220) 를 구성한다. 예를 들어, 오퍼레이팅 시스템 모듈 (245) 은 이미징 센서 어셈블리들 (215a-n) 과 같은 하드웨어 자원을 관리하기 위한 디바이스 드라이버들을 포함할 수도 있다. 따라서, 일부 실시형태들에서, 상기 논의된 이미지 프로세싱 모듈들에 포함된 명령들은 이들 하드웨어 자원들과 직접 상호작용하지 않을 수도 있지만, 대신에, 오퍼레이팅 시스템 컴포넌트 (270) 에 위치된 표준 서브루틴들 또는 API 들을 통해 상호작용할 수도 있다. 오퍼레이팅 시스템 (245) 내의 명령들은 그 다음 이들 하드웨어 컴포넌트들과 직접 상호작용할 수도 있다. 오퍼레이팅 시스템 모듈 (245) 은 디바이스 프로세서 (250) 와 정보를 공유하도록 이미지 프로세서 (220) 를 추가로 구성할 수도 있다.

[0036] 디바이스 프로세서 (250) 는 사용자에게 캡처된 이미지 또는 캡처된 이미지의 프리뷰를 표시하도록 디스플레이 (225) 를 제어하도록 구성될 수도 있다. 디스플레이 (225) 는 이미징 디바이스 (200) 의 외부에 있을 수도 있고, 또는 이미징 디바이스 (200) 의 일부일 수도 있다. 디스플레이 (225) 는 또한, 이미지를 캡처하기 이전에 사용자에 대해 프리뷰 이미지를 디스플레이하는 뷰 파인더 (view finder) 를 제공하도록 구성될 수도 있고, 또는, 사용자에 의해 최근에 캡처된 또는 메모리에 저장된 캡처된 이미지를 디스플레이하도록 구성될 수도 있다. 디스플레이 (225) 는 LCD 또는 LED 스크린을 포함할 수도 있고, 터치 감지 기술들을 구현할 수도 있다.

[0037] 디바이스 프로세서 (250) 는 예를 들어 캡처된 이미지들을 나타내는 데이터를 스토리지 모듈 (210) 에 기입할 수도 있다. 스토리지 모듈 (210) 은 전통적인 디스크 디바이스로서 도표로 표현되지만, 통상의 기술자는, 스토리지 모듈 (210) 은 임의의 스토리지 매체 디바이스로서 구성될 수도 있다는 것을 이해할 것이다. 예를 들어, 스토리지 모듈 (210) 은, 플로피 디스크 드라이브, 하드 디스크 드라이브, 광학 디스크 드라이브 또는 광자기 디스크 드라이브와 같은 디스크 드라이브, 또는 플래시 메모리, RAM, ROM, 및/또는 EEPROM 과 같은 솔리드 스테이트 메모리를 포함할 수도 있다. 스토리지 모듈 (210) 은 또한 다수의 메모리 유닛들을 포함할 수 있고, 메모리 유닛들 중 임의의 것은 이미지 캡처 디바이스 (200) 내에 있도록 구성될 수도 있고, 또는, 이미지 캡처 디바이스 (200) 외부에 있을 수도 있다. 예를 들어, 스토리지 모듈 (210) 은 이미지 캡처 디바이스 (200) 내에 저장된 시스템 프로그램 명령들을 포함하는 ROM 메모리를 포함할 수도 있다. 저장 모듈 (210) 은 또한, 카메라로부터 착탈 가능할 수도 있는, 캡처된 이미지들을 저장하도록 구성된 메모리 카드들 또는 고속 메모리들을 포함할 수도 있다.

[0038] 비록 도 2 는 프로세서, 이미징 센서, 및 메모리를 포함하도록 별개의 컴포넌트들을 갖는 디바이스를 묘사하지만, 통상의 기술자는, 이들 별개의 컴포넌트들은 특정 설계 목적들을 달성하기 위해 다양한 방식들로 결합될 수도 있다는 것을 인식할 것이다. 예를 들어, 대안적인 실시형태에서, 메모리 컴포넌트들은 비용을 절약하고 성능을 향상시키기 위해 프로세서 컴포넌트들과 결합될 수도 있다.

[0039] 또한, 비록 도 2 는 수개의 모듈들을 포함하는 메모리 컴포넌트 (230) 및 작업 메모리를 포함하는 별개의 메모리 (205) 를 포함하는 2 개의 메모리 컴포넌트들을 도시하지만, 통상의 기술자는 상이한 메모리 아키텍쳐들 (architectures) 을 이용한 수개의 실시형태들을 인식할 것이다. 예를 들어, 설계는 메모리 (230) 에 포함된 모듈들을 구현하는 프로세서 명령들의 스토리지를 위해 ROM 또는 정적 RAM 을 이용할 수도 있다. 프로세서 명령들은 이미지 프로세서 (220) 에 의한 실행을 용이하게 하기 위해 RAM 내로 로딩될 수도 있다. 예를 들어, 작업 메모리 (205) 는, 프로세서 (220) 에 의한 실행 전에 작업 메모리 (205) 로 로딩되는 명령들을 갖는 RAM 메모리를 포함할 수도 있다.

[0040] 도 3a 내지 도 3c 로 가서, 폴드형 광학 센서 어레이 (300) 의 하나의 실시형태가 보다 자세히 설명될 것이다. 어레이 (300) 는 2 개의 2x1 열들 (rows) 의 센서 어셈블리들 및 중앙 광 반사 면 (335), 예컨대 거울을 포함한다. 도 1a 에서 도시된 바와 같이, 센서 어셈블리들 A-F 은 각각, 이미지 센서, 렌즈 어셈블리, 및 부 반사 면을 포함할 수도 있다. 센서 어레이 (300) 구성의 일부 실시형태들은 82 도의 시야를 가질 수도 있다.

[0041] 도 3a 및 도 3b 에서 도시된 바와 같이, 센서 어셈블리 A (305), 센서 어셈블리 B (310), 및 센서 어셈블리 C (315) 는 중앙 미러 (335) 의 일 측 (337) 에 제 1 축 (301) 을 따라 서로 인접하게 평행하게 정렬된다. 센서 어셈블리 D (320), 센서 어셈블리 E (325), 및 센서 어셈블리 F (330) 는 중앙 미러 (335) 의 대향 측 (338) 에 제 2 축 (302) 을 따라 서로 인접하게 평행하게 정렬된다. 제 1 및 제 2 축은 중앙 거울 (335) 의 대칭의 중앙 라인 (336) 에 대해 평행하게 정렬된다. 비록 축 상의 각 센서 어셈블리 사이에 균일한 갭 (gap) 이 존재하는 것으로 묘사되었지만, 이 갭의 양은 가변적이고, 일부 실시형태들은, 예를 들어 센서들을 실리콘 웨이퍼의 그룹으로서 컷팅함으로써, 그들 사이에 갭이 없이 센서들을 배열할 수도 있다.

[0042] 도 3b 는 3 개의 구분 미러링되는 면들 (337, 338, 및 339) 을 디스플레이하는 중앙 거울 (335) 의 투시도를 나타낸다. 미러링된 면 (337) 은 타겟 이미지의 일부분을 포함하는 광을 센서 어셈블리 (320) 를 향해 재지향시킨다. 타겟 이미지의 이 부분은 센서 (320) 의 시야에 대응한다. 미러링된 면 (338) 은 타겟 이미지의 다른 부분을 센서 어셈블리 (325) 를 향해 재지향시키고, 미러링된 면 (339) 은 타겟 이미지의 제 3 부분을 센서 어셈블리 (330) 를 향해 재지향시킨다. 비록 도 3b 에 의해 도시된 도에서는 나타나지 않지만, 중앙 거울의 대향 측은 센서 어셈블리 (305, 310, 및 315) 를 향해 광을 반사시키는 3 개의 유사한 면들을 포함한다.

[0043] 어레이 (300) 에서의 센서들의 각각의 시야들이 도 3c 에서 도시된다. 시야 (360) 는 센서 (320) 에 대응하고, 시야 (365) 는 센서 (325) 에 대응하며, 시야 (370) 는 센서 (330) 에 대응한다. 부분적으로 중앙 거울 면들 (337 및 338) 의 상대 각도로 인해, 시야들 (360 및 365) 은 삼각형의 오버랩을 공유한다. 시야들 (365 및 370) 은 또한 동일한 사양들의 삼각형의 오버랩을 공유할 수도 있다. 중앙 거울 (335) 이 대칭 라인 (336) 에 관해 대칭적이므로, 시야들 (345, 350, 및 355) 은 시야들 (360, 365, 및 370) 과 서로에 대해 유사한 관계를 보유할 수도 있다. 또한, 센서 어레이의 2 열들은 중첩하는 시야들을 공유할 수도 있다. 시야들 (365 및 350) 은 직사각형 오버랩을 공유한다. 일부 실시형태들에서, 어레이에서의 센서들은 에지된 시야들에 따라 복수의 이미지들을 캡처할 수도 있고, 복수의 이미지들은 함께 스티칭되고 직사각형 경계 (340) 로 크로핑되어 타겟 이미지를 생성할 수도 있다.

[0044] 도 4 는 센서 (405), 렌즈 시스템 (495), 제 1 반사면 (480) 및 제 2 반사 면 (401) 을 포함하는 폴드형 광학 센서 어셈블리 (400) 의 일 실시형태를 나타낸다.

[0045] 폴드형 광학 센서 어셈블리 (400) 에서, 제 1 반사 면 (480) 은 센서 (405) 가 캡쳐되는 평면에 대해 각도 τ_0 로 포지셔닝될 수도 있다. 제 2 반사 면 (401) 은 센서 (405) 가 캡쳐되는 평면에 대해 각도 τ_1 로 포지셔닝될 수도 있다. 센서 (405) 는 적어도 부분적으로 센서 높이 (410) 에 의해 결정된 센서의 높이의 시야 (γ_y) 및 대각선 시야 (γ) 를 가질 수도 있다. 렌즈 시스템 (495) 은, 렌즈 시스템 (495) 의 수용 에지 상의 포인트 (d_0) 로부터 반사 면 (480) 상의 포인트 (Q_0) 까지 중앙 축을 따라서 측정된, 제 1 반사 면 (480) 으로부터 거리 (445) 에 포지셔닝될 수도 있다. 렌즈 시스템은, 렌즈 시스템 (495) 의 송광 에지 상의 포인트 (d_1) 로부터 반사 면 (401) 상의 포인트 (Q_1) 까지 중앙 축을 따라서 측정된, 제 2 반사 면 (401) 으로부터의 거리 (430) 에 포지셔닝될 수도 있다.

[0046] 타겟 이미지 장면을 포함하는 입사 광 (475) 은 제 1 반사면 (480) 을 향해 이동한다. 입사 빔 (475) 은 포인트 (P_0) 에서 면 (480) 을 때리고, 그 다음, 면 (480) 에서 반사되어 렌즈 시스템 (495) 을 향해 반사된 빔 (470) 으로서 이동한다. 입사 빔 (475) 은 렌즈 시스템 (495) 의 수용 에지에 대해 각도 (α_0) 를 형성하고, 반사된 빔 (470) 은 렌즈 시스템 (495) 의 수용 에지에 대해 각도 (β_0) 를 형성한다. 입사 빔 (475) 과 반사된 빔 (470) 사이의 반사각은 변수 (δ_0) 에 의해 표시된다.

[0047] 반사된 빔 (470) 은 그 다음 렌즈 시스템 (495) 으로 들어가고, 적어도 하나의 직경 (465) 의 렌즈를 통과한다. 렌즈 시스템 (495) 은 길이 (435) 및 직경 (425) 을 갖는다. 렌즈 시스템 내에서, 타겟 이미지는 높이 (460) 의 것이다. 거리 (440) 는 렌즈 시스템 (495) 의 에지로부터 렌즈 다이어프램의 포지션을 나타낸다.

수렴 렌즈를 채용하는 실시형태들에서, 광은 초점 포인트 R 에서 수렴할 수도 있고, 그 다음, 렌즈 시스템 (495) 의 다른 측으로 밖으로 이동한다.

[0048] 렌즈 시스템 (495) 을 떠난 후에, 광의 빔 (455) 은 부 반사 면 (401) 에 입사한다. 입사 빔 (455) 은 포인트 (P_1) 에서 면 (480) 을 때리고, 그 다음, 면 (401) 에서 반사되어 센서 (405) 를 향해 반사된 빔 (450) 으로서 이동한다. 반사된 빔 (450) 은 렌즈 시스템 (495) 의 송광 에지에 대해 각도 (α_1) 를 형성하고, 입사 빔 (455) 은 렌즈 시스템 (495) 의 송광 에지에 대해 각도 (β_1) 를 형성한다. 입사 빔 (455) 과 반사 빔 (450) 사이의 반사의 각도는 변수 (δ_1) 에 의해 표시된다.

[0049] 전술한 변수들 사이의 관계는, 일부 2D 실시형태들에서, 다음 식들에 의해 정의된다:

$$\alpha = \pi - \beta - \delta$$

$$\beta = (\pi - \gamma_H) / 2$$

$$\delta = \pi - \gamma_H - 2\tau$$

[0050]

[0051] 폴드형 광학들을 갖는 시스템 (400) 의 최소 Z-높이 (480) 는 최소 백 초점 길이 (minimum back focal length) 에 의해 결정된다. 최소 백 초점 길이는 렌즈 시스템의 직경 (425) 에 대한 최대 값을 계산하기 위해 이용될 수도 있다. 렌즈 시스템의 직경 (425) 은 센서에 대한 Z-거리의 값 (420) 및 거울의 상부에 대한 Z-거리의 값 (485) 을 결정한다. 센서에 대한 Z-거리 (420) 및 거울의 상부에 대한 Z-거리 (485) 의 값들은 시스템 (480) 에 대한 최소 Z-높이를 제공한다.

[0052] 일 실시형태에서, 센서에 대한 Z-거리 (420) 및 부 반사 면에 대한 거리 (430) 양자 모두는 최소이고, 따라서, 어셈블리 (400) 는 폴드형 광학들 (folded optics) 을 이용하기 위해 필요한 최소 백 초점 길이를 갖는다. 이것은, 반사된 빔 (450) 이 단지 렌즈 시스템 (495) 과 교차하지 않고 센서 (405) 가 단지 렌즈 시스템 (495) 및 부 반사 면 (401) 과 교차하지 않는 포인트까지 렌즈 시스템의 직경 (425) 이 증가될 때, 발생할 수도 있다. 이 포인트에서, 렌즈 시스템의 직경 (425) 은 또한 그것의 최대 값에 도달했을 수도 있다.

[0053] 폴드형 광학들을 갖는 시스템 (490) 의 최소 Z-높이는 최소 백 초점 길이에 관련되고, 최소 백 초점 길이로부터, 렌즈 시스템의 직경 (425) 에 대한 최대 값이 계산될 수도 있다. 폴드형 광학들을 갖는 렌즈 시스템 (495) 의 백 초점 길이는 부 반사 면 (401) 까지의 거리와 센서 (415) 까지의 거리를 합산함으로써 계산될 수도 있다. 일 실시형태에서, 시야 (γ_H) 는 40 도로 고정될 수도 있고, 센서 (405) 의 높이는 1.6㎜ 일 수도 있으며, 센서 (405) 는 1㎛px 센서일 수도 있다. 백 초점 길이는 렌즈 직경 (465) 이 .5㎜ 인 경우에 2㎜ 일 수도 있다. 일부 실시형태들에서, 폴드형 광학 센서 어레이에서의 센서들의 수는 보다 낮은 Z-높이들을 달성하기 위해 증가될 수도 있다.

[0054] 일 실시형태들에서, 센서 (405) 는 1.4㎛ 픽셀 피치를 갖는 5MP 센서일 수도 있고, 시야 (γ_H) 는 65 도일 수도 있다. 이 실시형태의 유효 초점 길이는 유한에서 포커싱될 때 3.57㎜ 일 수도 있다. 유사하게, 1.12㎛ 픽셀 피치를 갖는 8MP 센서를 갖는 실시형태의 유효 초점 길이는 또한, 센서가 5MP 센서와 동일한 물리적 사이즈일 수 있으므로, 3.57㎜ 일 수도 있다. 이들 실시형태들의 시스템의 Z-높이 (490) 가 3.9㎜ 정도이도록 하는 것이 가능하다.

[0055] 도 5a 및 도 5b 는 대응하는 시야들을 갖는 6 센서 폴드형 광학 어레이들의 2 개의 실시형태들을 나타낸다. 도 4 와 관련하여 상기 논의된 바와 같이, 이들 실시형태들의 센서 어셈블리들은 각각, 센서, 렌즈 시스템, 및 광을 센서 상으로 가이드하기 위해 포지셔닝된 반사 면을 포함할 수도 있다. 이들 실시형태들에서 논의된 중앙 거울은 별개의 반사 면들의 어셈블리 (assembly) 로서 제조될 수도 있고, 또는, 다중 반사 면들을 갖는 단일 프리즘으로서 제조될 수도 있다.

[0056] 도 5a 는 중앙 거울 (505) 주위에 센서 어셈블리들 (510, 520, 및 530) 의 제 1 열 및 센서 어셈블리들 (540, 550, 및 560) 의 제 2 열을 갖는 폴드형 광학 센서 어레이 (500) 의 다른 실시형태를 나타낸다. 각 열의 센서 어셈블리들은, 센서들이 동일 평면에 탑재되지 않도록, 서로에 대해 회전 또는 경사될 수도 있다. 예를 들어, 외측 센서 어셈블리들 (510, 530 및 540, 560) 은 중앙 센서들 (520, 550) 에 대해 대략적으로 21 도 폴리스 또는 마이너스로 회전될 수도 있다. 어셈블리들의 중앙 축들은 이미지 평면에 대해 평행한 하나의 평

면 내에 있을 수도 있다. 센서 어셈블리 (500) 의 어떤 실시형태들은 11㎜ × 12㎜ - 4.5㎜ (W × L - Z-높이) 를 측정할 수도 있다. 물론, 실시형태들이 이들 최전에 제한되지 않고, 다른 정도의 최전이 고려된다.

[0057] 중앙 거울 (505) 은 6 개의 면들을 포함할 수도 있고, 각 면은 타겟 이미지 장면의 일부분을 포함하는 광을 센서 어셈블리들 중의 하나를 향해 재지향시키도록 구성된다. 예를 들어, 면 (570) 은 광을 센서 어셈블리 (540) 에 지향시킬 수도 있고, 면 (580) 은 광을 센서 어셈블리 (550) 에 지향시킬 수도 있으며, 면 (590) 은 광을 센서 어셈블리 (560) 에 지향시킬 수도 있다. 일 실시형태에서, 면들 (570 및 590) 은 76 × 31.3 도 (상부 × 하부) 로 각을 이룰 수도 있고, 면 (580) 은 76.4 도 × 0 도 (상부 × 하부) 로 각도를 이룰 수도 있다. 비록 도 5a 의 투시도에서는 보이지 않지만, 중앙 거울 (505) 의 측면은 센서 어셈블리들 (510, 520, 및 530) 에 대응하는 3 개의 추가적인 면들을 포함할 수도 있다. 일 실시형태는 10 개의 면들을 갖는 복잡한 거울을 포함할 수도 있고, 이 중 6 개는 반사 면들일 수도 있다. 중앙 거울의 일부 실시형태들은 6 개의 면들을 갖는 복잡한 거울을 포함할 수도 있고, 다른 실시형태들은 3 개의 별개의 웨지 (wedge) 형상의 거울들을 포함할 수도 있다. N 개의 센서들을 갖는 다른 실시형태들에서, 중앙 거울은 N 개의 면들을 포함할 수도 있고, 여기서, N 개의 면들의 각각은 타겟 이미지 장면의 일부분을 포함하는 광을 N 개의 센서들 중의 하나를 향해 지향시키도록 구성된다.

[0058] 도 5b 는 6 개의 센서 어셈블리들 (511, 521, 531, 541, 551, 및 561) 의 3 개의 중앙 거울들 (571, 581, 및 591) 의 클러스터 (cluster) 주위에 일반적으로 원형 패턴으로 주위에 탑재된 폴드형 광학 센서 어레이 (501) 의 다른 실시형태를 나타낸다. 일부 실시형태들에서, 센서 어셈블리들 (511 및 541) 및 센서 어셈블리들 (531 및 561) 사이에는 대략적으로 76 도의 각도가 존재할 수도 있다. 센서 어셈블리들은 동일 평면에, 예컨대 실질적으로 평평한 기판 상에 탑재될 수도 있다. 일부 실시형태들에서, 센서 어셈블리들에서의 센서들은 탑계 면에 대해 수직으로 배열될 수도 있다. 각 센서는 전체 시야의 상이한 부분을 보여줄 수도 있다.

[0059] 중앙 거울들 (571, 581, 및 591) 은 또한 기판 상에 탑재될 수도 있다. 중앙 거울들 (571, 581, 및 591) 은 각각 별개의 웨지 형상의 거울일 수도 있다. 면 (571) 은 광을 양 센서 어셈블리들 (511 및 541) 에 지향시킬 수도 있다. 면 (581) 은 2 개의 별개의 반사 면들을 포함할 수도 있고, 그것의 제 1 면은 광을 센서 어셈블리 (551) 에 지향시킬 수도 있고, 그것의 제 2 면은 광을 센서 어셈블리 (521) 에 지향시킬 수도 있다. 면 (591) 은 광을 양 센서 어셈블리들 (531 및 561) 에 지향시킬 수도 있다. 센서 어레이 (501) 의 어떤 실시형태들은 15㎜ × 17㎜ - 3.6㎜ (W × L - Z-높이) 를 측정할 수도 있다.

[0060] 일 실시형태에서, 어레이 (501) 에서의 센서들은 1.4㎛ 픽셀 사이즈 및 4:3 비를 가지고 3.61 ㎜ × 2.71 ㎜ (W × H) 를 갖는 5 메가픽셀들일 수도 있다. 다른 실시형태들에서, 센서들은 1.12㎛ 픽셀 사이즈 및 4:3 비를 가지고 3.66 × 2.74 ㎜ (W × H) 를 갖는 8 메가픽셀들일 수도 있다. 각 센서의 시야는 40 도일 수도 있다.

어떤 실시형태들에서 어레이 (501) 의 전체 사이즈는 18 × 18 - 2.5 ㎜ (W × L - Z-높이) 보다 더 크지 않을 수도 있다. 20㎝ 이상인 대상 거리에서 여러 센서들의 시야들 사이에 5% 내지 10% 의 오버랩이 존재할 수도 있다. 각도 오버랩은 대상 거리의 함수로서 일정할 수도 있고, 또는, 적어도 점근적으로 일정하다.

[0061] 어레이들 (500, 501) 의 어떤 실시형태들은 도 4 에서 보여진 렌즈 시스템 (405) 에 유사한 렌즈 어셈블리를 채용할 수도 있다. 어레이의 어떤 실시형태들에서의 모든 렌즈 시스템들은 동일한 초점 길이, 렌즈 직경 및 길이를 가질 수도 있고, 이는 이용가능한 센서 면적을 최대화시키는 것과 관련하여 바람직한 결과들을 가져올 수도 있다. 이용가능한 센서 면적을 최대화하는 것은 또한 내측 및 외측 센서들의 렌즈 시스템들에 대해 상이한 설계들을 이용함으로써 달성될 수도 있다. 일부 실시형태들에서, 렌즈 직경은 대략적으로 1.3㎜ 일 수도 있고, 초점 거리는 대략적으로 2.7㎜ 일 수도 있다. 렌즈 시스템의 최대 가능 길이는 대략적으로 2.3㎜ 일 수도 있고, 렌즈 시스템의 직경 (높이) 은 대략적으로 1.6㎜ 일 수도 있다. 어레이 (501) 의 총 시야는 83 도일 수도 있다.

[0062] 도 5c 는 도 5a 및 도 5b 의 폴드형 광학 센서 어레이 실시형태들의 투영된 시야들의 일 실시형태를 나타낸다. 비록 2 개의 어레이 실시형태들 (500, 501) 사이에 센서 및 중앙 거울 구성들이 상이하지만, 그들은 동일한 시야 구성을 공유한다. 시야 (515) 는 센서들 (510, 511) 에 대응하고; 시야 (525) 는 센서들 (520, 521) 에 대응하고; 시야 (535) 는 센서들 (530, 531) 에 대응하고; 시야 (545) 는 센서들 (540, 541) 에 대응하며; 시야 (555) 는 센서들 (550, 551) 에 대응하고; 시야 (565) 는 센서들 (560, 561) 에 대응한다.

[0063] 시야들 (515 및 525) 은 삼각형 오버랩을 공유하고, 여기서, 각도 오버랩은 X 및 Y-방향들에서 1-4 도 사이에서 변화한다. 일부 실시형태들에서, 오버랩은 4 도보다 더 크다. 예를 들어, 일부 실시형태들에서, 센서 면적의 이용 효율 및 관련된 손실에 적어도 부분적으로 기초하여, 설계로서 적절할 수도 있는 경우에, 오버랩은

10 도 이상일 수도 있다. 각도 오버랩이 3 도인 일부 실시형태들에서, 1 미터 시야들 (515 및 525) 은 2 개의 중첩하는 시야들의 전체 캡처된 면적의 3.3% 를 포함하는 오버랩을 가질 수도 있다. 시야들 (525 및 535), 시야들 (545 및 555), 및 시야들 (555 및 565) 은 또한 동일 사양의 삼각형 오버랩을 공유할 수도 있다.

또한, 시야들 (515 및 545) 은 4 도에서 5.1% 의 삼각형 오버랩을 공유할 수도 있다. 시야들 (535 및 565) 은 유사한 오버랩을 공유할 수도 있다. 시야들 (525 및 555) 은 센서 어레이 (500, 501) 에 걸쳐 중첩할 수도 있고, 3 도에서 3.3% 를 공유할 수도 있다. 전체 어레이 (500, 501) 의 시야는 82 도일 수도 있다.

중첩하는 시야들의 일부 실시형태들은 직사각형 4:3 애스펙트 비 (596) 로 크로핑되어 18.8% 의 손실을 초래할 수도 있다. 다른 실시형태들은 1:1 정사각형 애스펙트 비 (595) 로 크로핑되어 11.3% 의 손실을 초래할 수도 있다.

[0064] 다른 실시형태들에서, 시야들 (515 및 525) 은 2 개의 중첩하는 시야들의 전체 캡처된 면적의 6.7% 를 포함하는 5.2 도의 오버랩을 가질 수도 있다. 시야들 (525 및 535), 시야들 (545 및 555), 및 시야 (555 및 565) 는 또한 동일 사양들의 삼각형 오버랩을 공유할 수도 있다. 또한, 시야들 (515 및 545) 은 4.9 도에서 8.5% 의 삼각형 오버랩을 공유할 수도 있다. 도시된 바와 같이, 시야들 (535 및 565) 은 유사한 오버랩을 공유한다.

시야들 (525 및 555) 은 센서 어레이 (500, 501) 에 걸쳐 중첩하고, 5.3 도에서 7.5% 를 공유할 수도 있다.

다른 실시형태들은 다양한 각도들에서 더 크거나 더 작은 백분율의 캡처된 영역을 공유할 수도 있다. 중첩 시야들의 일부 실시형태들은 직사각형 4:3 의 애스펙트 비 (596) 로 크로핑되어 24.2% 의 손실을 초래할 수도 있다. 다른 실시형태들은 최대 직사각형으로 크로핑되어 6.6% 의 손실을 초래할 수도 있다. 전체 시야는 76 도일 수도 있다. 하지만, 이들 수들은 오버랩 영역들의 가시적 최적화에 기초하고, 허용가능한 손실 면적 및 대상 거리와 같은 팩터들에 따라 변화한다.

[0065] 센서 어레이 (500) 의 일 실시형태에서, 중앙-중앙 오버랩 (525, 555) 은 3.7 도에서 5% 일 수도 있고, 측면-측면 오버랩은 4 도에서 5.1% 일 수도 있으며, 중앙-측면 오버랩은 3.3 도에서 3.3% 일 수도 있다. 4:3 직사각형 애스펙트 비에서의 크로핑은 18.8% 의 손실을 초래할 수도 있는 한편, 가능 최대 직사각형에서의 크로핑은 11.3% 의 손실을 초래할 수도 있다. 센서 어레이 (501) 의 일 실시형태에서, 중앙-중앙 오버랩 (525, 555) 은 4.7 도에서 5% 일 수도 있고, 측면-측면 오버랩은 4 도에서 5% 일 수도 있으며, 중앙-측면 오버랩은 2.2 도에서 3.6% 일 수도 있다. 4:3 직사각형 애스펙트 비에서의 크로핑은 19.4% 의 손실을 초래할 수도 있는 한편, 가능 최대 직사각형에서의 크로핑은 11.2% 의 손실을 초래할 수도 있다. 센서 어레이 (501) 의 다른 실시형태에서, 중앙-중앙 오버랩 (525, 555) 은 1.6 도에서 2.4% 일 수도 있고, 측면-측면 오버랩은 6.2 도에서 8% 일 수도 있으며, 중앙-측면 오버랩은 4.3 도에서 6.9% 일 수도 있다. 4:3 직사각형 애스펙트 비에서의 크로핑은 14.2% 의 손실을 초래할 수도 있는 한편, 가능 최대 직사각형에서의 크로핑은 14.2% 의 손실을 초래할 수도 있다. 전체 시야는 83 도일 수도 있다. 일 실시형태에서, 최종 이미지는 4:3 크로핑 후에 19 메가픽셀들 정도일 수도 있다.

[0066] 시스템의 총 Z-높이를 제한하는 것은 어레이에서의 각 센서의 일부분이 각 부 거울의 제한된 높이로 인해 사용가능하지 않게 되는 결과를 초래할 수도 있다.예를 들어, 도 4 에서 기술된 것과 같은 센서 어셈블리들을 채용하는 어레이 (501) 의 일 실시형태에서, 크리고 시스템의 Z-높이가 2.5㎜ 로 제한되는 경우에, 센서들 (551 및 521) 은 54.2% 의 가용 면적을 가질 수도 있고, 센서들 (511, 531, 541, 및 561) 은 52.1% 의 가용 면적을 가질 수도 있다. 이용가능한 센서의 높이는 시스템에 대한 높이 제약 하에서 2㎜ 정도일 수도 있다.

[0067] 도 6a 는 폴드형 광학 센서 어레이 (600) 의 다른 실시형태를 나타낸다. 센서 어레이 (600) 는 중앙 거울 (505) 주위로 제 1 열의 센서 어셈블리들 (610, 620, 및 630) 및 제 2 열의 센서 어셈블리들 (640, 650, 및 660) 을 갖는다. 각 열의 센서 어셈블리들은, 센서들이 동일 평면에 랩핑되지 않도록, 서로에 대해 회전 또는 경사될 수도 있다. 일부 실시형태들에서, 이러한 센서 구성은, 이미지 평면 및 초점 평면이 평행할 수도 있으므로, 복수의 직사각형 이미지들을 제공한다. 센서 어레이 (600) 의 어떤 실시형태들은 12㎜ × 15㎜ - 4.6㎜ (W / L - Z-높이) 를 측정할 수도 있다.

[0068] 중앙 거울 (670) 은 6 개의 면들을 포함할 수도 있고, 각 면은 타겟 이미지 장면의 일부분을 포함하는 광을 센서 어셈블리들 중의 하나를 향해 재지향시키도록 구성된다. 중앙 거울의 일부 실시형태들은 6 개의 면들을 갖는 복합 거울을 포함할 수도 있고, 다른 실시형태들은 3 개의 별개의 쌍지 형상의 거울들을 포함할 수도 있다. 예를 들어, 면 (673) 은 광을 센서 어셈블리 (640) 에 지향시킬 수도 있고, 면 (672) 은 광을 센서 어셈블리 (650) 에 지향시킬 수도 있으며, 면 (671) 은 광을 센서 어셈블리 (660) 에 지향시킬 수도 있고, 면 (674) 은 광을 센서 어셈블리 (630) 에 지향시킬 수도 있다. 비록 도 6a 의 투시도에서는 보이지 않지만, 중앙 거울 (505) 의 대향 측은 센서 어셈블리들 (510 및 520) 에 대응하는 2 개의 추가적인 면들을 포함할 수도

있다. N 개의 센서들을 갖는 다른 실시형태들에서, 중앙 거울은 N 개의 면들을 포함할 수도 있고, 여기서, N 개의 면들의 각각은 타겟 이미지 장면의 일부분을 포함하는 광을 N 개의 센서들 중의 하나를 향해 지향시키도록 구성된다.

[0069] 도 6b 는 도 6a 의 폴드형 광학 센서 어레이 (600) 의 투영된 시야들의 일 실시형태를 나타낸다. 시야 (615) 는 센서 (610) 에 대응하고; 시야 (625) 는 센서 (620) 에 대응하고; 시야 (635) 는 센서 (630) 에 대응하고; 시야 (645) 는 센서 (640) 에 대응하며; 시야 (655) 는 센서 (650) 에 대응하고; 시야 (665) 는 센서 (660) 에 대응한다.

[0070] 시야들 (615 및 625) 은 X- 및 Y-방향에서 일정하고 Z-방향에서 점근적으로 일정한 직사각형 오버랩을 공유할 수도 있다. 각도 오버랩이 1.8 도인 일부 실시형태들에서, 1 미터 시야들 (615 및 625) 은 2 개의 중첩하는 시야들의 전체 캡처된 면적의 3.3% 을 포함하는 오버랩을 가질 수도 있다. 시야들 (625 및 635), 시야들 (645 및 655), 및 시야들 (655 및 665) 은 또한 동일 사양들의 직사각형 오버랩을 공유할 수도 있다. 중앙 시야들 (625 및 655) 은 3.4 도에서 5.1% 의 직사각형 오버랩을 공유할 수도 있다. 측면 시야들 (615 및 645, 및 635 및 665) 은 3.6 도에서 5% 의 직사각형 오버랩을 공유할 수도 있다. 직사각형 4:3 애스펙트 비로의 크로핑 (680) 은 15.6% 의 손실을 초래할 수도 있고, 1:1 정사각형 애스펙트 비로의 크로핑 (690) 은 45 의 손실을 초래할 수도 있다.

[0071] 다른 실시형태들에서, 시야들 (615 및 625) 사이의 각도 오버랩은 3-5 도일 수도 있고, 1 미터 시야들 (615 및 625) 은 2 개의 중첩하는 시야들의 전체 캡처된 면적의 4% - 6% 를 포함하는 오버랩을 가질 수도 있다. 시야들 (625 및 635), 시야들 (645 및 655), 및 시야들 (655 및 665) 은 또한 동일 사양들의 직사각형 오버랩을 공유할 수도 있다. 중앙 시야들 (625 및 655) 은 4-8 도에서 6%-8% 의 직사각형 오버랩을 공유할 수도 있다. 측면 시야들 (615 및 645, 및 635 및 665) 은 4-10 도에서 6% - 9% 의 직사각형 오버랩을 공유할 수도 있다. 직사각형 4:3 애스펙트 비로의 크로핑 (680) 은 17.8% 의 손실을 초래할 수도 있고, 최대 직사각형으로의 크로핑은 4.5% 의 손실을 초래할 수도 있다. 전체 시야는 70 도와 120 도 사이일 수도 있다. 하지만, 이들 수들은 오버랩 영역들의 가시적 최적화에 기초하고, 허용가능한 손실 면적 및 대상 거리와 같은 팩터들에 따라 변화한다.

[0072] 도 7 은 복수의 센서 어셈블리들 (705) 및 복수의 중앙 거울들 (710) 을 갖는 폴드형 광학 센서 어레이 (700) 의 다른 실시형태를 나타낸다. 도 4 에 대해 상기 논의된 바와 같이, 각 센서 어셈블리는 센서, 렌즈 시스템, 및 렌즈 시스템으로부터의 광을 센서 상으로 재지향시키도록 구성된 반사 면을 포함할 수도 있다. 이 실시형태에서, 중앙 거울 (710) 의 양 측에 2 개의 3x1 어레이들을 포함하는 센서 어레이는, 센서 어레이들의 2x2 캐스케이딩 어레이가 존재하도록 반복되었다. 다른 실시형태들은 임의의 적합한 캐스케이드된 어레이 구성을 채용할 수도 있다.

[0073] 도 8 은 폴드형 광학 센서 어셈블리 (800) 의 다른 실시형태를 나타낸다. 본질적으로, 거울들은 상기 설명된 실시형태들에 비해 역 포지션이다. 예를 들어, 타겟 이미지를 포함하는 광은 센서 (810, 811) 를 둘러싸는 2 개의 주 반사 면들 (820, 821) 에 입사한다. 광은 2 개의 렌즈 어셈블리들 (840, 841) 을 통해 안쪽으로 재지향되고, 그 다음, 중앙의 부 반사 면들 (830, 831) 에서 반사되어 센서들 (810, 811) 상으로 아래로 향한다. 센서들 (810, 811) 은 개별 센서들 또는 센서들의 어레이들을 나타낼 수도 있다.

[0074] 도 9 는 폴드형 광학 이미지 캡처 프로세스 (900) 의 일 실시형태를 나타낸다. 프로세스 (900) 는 복수의 이미징 센서 어셈블리들이 있는 단계 905 에서 시작한다. 이 단계는 이전 이미지들에 대해 상기 논의된 센서 어레이 구성들 중 임의의 것을 포함한다. 센서 어셈블리들은, 도 4 에 대해 상기 논의된 바와 같이, 센서, 렌즈 시스템, 렌즈 시스템으로부터의 광을 센서 상으로 재지향시키도록 포지셔닝된 반사 면을 포함할 수도 있다. 프로세스 (900) 는 그 다음 단계 910 로 이동하고, 여기서, 적어도 하나의 반사 면이 복수의 이미지 센서들에 근접하여 포지션된다. 예를 들어, 이 단계는 2 개 열의 센서 어레이들 사이에 중앙 거울을 포지션하는 것을 포함할 수 있을 것이고, 여기서, 중앙 거울은 어레이들에서의 각 센서와 연관된 면을 포함한다.

[0075] 프로세스 (900) 는 그 다음 단계 915 로 천이하고, 여기서, 강인의 타겟 이미지를 포함하는 광이 이미징 센서들을 향해 적어도 하나의 반사 면에서 반사된다. 예를 들어, 광의 일부분은 복수의 면들의 각각에서 복수의 센서들의 각각을 향해 반사될 수도 있다. 이 단계는, 광을 각 센서와 연관된 렌즈 어셈블리를 통과하게 하는 것을 더 포함할 수도 있고, 제 2 면에서 센서 상으로 광을 반사시키는 것을 또한 포함할 수도 있다. 단계 915 는 렌즈 어셈블리를 이용하여 또는 반사 면들 중 임의의 것의 움직임을 통해 광을 포커싱 (focusing) 하는 것을 더 포함할 수도 있다.

[0076] 프로세스 (900) 는 그 다음 단계 920 으로 이동할 수도 있고, 여기서, 센서들은 타겟 이미지 장면의 복수의 이미지들을 캡처한다. 예를 들어, 각 센서는 그 센서의 시야에 대응하는 장면의 일부분의 이미지를 캡처할 수도 있다. 함께, 복수의 센서들의 시야들은 적어도 대상 공간에서의 타겟 이미지를 커버한다.

[0077] 프로세스 (900) 는 그 다음 단계 925 로 천이할 수도 있고, 여기서, 복수의 이미지들로부터 단일 이미지를 생성하기 위해 이미지 스티칭 방법이 수행된다. 일부 실시형태들에서, 도 2 의 이미지 스티칭 모듈 (240) 이 이 단계를 수행할 수도 있다. 이것은 공기의 이미지 스티칭 기법들을 포함할 수도 있다. 또한, 시야들에서의 오버랩의 임의의 영역들은, 스티칭 프로세스에서 이미지들을 정렬시키는데 사용될 수도 있는, 복수의 이미지들에서의 오버랩을 생성할 수도 있다. 예를 들어, 단계 925 는 인접 이미지들의 중첩하는 영역에서의 공통 피처들을 식별하는 것 및 이미지들을 정렬하기 위해 그 공통 피처들을 이용하는 것을 더 포함할 수도 있다.

[0078] 다음으로, 프로세스 (900) 는 단계 930 으로 천이하고, 여기서, 스티칭된 이미지는 특정 애프펙트 비, 예컨대 4:3 또는 1:1 로 프로핑된다. 마지막으로, 단계 935 에서 크로핑된 이미지를 저장한 후에 프로세스는 종료된다. 예를 들어, 이미지는 도 2 의 스토리지 (210) 에 저장될 수도 있고, 또는, 타겟 장면의 프리뷰 이미지로서의 디스플레이를 위해 도 2 의 작업 메모리 (205) 에 저장될 수도 있다.

[0079] 용어에 관한 명료화

[0080] 통상의 기술자는, 본 명세서에서 개시된 구현형태들과 관련하여 기술된 다양한 예시적인 논리 블록들, 모듈들, 회로들, 및 알고리즘 단계들이 전자적 하드웨어, 컴퓨터 소프트웨어, 또는 양자의 조합으로서 구현될 수도 있다는 것을 또한 이해할 것이다. 하드웨어와 소프트웨어의 이러한 상호교환가능성을 명확히 예시하기 위해, 다양한 예시적인 컴포넌트들, 블록들, 모듈들, 회로들, 및 단계들이 그들의 기능성 관점에서 일반적으로 상기 설명되었다. 이러한 기능성이 하드웨어로 구현될지 또는 소프트웨어로 구현될 지는 전체 시스템에 부과되는 설계 제약들 및 특정 애플리케이션들에 의존한다. 통상의 기술자는 각각의 특정 애플리케이션에 대하여 다양한 방식들로 기술된 기능성을 구현할 수도 있지만, 이러한 구현 결정들이 본 발명의 범위로부터의 이탈을 야기하는 것으로 해석되어서는 아니된다. 통상의 기술자는, 부분 또는 일부분은 전체보다 적거나 전체와 동일한 어떤 것을 포함할 수도 있다는 것을 인식할 것이다. 예를 들어, 픽셀들의 집합의 부분은 그들 픽셀들의 하위 집합을 지칭할 수도 있다.

[0081] 본 명세서에서 개시된 구현형태들과 관련하여 기술된 다양한 예시적인 논리 블록들, 모듈들, 및 회로들은 범용 프로세서, 디지털 신호 프로세서 (DSP), 주문형 집적 회로 (ASIC), 필드 프로그래머블 게이트 어레이 (FPGA) 또는 다른 프로그래머블 로직 디바이스, 이산 게이트 또는 트랜지스터 로직, 이산 하드웨어 컴포넌트들, 또는 본 명세서에서 기술된 기능들을 수행하도록 설계되는 이들의 임의의 조합으로 구현 또는 수행될 수도 있다. 범용 프로세서는 마이크로프로세서일 수도 있지만, 대안적으로, 그 프로세서는 임의의 종래의 프로세서, 제어기, 마이크로제어기, 또는 상태 머신일 수도 있다. 프로세서는 또한 컴퓨팅 디바이스들의 조합, 예를 들어, DSP 와 마이크로프로세서, 복수의 마이크로프로세서들, DSP 코어와 결합된 하나 이상의 마이크로프로세서들의 조합, 또는 임의의 다른 이러한 구성으로서 구현될 수도 있다.

[0082] 본 명세서에서 개시된 실시형태들과 함께 기술된 방법 또는 프로세스의 단계들은 직접 하드웨어에, 프로세서에 의해 실행된 소프트웨어 모듈에, 또는 이 둘의 조합으로 구현될 수도 있다. 소프트웨어 모듈은 RAM 메모리, 플래시 메모리, ROM 메모리, EPROM 메모리, EEPROM 메모리, 레지스터들, 하드 디스크, 착탈식 디스크, CD-ROM, 또는 당해 기술분야에 공지된 임의의 다른 형태의 비-일시적 (non-transitory) 저장 매체에 상주할 수도 있다. 일 예시적인 컴퓨터 판독가능 저장 매체는 프로세서가 컴퓨터 판독가능 저장 매체로부터 정보를 판독할 수 있고 컴퓨터 판독가능 저장 매체에 정보를 기입할 수 있도록 프로세서에 커플링된다. 대안적으로, 저장 매체는 프로세서와 일체형일 수도 있다. 프로세서 및 저장 매체는 ASIC 에 상주할 수도 있다. ASIC 은 사용자 단말기, 카메라, 또는 다른 디바이스에 상주할 수도 있다. 대안적으로, 프로세서 및 저장 매체는 이산 컴포넌트들로서 사용자 단말기, 카메라, 또는 다른 디바이스에 상주할 수도 있다.

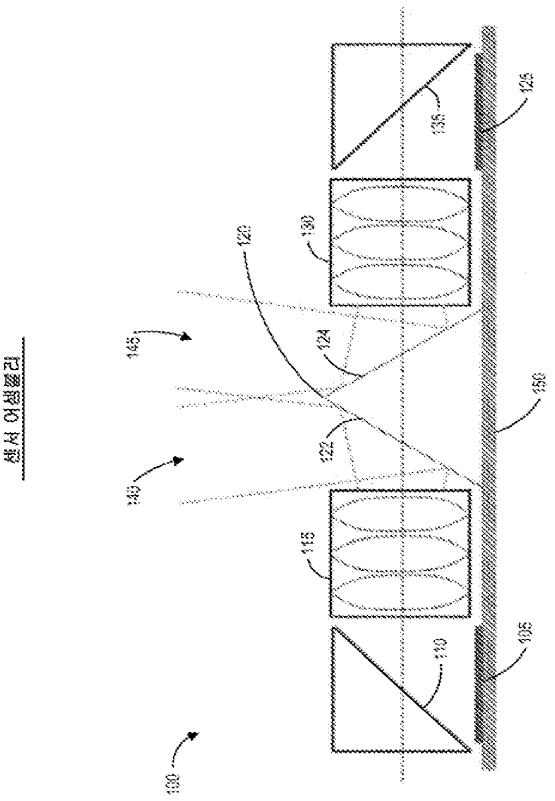
[0083] 제목들은 참조를 위해 그리고 여러 섹션들을 위치시키는 것을 돕기 위해 본 명세서에 포함된다. 이들 제목들은 그에 대해 기술된 개념들의 범위를 제한하도록 의도되지 아니한다. 이러한 개념들은 전체 명세서에 걸쳐 적용성을 가질 수도 있다.

[0084] 개시된 구현형태들의 이전 설명은 통상의 기술자가 본 발명을 실시 또는 이용할 수 있도록 하기 위해 제공된다. 이들 구현형태들에 대한 다양한 변형들은 통상의 기술자에게 자명할 것이며, 본 명세서에서 정의된 일반적인 원리들은 본 발명의 사상 또는 범위로부터 벗어나지 않고도 다른 구현형태들에 적용될 수도 있다. 따라서,

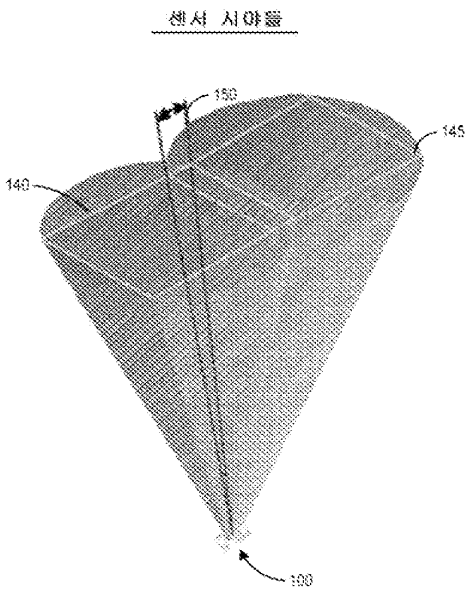
본 발명은 본 명세서에 나타난 구현형태들로 제한되는 것으로 의도되지 않고, 본 명세서에 개시된 원리들 및 신규한 특징들과 부합하는 최광의 범위에 부합한다.

도면

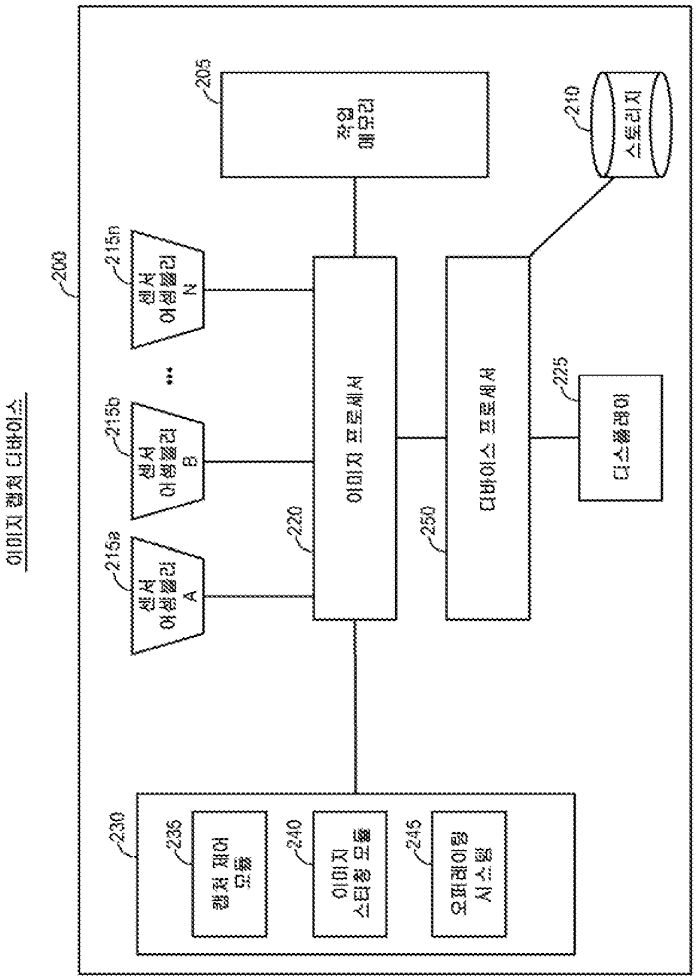
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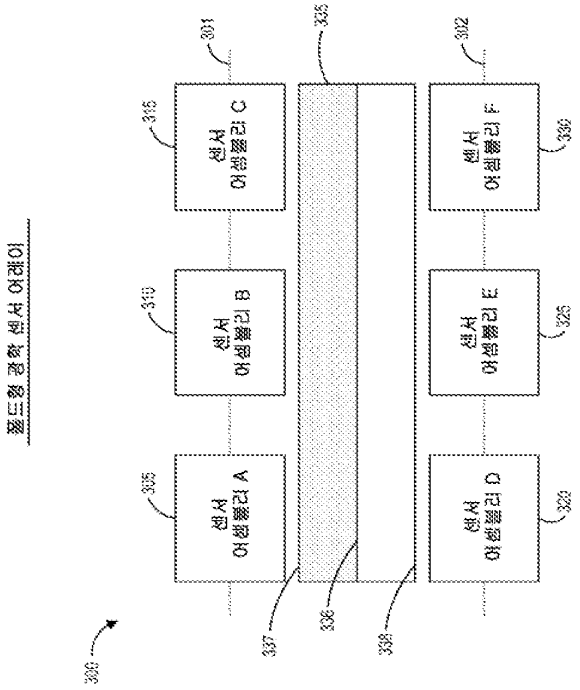
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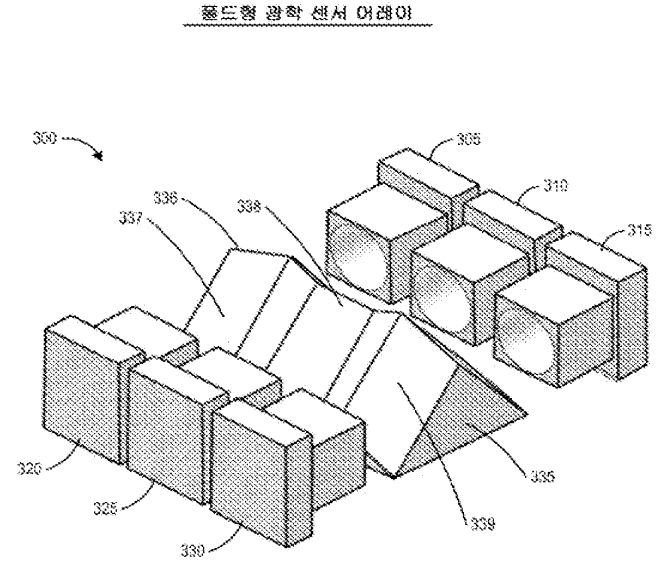
도면2


이미지 캡처 디바이스
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작업 메모리
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스토리지
215n
센서 어셈블리 N
215b
센서 어셈블리 B
215a
센서 어셈블리 A
220
이미지 프로세서
250
디바이스 프로세서
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디스플레이
230
235
캡처 제어 모듈
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이미지 스티칭 모듈
245
오퍼레이팅 시스템

도 3a

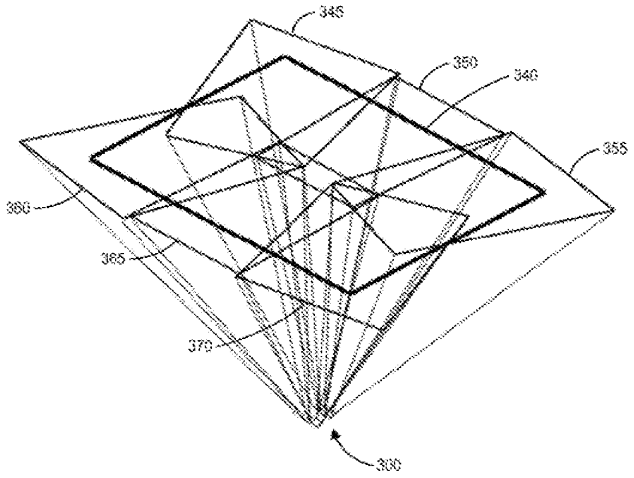

폴드형 광학 센서 어레이
센서 어셈블리 A
센서 어셈블리 B
센서 어셈블리 C
센서 어셈블리 D
센서 어셈블리 E
센서 어셈블리 F
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도 3b


폴드형 광학 센서 어레이
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폴드형 광학 센서 시야들

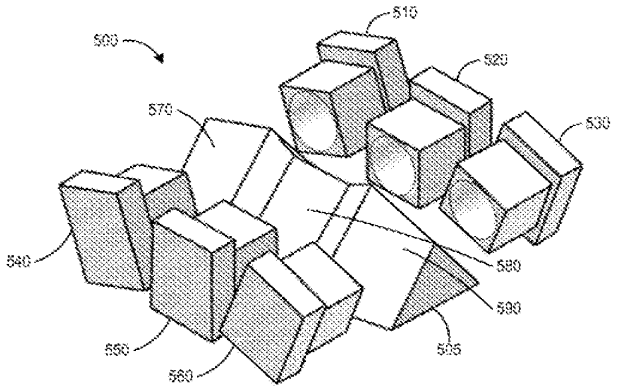


도면4

휨드림 광학 센서 어셈블리
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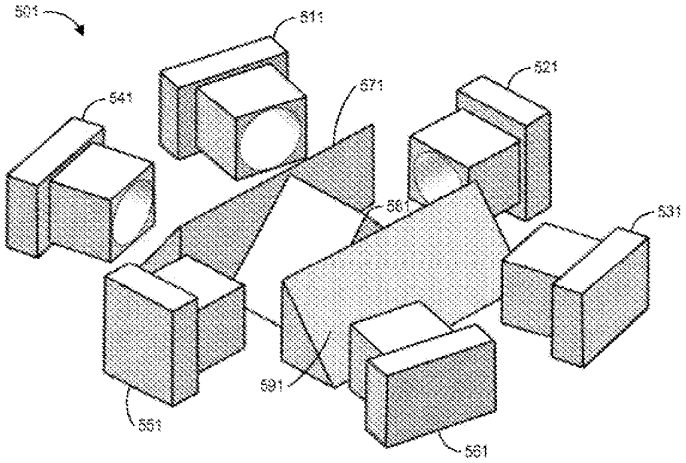
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폴드형 광학 센서 어레이



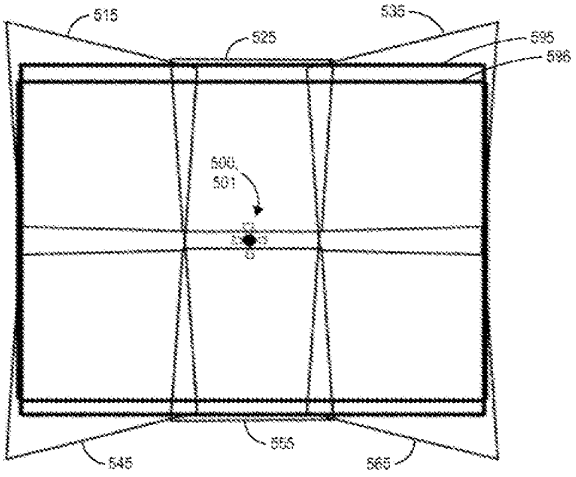
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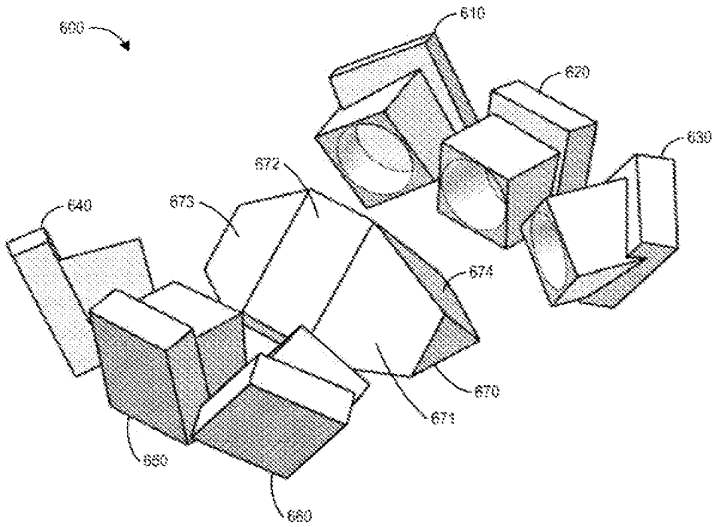
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폴드형 광학 센서 시야들



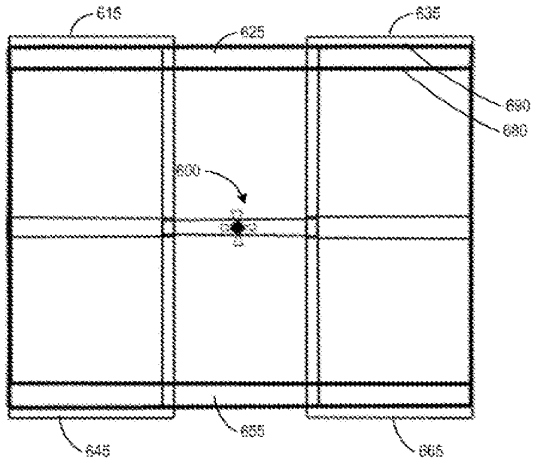
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폴드형 광학 센서 어레이

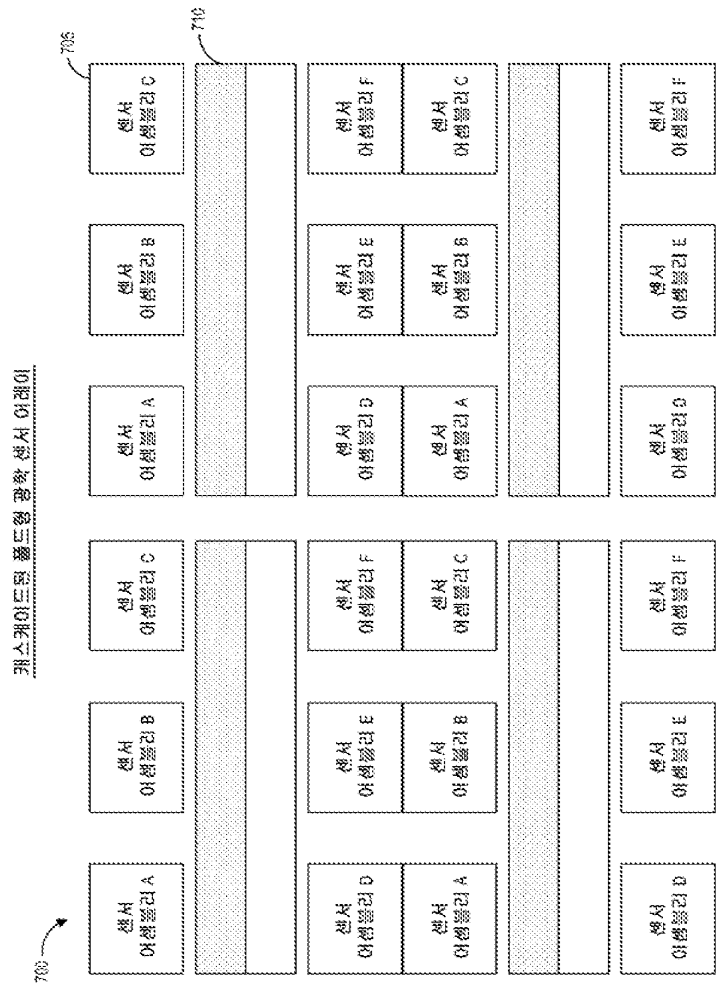


도면6b

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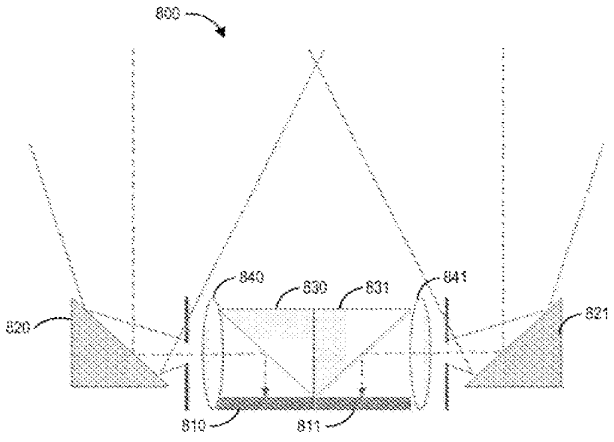


도면7

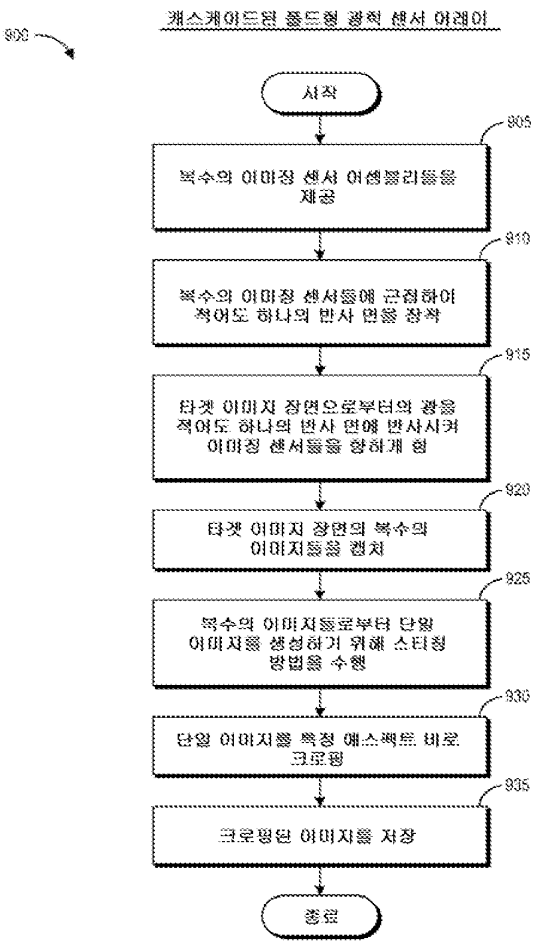

캐스케이드된 풀드형 광학 센서 어레이
700
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센서 어셈블리 A
센서 어셈블리 B
센서 어셈블리 C
센서 어셈블리 D
센서 어셈블리 E
센서 어셈블리 F

도면8

볼드형 광학 센서 어레이



도면9


900
캐스케이드된 풀드형 광학 센서 어레이
시작
905
복수의 이미징 센서 어셈블리들을 제공
910
복수의 이미징 센서들에 근접하여 적어도 하나의 반사 면을 장착
915
타겟 이미지 장면으로부터의 광을 적어도 하나의 반사 면에 반사시켜 이미징 센서들을 향하게 함
920
타겟 이미지 장면의 복수의 이미지들을 캡처
925
복수의 이미지들로부터 단일 이미지를 생성하기 위해 스티칭 방법을 수행
930
단일 이미지를 특정 예스펙트 비로 크로핑
935
크로핑된 이미지를 저장
종료

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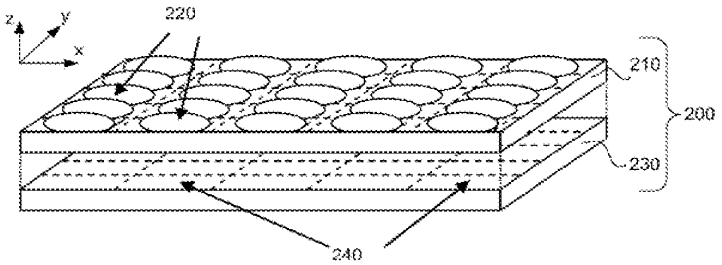


FIG. 2A

(57) Abstract: Systems and methods for implementing array cameras configured to perform super- resolution processing to generate higher resolution super-resolved images using a plurality of captured images and lens stack arrays that can be utilized in array cameras are disclosed. Lens stack arrays in accordance with many embodiments of the invention include lens elements formed on substrates separated by spacers, where the lens elements, substrates and spacers are configured to form a plurality of optical channels, at least one aperture located within each optical channel, at least one spectral filter located within each optical channel, where each spectral filter is configured to pass a specific spectral band of light, and light blocking materials located within the lens stack array to optically isolate the optical channels.

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CAPTURING AND PROCESSING OF IMAGES USING MONOLITHIC CAMERA ARRAY WITH HETEROGENEOUS IMAGERS

FIELD OF THE INVENTION

[0001] The present invention is related to an image sensor including a plurality of heterogeneous imagers, more specifically to an image sensor with a plurality of wafer-level imagers having custom filters, sensors and optics of varying configurations.

BACKGROUND

[0002] Image sensors are used in cameras and other imaging devices to capture images. In a typical imaging device, light enters through an opening (aperture) at one end of the imaging device and is directed to an image sensor by an optical element such as a lens. In most imaging devices, one or more layers of optical elements are placed between the aperture and the image sensor to focus light onto the image sensor. The image sensor consists of pixels that generate signals upon receiving light via the optical element. Commonly used image sensors include CCD (charge-coupled device) image sensors and CMOS (complementary metal-oxide-semiconductor) sensors.

[0003] Filters are often employed in the image sensor to selectively transmit lights of certain wavelengths onto pixels. A Bayer filter mosaic is often formed on the image sensor. The Bayer filter is a color filter array that arranges one of the RGB color filters on each of the color pixels. The Bayer filter pattern includes 50% green filters, 25% red filters and 25% blue filters. Since each pixel generates a signal representing strength of a color component in the light and not the full range of colors, demosaicing is performed to interpolate a set of red, green and blue values for each image pixel.

[0004] The image sensors are subject to various performance constraints. The performance constraints for the image sensors include, among others, dynamic range, signal to noise (SNR) ratio and low light sensitivity. The dynamic range is defined as the ratio of the maximum possible signal that can be captured by a pixel to the total noise signal. Typically, the well capacity of an image sensor limits the maximum possible signal that can be captured by the image sensor. The maximum possible signal in turn is dependent on the strength of the incident illumination and the duration of exposure (e.g., integration time, and

shutter width). The dynamic range can be expressed as a dimensionless quantity in decibels (dB) as:

$$DR = \frac{full\ well\ capacity}{RMS\ noise} \quad \text{.....equation} \quad (1)$$

Typically, the noise level in the captured image influences the floor of the dynamic range. Thus, for an 8 bit image, the best case would be 48dB assuming the RMS noise level is 1 bit. In reality, however, the RMS noise levels are higher than 1 bit, and this further reduces the dynamic range.

[0005] The signal to noise ratio (SNR) of a captured image is, to a great extent, a measure of image quality. In general, as more light is captured by the pixel, the higher the SNR. The SNR of a captured image is usually related to the light gathering capability of the pixel.

[0006] Generally, Bayer filter sensors have low light sensitivity. At low light levels, each pixel's light gathering capability is constrained by the low signal levels incident upon each pixel. In addition, the color filters over the pixel further constrain the signal reaching the pixel. IR (Infrared) filters also reduce the photo-response from near-IR signals, which can carry valuable information.

[0007] These performance constraints of image sensors are greatly magnified in cameras designed for mobile systems due to the nature of design constraints. Pixels for mobile cameras are typically much smaller than the pixels of digital still cameras (DSC). Due to limits in light gathering ability, reduced SNR, limits in the dynamic range, and reduced sensitivity to low light scenes, the cameras in mobile cameras show poor performance.

SUMMARY

[0008] Camera arrays, imaging devices including a camera array and/or a method for capturing an image that employ a plurality of imagers where each imager includes a plurality of sensor elements, and lens stack arrays that can be utilized in camera arrays in accordance with embodiments of the invention are disclosed. The plurality of imagers can include at least a first imager and a second imager, where the first imager and the second imager may have the same imaging characteristics or different imaging characteristics.

[0009] In one embodiment, the first imaging characteristics and the second imager have different imaging characteristics. The imaging characteristics may include, among others, the size of the imager, the type of pixels included in the imager, the shape of the imager, filters associated with the imager, exposure time of the imager, aperture size associated with the

imager, the configuration of the optical element associated with the imager, gain of the imager, the resolution of the imager, and operational timing of the imager.

[0010] In one embodiment, the first imager includes a filter for transmitting a light spectrum. The second imager also includes the same type of filter for transmitting the same light spectrum as the first imager but captures an image that is sub-pixel phase shifted from an image captured by the first imager. The images from the first imager and the second imager are combined using a super-resolution process to obtain images of higher resolution.

[0011] In one embodiment, the first imager includes a first filter for transmitting a first light spectrum and the second imager includes a second filter for transmitting a second light spectrum. The images from the first and second imagers are then processed to obtain a higher quality image.

[0012] In one embodiment, lens elements are provided to direct and focus light onto the imagers. The lens elements form lens stacks that create optical channels, and each lens stack focuses light onto one imager. Because each lens element is associated with one imager, each lens element may be designed and configured for a narrow light spectrum. Further, the thickness of the lens element may be reduced, decreasing the overall thickness of the camera array. In such an embodiment, the lens elements may be made using any suitable fabrication technique, such as, for example using wafer level optics (WLO) technology, injection molding, and/or glass molding.

[0013] In one embodiment, the plurality of imagers include at least one near-IR imager dedicated to receiving near-IR (Infrared) spectrum. An image generated from the near-IR imager may be fused with images generated from other imagers with color filters to reduce noise and increase the quality of the images. In another such embodiment, imagers covering other spectrum ranges including far-IR and UV spectra may be included as well.

[0014] In one embodiment, the plurality of imagers may be associated with lens elements that provide a zooming capability. In one such embodiment, different imagers may be associated with lenses of different focal lengths to have different fields-of-views and provide different levels of zooming capability. Different fields-of-view can also be achieved using imagers having different sensor sizes/formats by means of different pixel sizes or different numbers of pixels/light sensing elements. A mechanism may be provided to provide smooth transition from one zoom level to another zoom level.

[0015] In one or more embodiments, the plurality of imagers is coordinated and operated to obtain at least one of a high dynamic range image, a panoramic image, a hyper-spectral image, distance to an object and a high frame rate video.

[0016] An imaging device in accordance with one embodiment of the invention includes at least one imager array, and each imager in the array comprises a plurality of light sensing elements and a lens stack including at least one lens surface, where the lens stack is configured to form an image on the light sensing elements, control circuitry configured to capture images formed on the light sensing elements of each of the imagers, and a super-resolution processing module configured to generate at least one higher resolution super-resolved image using a plurality of the captured images.

[0017] A lens stack array in accordance with another embodiment of the invention includes lens elements formed on substrates separated by spacers, where the lens elements, substrates and spacers are configured to form a plurality of optical channels, at least one aperture located within each optical channel, at least one spectral filter located within each optical channel, where each spectral filter is configured to pass a specific spectral band of light, and light blocking materials located within the lens stack array to optically isolate the optical channels.

[0018] The features and advantages described in the specification are not all inclusive and, in particular, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and may not have been selected to delineate or circumscribe the inventive subject matter.

BRIEF DESCRIPTION OF DRAWINGS

[0019] Figure 1 is a plan view of a camera array with a plurality of imagers, according to one embodiment.

[0020] Figure 2A is a perspective view of a camera array with lens elements, according to one embodiment.

[0021] Figure 2B is a cross-sectional view of a camera array, according to one embodiment.

[0022] Figure 2C is a cross-sectional view of a camera array with optical crosstalk suppression, according to one embodiment.

[0023] Figure 2D is a cross-sectional view of a camera array with optical crosstalk suppression, according to a second embodiment.

[0024] Figure 2E is a cross-sectional view of a camera array incorporating opaque spacers to provide optical crosstalk suppression, according to a further embodiment.

[0025] Figure 2F is a cross-sectional view of a camera array incorporating spacers coated with opaque material to provide crosstalk suppression, according to another embodiment.

[0026] Figures 3A and 3B are sectional diagrams illustrating changes in the heights of lens elements depending on changes in the dimensions of imagers, according to one embodiment.

[0027] Figure 3C is a diagram illustrating chief ray angles varying depending on differing dimensions of the lens elements.

[0028] Figure 3D is a cross-sectional view of a camera array with field flattening, according to one embodiment.

[0029] Figure 4 is a functional block diagram for an imaging device, according to one embodiment.

[0030] Figure 5 is a functional block diagram of an image processing pipeline module, according to one embodiment.

[0031] Figures 6A through 6F are plan views of camera arrays having different layouts of heterogeneous imagers, according to embodiments.

[0032] Figure 6G is a diagram conceptually illustrating the manner in which sampling diversity can depend upon object distance.

[0033] Figure 6H is a is a cross sectional view of pixels of an imager in accordance with an embodiment of the invention

[0034] Figure 6I is a diagram conceptually illustrating occlusion zones created when Red and Blue imagers are not symmetrically distributed about the central access of a camera array.

[0035] Figure 6J is a diagram conceptually illustrating the manner in which the occlusion zones illustrated in Figure 6I are eliminated by distributing Red and Blue imagers symmetrically about the central access of a camera array.

[0036] Figure 7 is a flowchart illustrating a process of generating an enhanced image from lower resolution images captured by a plurality of imagers, according to one embodiment.

[0037] Figure 7A seems to be a flowchart is a flow chart illustrating a process for constructing a normalization plane during calibration in accordance with an embodiment of the invention.

[0038] Figure 7B conceptually illustrates the process for constructing a normalized plane during calibration in accordance with an embodiment of the invention illustrated in Figure 7A.

[0039] Figure 8A is a cross-sectional view of a camera array with optical zoom, according to one embodiment.

[0040] Figure 8B is a cross-sectional view of a camera array with optical zoom, according to a second embodiment.

[0041] Figure 8C is a cross-sectional view of a camera array with imagers having different fields-of-view, according to a further embodiment.

DETAILED DESCRIPTION

[0042] Embodiments of the invention are now described with reference to the figures where like reference numbers indicate identical or functionally similar elements. Also in the figures, the left most digits of each reference number corresponds to the figure in which the reference number is first used.

[0043] Many embodiments relate to using a distributed approach to capturing images using a plurality of imagers of different imaging characteristics. Each imager may be configured in such a manner that each imager captures an image that is shifted by a sub-pixel amount with respect to the image captured by other imagers having similar imaging characteristics. Each imager may also include separate optics with different filters and operate with different operating parameters (e.g., exposure time). Distinct images generated by the imagers are processed to obtain an enhanced image. In many embodiments, the separate optics incorporated into each imager are implemented using a lens stack array. The lens stack array can include one or more optical elements fabricated using wafer level optics (WLO) technology.

[0044] A sensor element or pixel refers to an individual light sensing element in an imager. The light sensing element can be, but is not limited to, traditional CIS (CMOS Image Sensor), CCD (charge-coupled device), high dynamic range pixel, multispectral pixel and various alternatives thereof.

[0045] A sensor refers to a two dimensional array of pixels used to capture an image formed on the sensor by the optics of the imager. The sensor elements of each sensor have similar physical properties and receive light through the same optical component. Further, the sensor elements in the each sensor may be associated with the same color filter.

[0046] A camera array refers to a collection of imagers designed to function as a unitary component. The camera array may be fabricated on a single chip for mounting or installing in various devices.

[0047] An array of camera arrays refers to an aggregation of two or more camera arrays. Two or more camera arrays may operate in conjunction to provide extended functionality over a single camera array, such as, for example, stereo resolution.

[0048] Image characteristics of an imager refer to any characteristics or parameters of the imager associated with capturing of images. The imaging characteristics may include, among others, the size of the imager, the type of pixels included in the imager, the shape of the imager, filters associated with the imager, the exposure time of the imager, aperture size associated with the imager, the configuration of the optical element associated with the imager (such as the number of elements, the shapes, profiles and sizes of the lens surfaces, including the radii of curvature, aspheric coefficients, focal lengths and FOVs of the objectives, color correction, F/#s, etc.), the gain of the imager, the resolution of the imager, and operational timing of the imager.

Structure of Camera array

[0049] Figure 1 is a plan view of a camera array 100 with imagers 1A through NM, according to one embodiment. The camera array 100 is fabricated on a semiconductor chip to include a plurality of imagers 1A through NM. Each of the imagers 1A through NM may include a plurality of pixels (e.g., 0.32 Mega pixels). In one embodiment, the imagers 1A through NM are arranged into a grid format as illustrated in Figure 1. In other embodiments, the imagers are arranged in a non-grid format. For example, the imagers may be arranged in

a circular pattern, zigzagged pattern or scattered pattern or an irregular pattern including sub-pixel offsets.

[0050] The camera array may include two or more types of heterogeneous imagers, each imager including two or more sensor elements or pixels. Each one of the imagers may have different imaging characteristics. Alternatively, there may be two or more different types of imagers where the same type of imager shares the same imaging characteristics.

[0051] In one embodiment, each imager 1A through NM has its own filter and/or optical element (e.g., lens). Specifically, each of the imagers 1A through NM or a group of imagers may be associated with spectral color filters to receive certain wavelengths of light. Example filters include a traditional filter used in the Bayer pattern (R, G, B or their complements C, M, Y), an IR-cut filter, a near-IR filter, a polarizing filter, and a custom filter to suit the needs of hyper-spectral imaging. Some imagers may have no filter to allow reception of both the entire visible spectra and near-IR, which increases the imager's signal-to-noise ratio. The number of distinct filters may be as large as the number of imagers in the camera array. Further, each of the imagers 1A through NM or a group of imagers may receive light through lenses having different optical characteristics (e.g., focal lengths) or apertures of different sizes.

[0052] In one embodiment, the camera array includes other related circuitry. The other circuitry may include, among others, circuitry to control imaging parameters and sensors to sense physical parameters. The control circuitry may control imaging parameters such as exposure times, gain, and black level offset. The sensor may include dark pixels to estimate dark current at the operating temperature. The dark current may be measured for on-the-fly compensation for any thermal creep that the substrate may suffer from. Alternatively, compensation of thermal effects associated with the optics, e.g., because of changes in refractive index of the lens material, may be accomplished by calibrating the PSF for different temperatures.

[0053] In one embodiment, the circuit for controlling imaging parameters may trigger each imager independently or in a synchronized manner. The start of the exposure periods for the various imagers in the camera array (analogous to opening a shutter) may be staggered in an overlapping manner so that the scenes are sampled sequentially while having several imagers being exposed to light at the same time. In a conventional video camera sampling a scene at N exposures per second, the exposure time per sample is limited to 1/N seconds.

With a plurality of imagers, there is no such limit to the exposure time per sample because multiple imagers may be operated to capture images in a staggered manner.

[0054] Each imager can be operated independently. Entire or most operations associated with each individual imager may be individualized. In one embodiment, a master setting is programmed and deviation (i.e., offset or gain) from such master setting is configured for each imager. The deviations may reflect functions such as high dynamic range, gain settings, integration time settings, digital processing settings or combinations thereof. These deviations can be specified at a low level (e.g., deviation in the gain) or at a higher level (e.g., difference in the ISO number, which is then automatically translated to deltas for gain, integration time, or otherwise as specified by context/master control registers) for the particular camera array. By setting the master values and deviations from the master values, higher levels of control abstraction can be achieved to facilitate a simpler programming model for many operations. In one embodiment, the parameters for the imagers are arbitrarily fixed for a target application. In another embodiment, the parameters are configured to allow a high degree of flexibility and programmability.

[0055] In one embodiment, the camera array is designed as a drop-in replacement for existing camera image sensors used in cell phones and other mobile devices. For this purpose, the camera array may be designed to be physically compatible with conventional image sensors of approximately the same resolution although the achieved resolution of the camera array may exceed conventional image sensors in many photographic situations. Taking advantage of the increased performance, the camera array in accordance with embodiments of the invention may include fewer pixels to obtain equal or better quality images compared to conventional image sensors. Alternatively, the size of the pixels in the imager may be reduced compared to pixels in conventional image sensors while achieving comparable results.

[0056] In order to match the raw pixel count of a conventional image sensor without increasing silicon area, the logic overhead for the individual imagers is preferably constrained in the silicon area. In one embodiment, much of the pixel control logic is a single collection of functions common to all or most of the imagers with a smaller set of functions applicable to each imager. In this embodiment, the conventional external interface for the imager may be used because the data output does not increase significantly for the imagers.

[0057] In one embodiment, the camera array including the imagers replaces a conventional image sensor of M megapixels. The camera array includes $N \times N$ imagers, each sensor including pixels of $\frac{M}{N^2}$. Each imager in the camera array also has the same aspect ratio as the conventional image sensor being replaced. Table 1 lists example configurations of camera arrays according to the present invention replacing conventional image sensor.

Table 1

Conventional Image Sensor		Camera array Including Imagers					
Total Mpixels	Effective Resolution	Total Mpixels	No. of Horizontal Imagers	No. of Vertical Imagers	Imager Mpixels	Super-Resolution Factor	Effective Resolution
8	3.2	8	5	5	0.32	3.2	3.2
		8	4	4	0.50	2.6	3.2
		8	3	3	0.89	1.9	3.2
5	2.0	5	5	5	0.20	3.2	2.0
		5	4	4	0.31	2.6	2.0
		5	3	3	0.56	1.9	2.0
3	1.2	3	5	5	0.12	3.2	1.2
		3	4	4	0.19	2.6	1.2
		3	3	3	0.33	1.9	1.2

[0058] The Super-Resolution Factors in Table 1 are estimates and the Effective Resolution values may differ based on the actual Super-Resolution factors achieved by processing.

[0059] The number of imagers in the camera array may be determined based on, among other factors, (i) resolution, (ii) parallax, (iii) sensitivity, and (iv) dynamic range. A first factor for the size of imager is the resolution. From a resolution point of view, the preferred number of the imagers ranges from 2 x 2 to 6 x 6 because an array size of larger than 6 x 6 is likely to destroy frequency information that cannot be recreated by the super-resolution process. For example, 8 Megapixel resolution with 2 x 2 imager will require each imager to have 2 Megapixels. Similarly, 8 Megapixel resolution with a 5 x 5 array will require each imager to have 0.32 Megapixels. In many embodiments, the number of imagers in the array is determined based upon the requirements of a specific application.

[0060] A second factor that may constrain the number of imagers is the issue of parallax and occlusion. With respect to an object captured in an image, the portion of the background

scene that is occluded from the view of the imager can be referred to as the "occlusion set." When two imagers capture the object from two different locations, the occlusion set of each imager is different. Hence, there may be scene pixels captured by one imager but not the other. To resolve this issue of occlusion, it is desirable to include a certain minimal set of imagers for a given type of imager and to distribute the imagers symmetrically around the central axis of the camera array.

[0061] A third factor that may put a lower bound on the number of imagers is the issue of sensitivity in low light conditions. To improve low light sensitivity, imagers for detecting near-IR spectrum may be needed. The number of imagers in the camera array may need to be increased to accommodate such near-IR imagers.

[0062] A fourth factor in determining the size of the imager is dynamic range. To provide dynamic range in the camera array, it is advantageous to provide several imagers of the same filter type (chroma or luma). Each imager of the same filter type may then be operated with different exposures simultaneously. The images captured with different exposures may be processed to generate a high dynamic range image.

[0063] Based on these factors, the preferred number of imagers is 2 x 2 to 6 x 6. 4 x 4 and 5 x 5 configurations are more preferable than 2 x 2 and 3 x 3 configurations because the former are likely to provide sufficient number of imagers to resolve occlusion issues, increase sensitivity and increase the dynamic range. In addition, rectangular arrays can also be preferred. At the same time, the computational load required to recover resolution from these array sizes will be modest in comparison to that required in the 6x6 array. Arrays larger than 6 x 6 may, however, be used to provide additional features such as optical zooming and multispectral imaging. Although only square imagers are described here, as will be discussed in greater detail later, such imagers may have different x- and y-dimensions.

[0064] Another consideration is the number of imagers dedicated to luma sampling. By ensuring that the imagers in the array dedicated to near-IR sampling do not reduce the achieved resolution, the information from the near-IR images is added to the resolution captured by the luma imagers. For this purpose, at least 50% of the imagers may be used for sampling the luma and/or near-IR spectra. In one embodiment with 4 x 4 imagers, 4 imagers samples luma, 4 imagers samples near-IR, and the remaining 8 imagers sample two chroma (Red and Blue). In another embodiment with 5 x 5 imagers, 9 imagers sample luma, 8 imagers sample near-IR, and the remaining 8 imagers sample two chroma (Red and Blue).

Further, the imagers with these filters may be arranged symmetrically within the camera array to address occlusion due to parallax. In a further embodiment with 5 x 5 imager, 17 imagers sample luma, 4 images sample Red, and 4 imagers sample Blue.

[0065] In one embodiment, the imagers in the camera array are spatially separated from each other by a predetermined distance. By increasing the spatial separation, the parallax between the images captured by the imagers may be increased. The increased parallax is advantageous where more accurate distance information is important. Separation between two imagers may also be increased to approximate the separation of a pair of human eyes. By approximating the separation of human eyes, a realistic stereoscopic 3D image may be provided to present the resulting image on an appropriate 3D display device.

[0066] In one embodiment, multiple camera arrays are provided at different locations on a device to overcome space constraints. One camera array may be designed to fit within a restricted space while another camera array may be placed in another restricted space of the device. For example, if a total of 20 imagers are required but the available space allows only a camera array of 1 x 10 imagers to be provided on either side of a device, two camera arrays each including 10 imagers may be placed on available space at both sides of the device. Each camera array may be fabricated on a substrate and be secured to a motherboard or other parts of a device. In addition, such imagers do not have to be homogenous in size, and may have different x- and y-dimensions. The images collected from multiple camera arrays may be processed to generate images of desired resolution and performance.

[0067] A design for a single imager may be applied to different camera arrays each including other types of imagers. Other variables in the camera array such as spatial distances, color filters and combination with the same or other sensors may be modified to produce a camera array with differing imaging characteristics. In this way, a diverse mix of camera arrays may be produced while maintaining the benefits from economies of scale.

Wafer Level Optics Integration

[0068] In one embodiment, the camera array employs wafer level optics (WLO) technology. Although in many embodiments, similar optical channels can be constructed using any of a variety of techniques including but not limited to injection molding, glass molding, and/or combinations of these techniques with other techniques including WLO techniques. WLO itself is a technology that encompasses a number of processes, including,

for example, molding optics (such as arrays of lens modules and arrays of those lens arrays) on glass wafers, stacking of those wafers (including wafers having lenses replicated on either side of the substrate) with appropriate spacers, at either a wafer or die-level, followed by packaging of the optics directly with the imager into a monolithic integrated module.

[0069] The WLO procedure may involve, among other procedures, using a diamond-turned mold to create each polymer lens element on a glass substrate. More specifically, the process chain in WLO generally includes producing a diamond turned lens master (both on an individual and array level), then producing a negative mold for replication of that master (also called a stamp or tool), and then finally forming a polymer replica on a glass substrate, which has been structured with appropriate supporting optical elements, such as, for example, apertures, light blocking materials, filters, etc.

[0070] Figure 2A is a perspective view of a camera array assembly 200 with wafer level optics 210 and a sensor array 230, according to one embodiment. The wafer level optics 210 includes a plurality of lens elements 220, each lens element 220 covering one of twenty-five imagers 240 in the sensor array 230. Note that the camera array assembly 200 has an array of smaller lens elements occupy much less space compared to a single large lens covering the entire sensor array 230. It should also be noted that each of the lenses may be of a different type. For example, each substrate level may contain lenses that are diffractive, refractive, Fresnel, or a combination thereof. It should be further noted that in the context of the camera array, that a lens element 220 may comprise one or multiple separate optical lens elements axially arranged with respect to each another. Finally, it should be noted that, for most lens materials there will be a thermal induced variance in the refractive index of the material, which must be corrected to obtain good image quality. A temperature normalization procedure will be described in greater detail in the sections to follow. Figure 2B is a sectional view of a camera array assembly 250, according to one embodiment. The camera assembly 250 includes a top lens wafer 262, a bottom lens wafer 268, a substrate 278 with multiple sensors and associated light sensing elements formed thereon and spacers 258, 264 and 270. The camera array assembly 250 is packaged within an encapsulation 254. An optional top spacer 258 may be placed between the encapsulation 254 and the top lens wafer 262; however, it is not essential to the construction of the camera assembly 250. Optical elements 288 are formed on the top lens wafer 262. Although these optical elements 288 are shown as being identical in Figure 2B, it should be understood that different types, sizes, and

shapes of elements may be used. A middle spacer 264 is placed between the top lens wafer 262 and a bottom lens wafer 268. Another set of optical elements 286 is formed on the bottom lens wafer 268. A bottom spacer 270 is placed between the bottom lens wafer 268 and the substrate 278. Through-silicon vias 274 are also provided to paths for transmitting signal from the imagers. The top lens wafer 262 may be partially coated with light blocking materials 284 (see discussion below) to block of light. The portions of the top lens wafer 262 not coated with the blocking materials 284 serve as aperture stops through which light passes to the bottom lens wafer 268 and the light sensing elements. Although only a single aperture stop is shown in the embodiment provided in Figure 2B, it should be understood that additional aperture stops may be formed from opaque layers disposed on any and all of the substrate faces in the camera assembly to improve stray light performance and reduced optical crosstalk. A fuller discussion of optical crosstalk suppression is provided below. In addition, although the above embodiment is shown with spacers 258, 264 and 270 the spacer function can also be directly implemented by modifying the lens structures (or substrates) so that the lenses can be directly interconnected. In such an embodiment, the lens height can be extended, and the lens glued directly to the upper substrates thereby eliminating the need for spacer layers.

[0071] In the embodiment of Figure 2B, filters 282 are formed on the bottom lens wafer 268. Light blocking materials 280 may also be coated on the bottom lens 268 to function as an optical isolator. A light blocking material 280 may also be coated on the substrate 278 to protect the sensor electronics from incident radiation. Spacers 283 can also be placed between the bottom lens wafer 268 and the substrate 278 and between the lens wafers 262, 268. In many embodiments, the spacers 283 are similar to the spacers 264 and 270. In a number of embodiments, each layer of spacers is implemented using a single plate. Although not illustrated in FIG. 2B, many embodiments of the invention also include spacers between each optical channel located on top of the top lens wafer 262 that are similar to, or implemented in single layer with, the spacer 258 shown at the edge of the lens stack array. As is discussed further below the spacers can be constructed from and/or coated in light blocking materials to isolate the optical channels formed by the wafer level optics. For the purposes of this application, suitable light blocking materials may include any opaque material, such as, for example, a metal material like Ti and Cr, or an oxide of these materials like black chromium (chrome and chrome oxide), or dark silicon, or a black particle filled photoresist

like a black matrix polymer (PSK2000 from Brewer Science). The bottom surface of the substrate is covered with a backside redistribution layer ("RDL") and solder balls 276.In one embodiment, the camera array assembly 250 includes 5 x 5 array of imagers. The camera array 250 has a width W of 7.2mm, and a length of 8.6mm. Each imager in the camera array may have a width S of 1.4mm. The total height t1 of the optical components is approximately 1.26mm and the total height t2 the camera array assembly is less than 2mm. Other heights t1 and t2 are possible for different lens designs.

Optical Crosstalk Suppression

[0072] As discussed above, the camera array assembly 250 is composed of multiple imagers, each of which, as shown in Figures 2A and 2B, have a corresponding optical pathway or channel that directs light from the scene through the top lens wafer 262, the middle spacer 264, bottom lens wafer 268, the bottom spacer 270 and onto a plurality of light sensing elements that form a sensor 240 disposed on the substrate 278. It is important to final image quality that the light impinging on any particular imager come only from its designated optical pathway or channel. Optical crosstalk can be considered to occur when light that is incident on the top of one imager is also received by light sensing elements of another imager within the array. Any crosstalk between optical channels from, for example, diffraction and/or scattering of light from elements within the camera, can introduce artifacts in the image data. In particular, crosstalk between optical channels means that an imager will sense the flux from a source on the imager that is inconsistent with the reconstructed position of the image of that detector and the position of the image. This results in both a loss of image data, and the introduction of overlapping noise that cannot be distinguished from real image data. Accordingly, all optical channels of the camera array should be optically isolated so that a ray of light from one lens or optical channel cannot cross from one optical channel to the other. In one embodiment, shown in Figure 2C, opaque spacers 281 or vertical opaque walls 282 are disposed between each of the optical channels 284. Although opaque spacers do provide a level of optical crosstalk suppression, vertical opaque walls are preferable because in such an embodiment both the space between substrates and the relevant sections of the substrates themselves are rendered non-transparent.

[0073] The optical crosstalk suppressing vertical opaque walls may be made using any suitable technique that provides for the introduction of an opaque surface or material between

the optical channels 284 of the camera array assembly 286. In one embodiment, the vertical opaque walls are formed by fully or partially introducing grooves into the lens stack 288 of the camera array assembly 286. It is preferable not to cut the grooves fully through the lens stack to preserve the mechanical integrity of the camera array assembly. Such grooves may be introduced by any suitable technique, such as, for example, by dicing into the front or backside of the lens array stack 286 using a wafer dicer (disk/blade), or by laser cutting, or water-jet cutting. Once the grooves are formed, they are filled with a light blocking material. Alternatively, the inner side walls of the grooves may be coated with a light blocking material and the remainder of the groove filled with another material with low shrinkage properties. As discussed above, a light blocking material is any opaque material, such as, for example, a metal material, a metal oxide, dark silicon, or a black particle filled photoresist like a black matrix polymer.

[0074] In another embodiment, shown schematically in Figure 2D, optical crosstalk suppression is achieved by creating a virtual opaque wall formed by a series of stacked apertures. In this embodiment, a series of aperture stops are formed on the various substrate levels 290 of the camera array assembly 292 by coating the substrates with opaque layers 294 provided with a narrow opening or aperture 296. If enough of these apertures are formed, it is possible to mimic the optical isolation provided by a vertical opaque wall. In such a system, a vertical wall would be the mathematical limit of stacking apertures one on top of each other. Preferably, as many apertures as possible, separated from each other by sufficient space, are provided so that such a virtual opaque wall is created. For any camera array assembly, the number and placement of opaque layers needed to form such a virtual vertical opaque wall can be determined through a ray tracing analysis.

[0075] In a further embodiment shown schematically in Figure 2E, optical crosstalk suppression is achieved using spacers 295 constructed from opaque materials. In another further embodiment shown schematically in Figure 2F, optical crosstalk suppression is achieved using spacers 296 coated with an opaque coating 297. The embodiments illustrated in Figures 2E and 2F include stacked apertures 294 similar to the stacked apertures 294 illustrated in Figure 2D. In several embodiments, optical crosstalk suppression is achieved without using stacked apertures. In many embodiments, any of a variety of light blocking materials can be used in the construction or coating of spacers to achieve optical isolation.

Lens Properties

[0076] Figures 3A and 3B are diagrams illustrating changes in the height t of a lens element pursuant to changes in dimensions in an x-y plane. A lens element 320 in Figure 3B is scaled by 1/n compared to a lens element 310 in Figure 3A. Note that during scaling it is important to keep the same F# so image properties don't change. As the diameter L/n of the lens element 320 is smaller than the diameter L by a factor of n, the height t/n of the lens element 320 is also smaller than the height t of the lens element 310 by a factor of n. Hence, by using an array of smaller lens elements, the height of the camera array assembly can be reduced significantly. The reduced height of the camera array assembly may be used to design less aggressive lenses having better optical properties such as improved chief ray angle, reduced distortion, and improved color aberration.

[0077] Figure 3C illustrates improving a chief ray angle (CRA) by reducing the thickness of the camera array assembly. CRA1 is the chief ray angle for a single lens covering an entire camera array. Although the chief ray angle can be reduced by increasing the distance between the camera array and the lens, the thickness constraints imposes constraints on increasing the distance. Hence, the CRA1 for camera array having a single lens element is large, resulting in reduced optical performance. CRA2 is the chief ray angle for an imager in the camera array that is scaled in thickness as well as other dimensions. The CRA2 remains the same as the CRA1 of the conventional camera array and results in no improvement in the chief ray angle. By modifying the distance between the imager and the lens element as illustrated in Figure 3C, however, the chief ray angle CRA3 in the camera array assembly may be reduced compared to CRA1 or CRA2, resulting in better optical performance. As described above, the camera arrays according to the present invention has reduced thickness requirements, and therefore, the distance of the lens element and the camera array may be increased to improve the chief ray angle. This relaxed CRA, in turn, results in a lower F# and improved Modulation Transfer Function (MTF).

[0078] Specifically, one of issues raised in camera design is how to correct for field curvature. An image projected through a lens is not planar, but has an inherently curved surface. One way to correct this field curvature is to position a thick negative lens element 312 close to or directly on the imager surface 314. The negative lens element planarizes the various angled beams of light 316 from the image, thereby addressing the field curvature problem. Such field flattened images provide superior image performance, allow for the

manufacture of array cameras with relaxed TTL requirements, and deliver very homogeneous MTF. However, one problem with this approach is that this field flattening approach intrinsically requires a high CRA. This makes the technique unsuitable for most cameras; however, the camera arrays of the current invention allow for the use of backside imaging (BSI). Positioning the image sensor behind the substrate relaxes the CRA angle requirement, thereby allowing for the use of the negative lens element field flattening approach shown in Figure 3D.

[0079] Another advantage of the array camera relates to chromatic aberrations. Specifically, in a conventional polychromatic lens, the lens has to be corrected for chromatic aberrations, because the focal length through the lens is different for different wavelengths of light. As a result, it is necessary to compromise the performance of the lens for some of the color wavelengths to get acceptable overall color performance. By making each optical channel narrow spectral band, color aberration is reduced and/or prevented, and each lens may be optimized to a specific color wavelength. For example, an imager receiving visible or near-IR spectrum may have a lens element specifically optimized for this spectral band of light. For imagers detecting other light spectrum, the lens element may be constructed with different properties, such as radii of curvature, so that a constant focal length across all wavelengths of light is achieved so that, in turn, the focal plane is the same for different spectral bands of light. The matching of the focal plane across different wavelengths of light increases the sharpness of image captured at the imager and reduces longitudinal chromatic aberration. Because each lens element may be designed to direct a narrow band of light, the concomitant lack of color aberration means that the lens elements can be subject to less rigorous design constraints, yet produce better or equivalent performance compared to conventional lens element covering a wide light spectrum. In particular, there is no need to undertake costly aberration balancing correction. What is more, simple lenses generally have better MTF and lower F# (higher sensitivity). It should be noted that although the lenses used in these array cameras have much smaller color aberrations when compared to conventional polychromatic lenses, each lens is still designed to focus a certain wavelength-bandwidth. Accordingly, in one embodiment each of these "monochromatic" lenses can be optimally color corrected by using combinations of high and low Abbe number materials (different optical dispersions).

[0080] Light of different wavelengths having different focal lengths (longitudinal color aberration) is not the only type of aberration that occurs in polychromatic optical systems. The refractive index of a lens is dependent on the wavelength of light passing through the lens. As a result, a lens will impart different magnification to colors of different wavelengths. For example, the red wavelength band might have a slightly smaller magnification than green, and green may in turn have a slightly smaller magnification than blue. If the images obtained from these different wavelengths of light are then overlaid without correction, the image will lose resolution because the different colors will not overlap correctly. Based on the properties of the material, the differential lateral distortions of the color magnification can be determined and then corrected. Correction can be accomplished by restricting the profiles of the lenses so that each color has the same magnification, but this reduces the possible degrees of freedom available for lens manufacture, and reduces the ability to optimize MTF. Accordingly, in one embodiment of the camera array, lateral distortion is permitted optically, and then corrected after imaging computationally. The electronic correction of the lateral color of the lens can actually provide improvements to system performance above and beyond simply correcting for the original distortion, because such correction directly improves the resolution of the system in terms of polychromatic MTF. In particular, lateral color aberrations in a lens can be seen as a color dependent distortion of the lens. By mapping all differently distorted single color images of an object back to the same rectangle, perfect overlap can be achieved in the full color image resulting in the polychromatic MTF being the same as the monochromatic one (not only due to the individual color channel color-blur correction, but also as a result of the exact superposition of the different colors).

[0081] Yet another advantage to using many lenses, each optimized for use with a narrow band of light, is that the there is no restriction on the type of lens that may be used. In particular, the array camera allows for the use of diffractive, refractive, Fresnel lenses, or combinations of these types of lenses. Diffractive lenses are attractive because they allow for the creation of complex wavefronts with an essentially flat optical element, and they are also relatively simple to manufacture. In conventional cameras it is not possible to use diffractive lenses because having a single imager means that the lens must be able to efficiently transmit a wide spectrum of light, and while diffractive lenses are very efficient at transmitting narrow wavelength bands of light, there is a steep drop-off in performance for wavelengths of light outside of this optimized range. Because each array of the current camera may be focused on

a narrow wavelength of light, the narrow optimized wavelength band of these diffractive lenses is not a limiting factor.

[0082] Other advantages of smaller lens elements include, among others, reduced cost, reduced amount of materials, and the reduction in the manufacturing steps. By providing n^2 lenses that are $1/n$ the size in x and y dimension (and thus 1/n thickness), the wafer size for producing the lens element may also be reduced. This reduces the cost and the amount of materials considerably. Further, the number of lens substrates is reduced, which results in a reduced number of manufacturing steps and reduced attendant yield costs. The placement accuracy required to register the lens array to the imagers is typically no more stringent than in the case of a conventional imager because the pixel size for the camera array according to the present invention may be substantially the same as a conventional image sensor. In addition, monochromatic aberrations scale with lens diameter. Because array cameras are able to use smaller lenses, any aberrations that exist are smaller so it is possible to use lenses with simpler profiles. This results in a system that is simultaneously better and less costly to fabricate. Smaller sized lenses also have a lower volume, which results in lower sag or shrinkage during manufacture. Shrinkage is bad for replication because it deforms the desired lens profile, and results in the need for the fabricator to precompensate for the predicted level of sag so that the final lens shape will be correct. This precompensation is difficult to control. With lower sag/shrinkage it is not necessary to have these tight fabrication controls, again lowering the overall cost of the manufacture of the lenses.

[0083] In one embodiment, the WLO fabrication process includes: (i) incorporating lens element stops by plating the lens element stops onto the substrate before lens molding, and (ii) etching holes in the substrate and performing two-sided molding of lenses through the substrate. The etching of holes in the substrate is advantageous because index mismatch is not caused between plastic and substrate. In this way, light absorbing substrate that forms natural stops for all lens elements (similar to painting lens edges black) may be used.

In one embodiment, filters are part of the imager. In another embodiment, filters are part of a WLO subsystem. In an embodiment including a filter, it is preferred to dispose the filter (whether CFA, IR and/or VIS) into or close to the aperture stop surface and not at the imager sensor surface, because when positioned at a distance from the imager sensor small defects in those filter layers are averaged out over all entrance pupil positions, and are therefore less visible.

Imaging System and Processing Pipeline

[0084] Figure 4 is a functional block diagram illustrating an imaging system 400, according to one embodiment. The imaging system 400 may include, among other components, the camera array 410, an image processing pipeline module 420 and a controller 440. The camera array 410 includes two or more imagers, as described above in detail with reference to Figures 1 and 2. Images 412 are captured by the two or more imagers in the camera array 410.

[0085] The controller 440 is hardware, software, firmware or a combination thereof for controlling various operation parameters of the camera array 410. The controller 440 receives inputs 446 from a user or other external components and sends operation signals 442 to control the camera array 410. The controller 440 may also send information 444 to the image processing pipeline module 420 to assist processing of the images 412.

[0086] The image processing pipeline module 420 is hardware, firmware, software or a combination for processing the images received from the camera array 410. The image processing pipeline module 420 processes multiple images 412, for example, as described below in detail with reference to Figure 5. The processed image 422 is then sent for display, storage, transmittal or further processing.

[0087] Figure 5 is a functional block diagram illustrating the image processing pipeline module 420, according to one embodiment. The image processing pipeline module 420 may include, among other components, an upstream pipeline processing module 510, an image pixel correlation module 514, a parallax confirmation and measurement module 518, a parallax compensation module 522, a super-resolution module 526, an address conversion module 530, an address and phase offset calibration module 554, and a downstream color processing module 564.

[0088] The address and phase offset calibration module 554 is a storage device for storing calibration data produced during camera array characterization in the manufacturing process or a subsequent recalibration process. In several embodiments, the calibration data can indicate mapping between the addresses of physical pixels 572 in the imagers and the logical addresses 546, 548 of an image. In other embodiments, a variety of calibration data appropriate to a specific application can be utilized in the address and phase offset calibration module.

[0089] The address conversion module 530 performs normalization based on the calibration data stored in the address and phase offset calibration module 554. Specifically, the address conversion module 530 converts "physical" addresses of the individual pixels in the image to "logical" addresses 548 of the individual pixels in the imagers or vice versa. In order for super-resolution processing to produce an image of enhanced resolution, the phase difference between corresponding pixels in the individual imagers needs to be resolved. The super-resolution process may assume that for each pixel in the resulting image the set of input pixels from each of the imager is consistently mapped and that the phase offset of the image captured by each imager is already known with respect to the position of the pixel in the resulting image. Alternatively, the pixel offsets can be estimated prior to the superresolution process. The address conversion module 530 resolves such phase differences by converting the physical addresses in the images 412 into logical addresses 548 of the resulting image for subsequent processing.

[0090] The images 412 captured by the imagers 540 are provided to the upstream pipeline processing module 510. The upstream pipe processing module 510 may perform one or more of normalization of the color planes, Black Level calculation and adjustments, fixed noise compensation, optical PSF (point spread function) deconvolution, noise reduction, lateral color correction and crosstalk reduction.

[0091] In one embodiment, the upstream pipeline processing module also performs temperature normalization. Temperature normalization corrects for changes in the refractive index of the optical components through which the imagers receive light that result from changes in the temperature of the camera during use. In several embodiments, the temperature normalization process involves determining the temperature of the camera array by measuring the dark current of one or an average of a number of the camera array's imagers. Using this measurement, a refractive index normalization is performed by picking the correct point spread function from temperature calibration data. Different point spread functions may be obtained during a temperature dependent refractive index characterization of the camera during manufacture, and stored in the imaging system for use in the temperature normalization process.

[0092] After the image is processed by the upstream pipeline processing module 510, an image pixel correlation module 514 performs calculation to account for parallax that becomes more apparent as objects being captured approach the camera array. Specifically, the image

pixel correlation module 514 aligns portions of images captured by different imagers to compensate for the parallax. In one embodiment, the image pixel correlation module 514 compares the difference between the average values of neighboring pixels with a threshold and flags the potential presence of parallax when the difference exceeds the threshold. The threshold may change dynamically as a function of the operating conditions of the camera array. Further, the neighborhood calculations may also be adaptive and reflect the particular operating conditions of the selected imagers.

[0093] The image is then processed by the parallax confirmation and measurement module 518 to detect and meter the parallax. In one embodiment, parallax detection is accomplished by a running pixel correlation monitor. This operation takes place in logical pixel space across the imagers with similar integration time conditions. When the scene is at practical infinity, the data from the imagers is highly correlated and subject only to noise-based variations. When an object is close enough to the camera, however, a parallax effect is introduced that changes the correlation between the imagers. Due to the spatial layout of the imagers, the nature of the parallax-induced change is consistent across all imagers. Within the limits of the measurement accuracy, the correlation difference between any pair of imagers dictates the difference between any other pair of imagers and the differences across the other imagers. This redundancy of information enables highly accurate parallax confirmation and measurement by performing the same or similar calculations on other pairs of imagers. If parallax is present in the other pairs, the parallax should occur at roughly the same physical location of the scene taking into account the positions of the imagers. The measurement of the parallax may be accomplished at the same time by keeping track of the various pair-wise measurements and calculating an "actual" parallax difference as a least squares (or similar statistic) fit to the sample data. Other methods for detecting the parallax may include detecting and tracking vertical and horizontal high-frequency image elements from frame-to-frame.

[0094] The parallax compensation module 522 processes images including objects close enough to the camera array to induce parallax differences larger than the accuracy of the phase offset information required by super resolution process. The parallax compensation module 522 uses the scan-line based parallax information generated in the parallax detection and measurement module 518 to further adjust mapping between physical pixel addresses and logical pixel addresses before the super-resolution process. There are two cases that occur

during this processing. In a more common case, addressing and offsetting adjustment are required when the input pixels have shifted positions relative to the image-wise-corresponding pixels in other imagers. In this case, no further processing with respect to parallax is required before performing super-resolution. In a less common case, a pixel or group of pixels are shifted in such a way that exposes the occlusion set. In this case, the parallax compensation process generates tagged pixel data indicating that the pixels of the occlusion set should not be considered in the super-resolution process.

[0095] After the parallax change has been accurately determined for a particular imager, the parallax information 524 is sent to the address conversion module 530. The address conversion module 530 uses the parallax information 524 along with the calibration data 558 from the address and phase offset calibration module 554 to determine the appropriate X and Y offsets to be applied to logical pixel address calculations. The address conversion module 530 also determines the associated sub-pixel offset for a particular imager pixel with respect to pixels in the resulting image 428 produced by the super-resolution process. The address conversion module 530 takes into account the parallax information 524 and provides logical addresses 546 accounting for the parallax.

[0096] After performing the parallax compensation, the image is processed by the super-resolution module 526 to obtain a high resolution synthesized image 422 from low resolution images, as described below in detail. The synthesized image 422 may then be fed to the downstream color processing module 564 to perform one or more of the following operations: focus recover, white balance, color correction, gamma correction, RGB to YUV correction, edge-aware sharpening, contrast enhancement and compression.

[0097] The image processing pipeline module 420 may include components for additional processing of the image. For example, the image processing pipeline module 420 may include a correction module for correcting abnormalities in images caused by a single pixel defect or a cluster of pixel defects. The correction module may be embodied on the same chip as the camera array, as a component separate from the camera array or as a part of the super-resolution module 526.

Super-Resolution Processing

[0098] In one embodiment, the super-resolution module 526 generates a higher resolution synthesized image by processing low resolution images captured by the imagers 540. The

overall image quality of the synthesized image is higher than images captured from any one of the imagers individually. In other words, the individual imagers operate synergistically, each contributing to higher quality images using their ability to capture a narrow part of the spectrum without sub-sampling. The image formation associated with the super-resolution techniques may be expressed as follows:

$$y_k = W_k \cdot x + n_k, \forall\, k = 1 \ldots p \qquad \ldots\ldots\ldots\ldots\ldots \text{equation} \quad (2)$$

where W_k represents the contribution of the HR scene (x) (via blurring, motion, and sub-sampling) to each of the LR images (y_k) captured on each of the k imagers and n_k is the noise contribution.

Imager Configurations

[0099] Figures 6A through 6F illustrate various configurations of imagers for obtaining a high resolution image through a super-resolution process, according to embodiments of the present invention. In Figures 6A through 6F, "R" represents an imager having a red filter, "G" represents a imager having a green filter, "B" represents an imager having a blue filter, "P" represents a polychromatic imager having sensitivity across the entire visible spectra and near-IR spectrum, and "I" represents an imager having a near-IR filter. The polychromatic imager may sample image from all parts of the visible spectra and the near-IR region (i.e., from 650nm to 800nm). In the embodiment of Figure 6A, the center columns and rows of the imagers include polychromatic imagers. The remaining areas of the camera array are filled with imagers having green filters, blue filters, and red filters. The embodiment of Figure 6A does not include any imagers for detecting near-IR spectrum alone.

[00100] The embodiment of Figure 6B has a configuration similar to conventional Bayer filter mapping. This embodiment does not include any polychromatic imagers or near-IR imagers. As described above in detail with reference to Figure 1, the embodiment of Figure 6B is different from conventional Bayer filter configuration in that each color filter is mapped to each imager instead of being mapped to an individual pixel.

[00101] Figure 6C illustrates an embodiment where the polychromatic imagers form a symmetric checkerboard pattern. Figure 6D illustrates an embodiment where four near-IR imagers are provided. Figure 6E illustrates an embodiment with irregular mapping of imagers. Figure 6F illustrates an embodiment where a 5 × 5 sensor array is organized into 17 imagers having green filters, four imagers having red filters, and four imagers having blue

filters. The sensors are distributed symmetrically around the central axis of the imaging array. As is discussed further below, distributing the imagers in this way prevents pixels that can be imaged by a sensor from being occluded from sensors capturing other wavelengths of light. The embodiments of Figures 6A through 6F are merely illustrative and various other layouts of imagers can also be used.

[00102] The use of polychromatic imagers and near-IR imagers is advantageous because these sensors may capture high quality images in low lighting conditions. The images captured by the polychromatic imager or the near-IR imager are used to denoise the images obtained from regular color imagers. However, as discussed above, these polychromatic lenses require that an associated color correction technique be used to address color aberrations inherent in a single lens trying to capture all wavelengths of light and deliver it to the same focal plane. Any conventional color correction technique may be utilized with the proposed array cameras.

Imager Layout

[00103] The premise of increasing resolution by aggregating multiple low resolution images relies upon the different low resolution images representing slightly different viewpoints of the same scene. If the LR images are all shifted by integer units of a pixel, then each image contains essentially the same information. Therefore, there is no new information in the LR images that can be used to create a HR image. In camera arrays according to embodiments of the invention, the layout of the imagers in the array may be preset and controlled so that each imager in a row or a column captures an image that is shifted a fixed sub-pixel distance relative to the images captured by its neighboring imagers. Ideally, the images captured by each imager are spatially offset from the other imagers in such a way as to provide uniform sampling of the scene or the light field and the uniformity of sampling is such that the LR images captured by each of the imagers yields non-redundant information about the sampled scene (light field). Such non-redundant information about the scene can be utilized by subsequent signal processing processes to synthesize a single HR image.

[00104] A sub-pixel shift between the images captured by two imagers is not, however, sufficient to ensure uniformity of sampling. The uniformity of sampling or sampling diversity of two imagers is a function of object distance. The sampled space by pixels of a

pair of imagers is illustrated in FIG. 6G. A first set of rays (610) map to pixels of imager A, while a second set of rays (620) map to pixels of imager B. Conceptually, two adjacent rays from a given imager define the part of the object space that is sampled by a specific pixel in that imager. At distance $z1$ from the camera plane, there is sufficient sampling diversity since the rays of the pixels of imager A are partially offset from the rays of the pixels of imager B. As the distance decreases there are specific distances ($z2$, $z3$, $z4$) where there is no sampling diversity between imager A and imager B. The lack of sampling diversity between the two imagers quite simply implies that there is no additional information in the scene captured by imager B as compared to that captured by imager A. As is discussed further below, an increased number of imagers in an array camera can mitigate the impact of object distances at which pair of imagers' sample space fully overlap. When a pair of imagers lack sampling diversity, the other imagers in the array provide the necessary sampling diversity to achieve resolution enhancement. Consequently, the ability of an imager system utilizing a 2x2 array of imagers to achieve superresolution is typically more limited than camera systems in accordance with embodiments of the invention that use a larger camera array.

[00105] Referring back to the camera array structures illustrated in FIGS. 2A – 2D the wafer level optics includes a plurality of lens elements, where each lens element covers one of the sensors in the array. The physical layout of pixels in a single imager of a camera array in accordance with an embodiment of the invention is illustrated in FIG. 6H. The imager is an array of pixels 650 overlaid with color filters 652 and microlenses 654. The microlenses that sit on top of the color filters are used to focus light on the active area of each underlying pixel. The microlenses can be thought of as sampling the continuous light field in object space sampled by the main lens. Whereas the main lens samples the scene radiance light field, the micro-lenses sample the sensor irradiance light field.

[00106] The main lens associated with each imager maps the points in the object space to points in the image space such at that the mapping is bijective (onto-to-one and onto). Each microlens samples a finite extent of the sensor irradiance light field. The sensor irradiance light field is continuous and is the result of a bijective mapping from the object space. Thus, the microlens sampling of a finite extent of the sensor irradiance light field is also a sampling of a corresponding finite extent of the scene radiance light field in object space.

[00107] Moving the microlens by a small amount δ laterally along the plain of the imager pixels changes the sampled object space at a certain distance z_k by a correspondingly

appropriate factor δ. With an $n \times n$ ($n > 2$) array camera, we can choose a baseline microlens shift can be determined by the main lens profile (for example, the chief ray angle) for a baseline imager. For each of the other imagers that sample the same wavelength as the baseline imager, the microlenses of each of the pixels in the imager are shifted by a sub-pixel amount to sample a different part of the scene radiance light field. Thus for a set of imagers arranged in an $n \times n$ grid, the sub-pixel shift for a imager that images the same wavelengths as the baseline imager (1,1) at a grid location (i,j) ($1 \leq i,j \leq n$) is governed by (δ_x, δ_y) where,

$$\frac{(i-1)}{n} \times pixelsize < \delta_x \leq \frac{i}{n} \times pixelsize$$
$$\frac{(j-1)}{n} \times pixelsize < \delta_y \leq \frac{j}{n} \times pixelsize$$

[00108] Many camera arrays in accordance with embodiments of the invention include significantly more Green imagers than Red and Blue imagers. For example, the array camera illustrated in FIG. 6F includes 17 Green imagers, 4 Red imagers, and 4 Blue imagers. For the purpose of calculating the sub-pixel shifts, the Green imagers can be treated as an $n \times n$ grid. Whereas the Red imagers and the Blue imagers can each be treated as a 2×2 grid for the purpose of calculating the sub-pixel shifts.

[00109] The sub-pixel shifts discussed above are determined relative to a baseline imager located at the corner of the grid, many embodiments of the invention utilize radial sub-pixel shifts from a baseline imager located at the center of the sensor array. In several embodiments, the radial sub-pixel shifts are chosen so the sub-pixel shifts are evenly distributed to enable the greatest sampling diversity.

[00110] The constraints on microlens sub-pixel shifts defined above achieve the highest increases in diversity and can enable the greatest increases in resolution through superresolution processing. Sub-pixel shifts that do not satisfy the constraints, but still provide an increase in sampling diversity can also be used to enable some increase in resolution through superresolution processing. Therefore, embodiments of the invention are not limited to microlens shifts that result in the greatest increases in diversity and in many instances utilize a variety of different microlens shift configurations that provide at least some increase in sampling diversity and that are satisfactory for the requirements of a specific application.

Symmetry of Imager Placement in Camera Array

[00111] An issue of separating the spectral sensing elements into different imagers is parallax caused by the physical separation of the imagers. By ensuring that the imagers are symmetrically placed, at least two imagers can capture the pixels around the edge of a foreground object. In this way, the pixels around the edge of a foreground object may be aggregated to increase resolution as well as avoiding any occlusions. In the absence of a symmetrical distribution, a pixel around the edge of a foreground object that is visible to a first imager, for example a Red camera, may be occluded to a second imager that captures different wavelengths, for example a blue imager. Accordingly, color information for the pixel cannot be accurately reconstructed. By symmetrically distributing the sensors, the likelihood that a foreground object will occlude pixels is significantly reduced.

[00112] Pixel occlusion caused by an asymmetric distribution of Red and Blue imagers in a simple array is illustrated in FIG. 6I. A pair of Red imagers 672 is located on the left hand side of the camera array 670 and a pair of Blue imagers 674 is located on the right hand side of the camera array. A foreground object 676 is present and the Red imagers 672 are capable of imaging regions beyond the foreground object on the left hand side of the foreground object. However, the foreground object occludes the Red imagers from imaging these regions. Therefore, the array camera is incapable of reconstructing color information for these regions.

[00113] An array that includes a symmetric distribution of Red and Blue imagers in accordance with an embodiment of the invention is illustrated in FIG. 6J. The camera array 780 includes a pair of Red imagers 782 symmetrically distributed around the central axis of the camera array and a pair of Blue imagers 784 symmetrically distributed around the central axis of the camera array. Due to the even distribution, a Red imager and a Blue imager are both able to image beyond the foreground object 786 on the left hand side of the foreground object and a Red imager and a Blue imager are both able to image beyond the foreground object on the right hand side of the foreground object.

[00114] The symmetrical arrangement of the simple embodiment illustrated in FIG. 6J can be generalized to array cameras including Red, Green, Blue cameras and/or additional polychromatic or near-IR cameras. By distributing each of the different types of imagers symmetrically around the central axis of the camera array, the effects of parallax introduced

by foreground objects can be significantly reduced and color artifacts that would otherwise be introduced, avoided.

[00115] The effects of parallax on the sampling of color can also be reduced by using parallax information in polychromatic imagers to improve the accuracy of the sampling of color from the color filtered imagers.

Use of Near-IR Imagers to Obtain Improved High Resolution Images

[00116] In one embodiment, near-IR imagers are used to determine relative luminance differences compared to a visible spectra imager. Objects have differing material reflectivity results in differences in the images captured by the visible spectra and the near-IR spectra. At low lighting conditions, the near-IR imager exhibits a higher signal to noise ratios. Therefore, the signals from the near-IR sensor may be used to enhance the luminance image. The transferring of details from the near-IR image to the luminance image may be performed before aggregating spectral images from different imagers through the super-resolution process. In this way, edge information about the scene may be improved to construct edge-preserving images that can be used effectively in the super-resolution process. The advantage of using near-IR imagers is apparent from equation (2) where any improvement in the estimate for the noise (i.e., n) leads to a better estimate of the original HR scene (x).

Generation of High Resolution Images

[00117] Figure 7 is a flowchart illustrating a process of generating an HR image from LR images captured by a plurality of imagers, according to one embodiment. First, luma images, near-IR images and chroma images are captured 710 by imagers in the camera array. Then normalization is performed 714 on the captured images. The images can be normalized in a variety of ways including but not limited to normalizing the color planes of the images, performing temperature compensation, and mapping physical addresses of the imagers to logical addresses in the enhanced image. In other embodiments, a variety of normalization process appropriate to the specific imagers and imaging applications. Parallax compensation is then performed 720 to resolve any differences in the field-of-views of the imagers due to spatial separations between the imagers. Super-resolution processing is then performed 724 to obtain super-resolved luma images, super-resolved near-IR images, and super-resolved chroma images.

[00118] Then it is determined 728 if the lighting condition is better than a preset parameter. If the lighting condition is better than the parameter, the process proceeds to normalize 730 a super-resolved near-IR image with respect to a super-resolved luma image. A focus recovery is then performed 742. In one embodiment, the focus recovery is performed 742 using PSF (point spread function) deblurring per each color channel. Then the super-resolution is processed 746 based on near-IR images and the luma images. A synthesized image is then constructed 750.

[00119] If it is determined 728 that the lighting condition is not better than the preset parameter, the super-resolved near-IR images and luma images are aligned 734. Then the super-resolved luma images are denoised 738 using the near-IR super-resolved images. Then the process proceeds to performing focus recovery 742 and repeats the same process as when the lighting condition is better than the preset parameter. Then the process terminates.

Normalization of Color Planes

[00120] The relative response of each of the Red, Green, Blue imagers across the imaging planes varies. The variance can be the result of many factors including the optical alignment of the lens and asymmetrical sensor light path geometry. For a given lens and imager, the variance can be compensated for by calibration and normalization. Without compensation, the variance can give rise to artifacts such as color shading.

[00121] A process for normalizing a imager with respect to a baseline imager, which is typically a Green imager located in the center of the camera array, in accordance with an embodiment of the invention is discussed below with reference to the normalization of a Red imager with respect to a baseline Green imager. A similar process can be used to normalize Blue imagers with respect to a baseline Green imager. In many embodiments, the process is applied to normalize each Red and Blue imager in a camera array.

[00122] A normalization surface can be calibrated by first capturing a scene with flat reflectance, and calculating a color ratio surface to serve as the basis for normalization. An ideal normalization surface is uniform and can be described as:

$$\text{Color Ratio } G/R = G(i,j) / R(i,j) = K = G_{center} / R_{center}$$

where (i,j) describe the pixel position, K is a constant, and G_{center}, and R_{center}, describe the pixel value at the center position.

[00123] The output pixel values of the calibration scene contain the ideal pixel values plus noise plus black level offset, and can be described as follows:

$$SR(i,j) = R(i,j) + \text{Noise R } (i,j) + \text{black offset}$$

$$SG(i,j) = G(i,j) + \text{Noise G } (i,j) + \text{black offset}$$

where SR, and SG are the output pixel values from each imager.

[00124] A process for calibrating the sensor in accordance with an embodiment of the invention is illustrated in FIG. 7A. The process 760 includes removing (762) the black level offset from the sensor pixel values, and low pass filtering (764) the image planes to reduce noise. The normalization plane is calculated (766) and several embodiments are calculated as follows:

$$\text{Norm R} = G(i,j) / (R(i,j) \times (G_{center} / R_{center}))$$

where G_{center}, and R_{center}, are the pixel values at the center position.

[00125] Following the calculation of the normalization plane, an averaging filter can be applied (768) and the values of the Norm R plane are stored (770).

[00126] The cost of carrying all of the normalization data for each of the sensors in a sensor array can be quite high. Therefore, many embodiments scan the Norm R plane using a space filling curve to form a one dimensional array. The resultant one dimensional array can be modeled in a variety of different ways including being modeled as a polynomial with suitable order. In several embodiments, the polynomials of the fitted polynomial are stored (810) as parameters that are used during calibration to reconstruct the two dimensional normalization plane. The construction of a space filling curve in accordance with several embodiments of the invention is discussed further below.

[00127] In several embodiments, a space filling curve is used to form a one dimensional array describing a normalization plane. A space filling curve, which is constructed using a spiral scan, is illustrated in FIG. 7B. A space filling curve 780 can be constructed by starting at the center of the normalization plane 781 and traversing a four sided square outwards. Each side of the square expands by two pixels compared to the previous square such that every pixel will be traversed exactly once. In the illustrated embodiment, each position 782 which is marked with an 'X' corresponds to a valid pixel position. The imager may not have a square geometry, so the scan path may traverse empty space (indicated as dashed lines). For each position traversed, if it is a valid pixel position, a new data entry is added to the one dimensional data array. Otherwise, the traversing continues without adding a new value to

the data array. In many embodiments, the one dimensional data array can be efficiently approximated using a 6th order polynomial that can be represented using the seven coefficients of the polynomial. Given that calibration data is typically required for each Red and Blue imager, expressing the normalization planes as coefficients of a polynomial represents a significant reduction in storage requirements. In many embodiments, higher or lower order polynomials, other functions, and/or other compressed representations are utilized to represent the normalization plane in accordance with the requirements of a specific application.

[00128] The data value along each side exhibits a fixed geometric relationship. The optical path to the focal point of the lens is shorter for the cells near the center line. The base sensitivity can be thought of as a one dimensional center cut of the calibration surface and approximated by a low order polynomial. The sensitivity polynomial can be either stored as a machine constant (i.e., common to all devices with the same design), or stored along with the scan polynomial to provide additional flexibility. Accordingly, many embodiments of the invention adjust the pixel value based upon the distance factor as follows. For each side scan, one of the coordinates will be a constant, i.e., constant 'y' for horizontal scan and constant 'x' for vertical scan. For each pixel in the side scan, the sensitivity factor is adjusted towards the constant 'x' or 'y' distance.

[00129] By way of example, for a horizontal scan the base value can be found by evaluating the sensitivity polynomial based on the distance 'y' from the center. In many embodiments, a suitable polynomial is a fourth order polynomial. Although other polynomials and/or other functions can be utilized in accordance with the requirements of a specific application. For each pixel in the scan path, the distance from the surface origin is used to find the corresponding sensitivity from the polynomial in the same manner. The pixel value is multiplied by an adjustment factor and then stored in the scanned data array. This adjustment factor is calculated by dividing the base value with the current sensitivity value. For the vertical scan a similar method can be applied. Although the example uses a polynomial based sensitivity adjustment, other sensitivity functions and/or adjustments can be utilized depending upon the requirements of a specific application in accordance with various embodiments of the invention.

[00130] Once calibration data has been obtained for an imager, the calibration data can be used in the normalization of pixel information captured by the imager. The process typically

involves retrieving the stored calibration data, removing the black offset from the captured image and multiplying the resultant values with the normalization plane. When the normalization plane is expressed as a polynomial in the manner outlined above, the polynomial is used to generate a one-dimensional array and an inverse scan of the one-dimensional array is used to form the two dimensional normalization plane. Where a sensitivity adjustment was applied during calibration, an adjustment factor is calculated that is the reciprocal of the adjustment factor applied during the calibration scan and the adjustment factor is applied to the values in the one dimensional array during the inverse scan. When other space filling curves, representations of the resulting one dimensional data array, and/or sensitivity adjustments are performed during the calibration process, the normalization process is adjusted accordingly.

[00131] As can be readily appreciated, calibration and normalization processes in accordance with embodiments of the invention can be applied to each of the Red and Blue imagers in the camera array. In many embodiments, a Green imager located in the center of the camera array is used when performing the calibration. In other embodiments, a different Green imager and/or multiple Green imagers can be utilized in the calibration of the Red and Blue imagers in the camera array.

Image Fusion of Color Images with Near-IR Images

[00132] The spectral response of CMOS imagers is typically very good in the near-IR regions covering 650nm to 800nm and reasonably good between 800nm and 1000nm. Although near-IR images having no chroma information, information in this spectral region is useful in low lighting conditions because the near-IR images are relatively free of noise. Hence, the near-IR images may be used to denoise color images under the low lighting conditions.

[00133] In one embodiment, an image from a near-IR imager is fused with another image from a visible light imager. Before proceeding with the fusion, a registration is performed between the near-IR image and the visible light image to resolve differences in viewpoints. The registration process may be performed in an offline, one-time, processing step. After the registration is performed, the luminance information on the near-IR image is interpolated to grid points that correspond to each grid point on the visible light image.

[00134] After the pixel correspondence between the near-IR image and the visible light image is established, a denoising and detail transfer process may be performed. The denoising process allows transfer of signal information from the near-IR image to the visible light image to improve the overall SNR of the fusion image. The detail transfer ensures that edges in the near-IR image and the visible light image are preserved and accentuated to improve the overall visibility of objects in the fused image.

[00135] In one embodiment, a near-IR flash may serve as a near-IR light source during capturing of an image by the near-IR imagers. Using the near-IR flash is advantageous, among other reasons, because (i) the harsh lighting on objects of interest may be prevented, (ii) ambient color of the object may be preserved, and (iii) red-eye effect may be prevented.

[00136] In one embodiment, a visible light filter that allows only near-IR rays to pass through is used to further optimize the optics for near-IR imaging. The visible light filter improves the near-IR optics transfer function because the light filter results in sharper details in the near-IR image. The details may then be transferred to the visible light images using a dual bilateral filter as described, for example, in Eric P. Bennett et al., "Multispectral Video Fusion," Computer Graphics (ACM SIGGRAPH Proceedings) (July 25, 2006), which is incorporated by reference herein in its entirety.

Dynamic Range Determination by Differing Exposures at Imagers

[00137] An auto-exposure (AE) algorithm is important to obtaining an appropriate exposure for the scene to be captured. The design of the AE algorithm affects the dynamic range of captured images. The AE algorithm determines an exposure value that allows the acquired image to fall in the linear region of the camera array's sensitivity range. The linear region is preferred because a good signal-to-noise ratio is obtained in this region. If the exposure is too low, the picture becomes under-saturated while if the exposure is too high the picture becomes over-saturated. In conventional cameras, an iterative process is taken to reduce the difference between measured picture brightness and previously defined brightness below a threshold. This iterative process requires a large amount of time for convergence, and sometimes results in an unacceptable shutter delay.

[00138] In one embodiment, the picture brightness of images captured by a plurality of imagers is independently measured. Specifically, a plurality of imagers are set to capturing images with different exposures to reduce the time for computing the adequate exposure. For

example, in a camera array with 5 x 5 imagers where 8 luma imagers and 9 near-IR imagers are provided, each of the imagers may be set with different exposures. The near-IR imagers are used to capture low-light aspects of the scene and the luma imagers are used to capture the high illumination aspects of the scene. This results in a total of 17 possible exposures. If exposure for each imager is offset from an adjacent imager by a factor of 2, for example, a maximum dynamic range of 2^{17} or 102dB can be captured. This maximum dynamic range is considerably higher than the typical 48dB attainable in a conventional camera with 8bit image outputs.

[00139] At each time instant, the responses (under-exposed, over-exposed or optimal) from each of the multiple imagers are analyzed based on how many exposures are needed at the subsequent time instant. The ability to query multiple exposures simultaneously in the range of possible exposures accelerates the search compared to the case where only one exposure is tested at once. By reducing the processing time for determining the adequate exposure, shutter delays and shot-to-shot lags may be reduced.

[00140] In one embodiment, the HDR image is synthesized from multiple exposures by combining the images after linearizing the imager response for each exposure. The images from the imagers may be registered before combining to account for the difference in the viewpoints of the imagers.

[00141] In one embodiment, at least one imager includes HDR pixels to generate HDR images. HDR pixels are specialized pixels that capture high dynamic range scenes. Although HDR pixels show superior performances compared to other pixels, HDR pixels show poor performance at low lighting conditions in comparison with near-IR imagers. To improve performance at low lighting conditions, signals from the near-IR imagers may be used in conjunction with the signal from the HDR imager to attain better quality images across different lighting conditions.

[00142] In one embodiment, an HDR image is obtained by processing images captured by multiple imagers by processing, as disclosed, for example, in Paul Debevec et al., "Recovering High Dynamic Range Radiance Maps from Photographs," Computer Graphics (ACM SIGGRAPH Proceedings), (August 16, 1997), which is incorporated by reference herein in its entirety. The ability to capture multiple exposures simultaneously using the imager is advantageous because artifacts caused by motion of objects in the scene can be mitigated or eliminated.

Hyperspectral Imaging by Multiple Imagers

[00143] In one embodiment, a multi-spectral image is rendered by multiple imagers to facilitate the segmentation or recognition of objects in a scene. Because the spectral reflectance coefficients vary smoothly in most real world objects, the spectral reflectance coefficients may be estimated by capturing the scene in multiple spectral dimensions using imagers with different color filters and analyzing the captured images using Principal Components Analysis (PCA).

[00144] In one embodiment, half of the imagers in the camera array are devoted to sampling in the basic spectral dimensions (R, G, and B) and the other half of the imagers are devoted to sampling in a shifted basic spectral dimensions (R', G', and B'). The shifted basic spectral dimensions are shifted from the basic spectral dimensions by a certain wavelength (e.g., 10nm).

[00145] In one embodiment, pixel correspondence and non-linear interpolation is performed to account for the sub-pixel shifted views of the scene. Then the spectral reflectance coefficients of the scene are synthesized using a set of orthogonal spectral basis functions as disclosed, for example, in J.P.S. Parkkinen, J. Hallikainen and T. Jaaskelainen, "Characteristic Spectra of Munsell Colors," J. Opt. Soc. Am., A 6:318 (August 1989), which is incorporated by reference herein in its entirety. The basis functions are eigenvectors derived by PCA of a correlation matrix and the correlation matrix is derived from a database storing spectral reflectance coefficients measured by, for example, Munsell color chips (a total of 1257) representing the spectral distribution of a wide range of real world materials to reconstruct the spectrum at each point in the scene.

[00146] At first glance, capturing different spectral images of the scene through different imagers in the camera array appears to trade resolution for higher dimensional spectral sampling. However, some of the lost resolution may be recovered. The multiple imagers sample the scene over different spectral dimensions where each sampling grid of each imager is offset by a sub-pixel shift from the others. In one embodiment, no two sampling grid of the imager overlap. That is, the superposition of all the sampling grids from all the imagers forms a dense, possibly non-uniform, montage of points. Scattered data interpolation methods may be used to determine the spectral density at each sample point in this non-uniform montage for each spectral image, as described, for example, in Shiaofen Fang et al., "Volume Morphing Methods for Landmark Based 3D Image Deformation" by SPIE vol.

2710, proc. 1996 SPIE Intl Symposium on Medical Imaging, page 404-415, Newport Beach, CA (February 1996), which is incorporated by reference herein in its entirety. In this way, a certain amount of resolution lost in the process of sampling the scene using different spectral filters may be recovered.

[00147] As described above, image segmentation and object recognition are facilitated by determining the spectral reflectance coefficients of the object. The situation often arises in security applications wherein a network of cameras is used to track an object as it moves from the operational zone of one camera to another. Each zone may have its own unique lighting conditions (fluorescent, incandescent, D65, etc.) that may cause the object to have a different appearance in each image captured by different cameras. If these cameras capture the images in a hyper-spectral mode, all images may be converted to the same illuminant to enhance object recognition performance.

[00148] In one embodiment, camera arrays with multiple imagers are used for providing medical diagnostic images. Full spectral digitized images of diagnostic samples contribute to accurate diagnosis because doctors and medical personnel can place higher confidence in the resulting diagnosis. The imagers in the camera arrays may be provided with color filters to provide full spectral data. Such camera array may be installed on cell phones to capture and transmit diagnostic information to remote locations as described, for example, in Andres W. Martinez et al., "Simple Telemedicine for Developing Regions: Camera Phones and Paper-Based Microfluidic Devices for Real-Time, Off-Site Diagnosis," Analytical Chemistry (American Chemical Society) (April 11, 2008), which is incorporated by reference herein in its entirety. Further, the camera arrays including multiple imagers may provide images with a large depth of field to enhance the reliability of image capture of wounds, rashes, and other symptoms.

[00149] In one embodiment, a small imager (including, for example, 20-500 pixels) with a narrow spectral bandpass filters is used to produce a signature of the ambient and local light sources in a scene. By using the small imager, the exposure and white balance characteristics may be determined more accurately at a faster speed. The spectral bandpass filters may be ordinary color filters or diffractive elements of a bandpass width adequate to allow the number of camera arrays to cover the visible spectrum of about 400nm. These imagers may run at a much higher frame rate and obtain data (which may or may not be used for its pictorial content) for processing into information to control the exposure and white balance of

other larger imagers in the same camera array. The small imagers may also be interspersed within the camera array.

Optical Zoom Implemented Using Multiple Imagers

[00150] In one embodiment, a subset of imagers in the camera array includes telephoto lenses. The subset of imagers may have other imaging characteristics that are the same as imagers with non-telephoto lenses. Images from this subset of imagers are combined and super-resolution processed to form a super-resolution telephoto image. In another embodiment, the camera array includes two or more subsets of imagers equipped with lenses of more than two magnifications to provide differing zoom magnifications.

[00151] Embodiments of the camera arrays may achieve its final resolution by aggregating images through super-resolution. Taking an example of providing 5 x 5 imagers with a 3X optical zoom feature, if 17 imagers are used to sample the luma (G) and 8 imagers are used to sample the chroma (R and B), 17 luma imagers allow a resolution that is four times higher than what is achieved by any single imager in the set of 17 imagers. If the number of the imagers is increased from 5 x 5 to 6 x 6, an addition of 11 extra imagers becomes available. In comparison with the 8 Megapixel conventional image sensor fitted with a 3X zoom lens, a resolution that is 60% of the conventional image sensor is achieved when 8 of the additional 11 imagers are dedicated to sampling luma (G) and the remaining 3 imagers are dedicated to chroma (R and B) and near-IR sampling at 3X zoom. This considerably reduces the chroma sampling (or near-IR sampling) to luma sampling ratio. The reduced chroma to luma sampling ratio is somewhat offset by using the super-resolved luma image at 3X zoom as a recognition prior on the chroma (and near-IR) image to resample the chroma image at a higher resolution.

[00152] With 6 x 6 imagers, a resolution equivalent to the resolution of conventional image sensor is achieved at 1X zoom. At 3X zoom, a resolution equivalent to about 60% of conventional image sensor outfitted with a 3X zoom lens is obtained by the same imagers. Also, there is a decrease in luma resolution at 3X zoom compared with conventional image sensors with resolution at 3X zoom. The decreased luma resolution, however, is offset by the fact that the optics of conventional image sensor has reduced efficiency at 3X zoom due to crosstalk and optical aberrations.

[00153] The zoom operation achieved by multiple imagers has the following advantages. First, the quality of the achieved zoom is considerably higher than what is achieved in the conventional image sensor due to the fact that the lens elements may be tailored for each change in focal length. In conventional image sensors, optical aberrations and field curvature must be corrected across the whole operating range of the lens, which is considerably harder in a zoom lens with moving elements than in a fixed lens element where only aberrations for a fixed focal length need to be corrected. Additionally, the fixed lens in the imagers has a fixed chief ray angle for a given height, which is not the case with conventional image sensor with a moving zoom lens. Second, the imagers allow simulation of zoom lenses without significantly increasing the optical track height. The reduced height allows implementation of thin modules even for camera arrays with zooming capability.

[00154] The overhead required to support a certain level of optical zoom in camera arrays according to some embodiments is tabulated in Table 2.

Table 2

No. of Imagers in Camera array	No. of Luma Imagers at different Zoom levels			No. of Chroma Imagers at different Zoom Levels		
	1X	2X	3X	1X	2X	3X
25	17	0	0	8	0	0
36	16	0	8	8	0	4

a.

b.

[00155] In one embodiment, the pixels in the images are mapped onto an output image with a size and resolution corresponding to the amount of zoom desired in order to provide a smooth zoom capability from the widest-angle view to the greatest-magnification view. Assuming that the higher magnification lenses have the same center of view as the lower magnification lenses, the image information available is such that a center area of the image has a higher resolution available than the outer area. In the case of three or more distinct magnifications, nested regions of different resolution may be provided with resolution increasing toward the center.

[00156] An image with the most telephoto effect has a resolution determined by the super-resolution ability of the imagers equipped with the telephoto lenses. An image with the widest field of view can be formatted in at least one of two following ways. First, the wide field image may be formatted as an image with a uniform resolution where the resolution is

determined by the super-resolution capability of the set of imagers having the wider-angle lenses. Second, the wide field image is formatted as a higher resolution image where the resolution of the central part of the image is determined by the super-resolution capability of the set of imagers equipped with telephoto lenses. In the lower resolution regions, information from the reduced number of pixels per image area is interpolated smoothly across the larger number of "digital" pixels. In such an image, the pixel information may be processed and interpolated so that the transition from higher to lower resolution regions occurs smoothly.

[00157] In one embodiment, zooming is achieved by inducing a barrel-like distortion into some, or all, of the array lens so that a disproportionate number of the pixels are dedicated to the central part of each image. In this embodiment, every image has to be processed to remove the barrel distortion. To generate a wide-angle image, pixels closer to the center are sub-sampled relative to outer pixels are super-sampled. As zooming is performed, the pixels at the periphery of the imagers are progressively discarded and the sampling of the pixels nearer the center of the imager is increased.

[00158] In one embodiment, mipmap filters are built to allow images to be rendered at a zoom scale that is between the specific zoom range of the optical elements (e.g., 1X and 3X zoom scales of the camera array). Mipmaps are a precalculated optimized set of images that accompany a baseline image. A set of images associated with the 3X zoom luma image can be created from a baseline scale at 3X down to 1X. Each image in this set is a version of the baseline 3X zoom image but at a reduced level of detail. Rendering an image at a desired zoom level is achieved using the mipmap by (i) taking the image at 1X zoom, and computing the coverage of the scene for the desired zoom level (i.e., what pixels in the baseline image needs to be rendered at the requested scale to produce the output image), (ii) for each pixel in the coverage set, determine if the pixel is in the image covered by the 3X zoom luma image, (iii) if the pixel is available in the 3X zoom luma image, then choose the two closest mipmap images and interpolate (using smoothing filter) the corresponding pixels from the two mipmap images to produce the output image, and (iv) if the pixel is unavailable in the 3X zoom luma image, then choose the pixel from the baseline 1X luma image and scale up to the desired scale to produce the output pixel. By using mipmaps, smooth optical zoom may be simulated at any point between two given discrete levels (i.e., 1X zoom and 3X zoom).

[00159] In one embodiment, zooming is achieved by realizing different Fields Of View (FOV)s by electronically switching between different optical channels having different sensor sizes, but fixed Effective Focal Lengths (EFL)s. In one such embodiment, shown schematically in Figure 8A, variable FOVs are achieved by creating optical channels on the same substrate that have different imager sizes 800 and 802 at the same fixed EFL 804. Using this structure, it would be possible to create an arbitrary number of zoom magnifications by including image sensors with larger or smaller numbers of pixels. This technique is particularly simple to incorporate into WLO array cameras as these variable zoom sensor arrays 800 and 802 can be fabricated directly onto the base camera array substrate without any further modification to the design of the array camera assembly itself.

[00160] In another embodiment, as shown in Figure 8B, different FOVs are achieved by engineering different EFLs 805 into specific optical channels of the camera array 806 while maintaining a fixed imager size 808. Implementing different EFLs on the same substrate stacks, i.e., substrate stacks with constant thicknesses and spacings, is more complicated, because the distance of the principal plane and with it the entrance pupil and consequently the aperture stop 810 with respect to the image sensor 814 needs to be changed in order to change the focal length of the optical channel. In the current embodiment, this is accomplished by the introduction of "dummy substrates" 816, 818 and 820 into the stack 806, such that each zoom channel 822, 824 and 826 has an associated aperture stop 828, 830 and 832 disposed on a different substrate or a different face of a substrate, such that different EFLs can be achieved. As shown, while the distribution and positioning of the lenses (834, 836 and 838) and the aperture stops (828, 830 and 832) on the particular substrate or substrate face is entirely dependent on the desired EFL, in all cases the substrate thicknesses and distances remain fixed. Alternatively, in such an embodiment, each of the substrates could be provided with lenses, but in different distributions in order to allow for different EFLs. Such a structure would allow for higher image quality, but at higher cost.

[00161] In another further embodiment, as shown in Figure 8C, different FOVs can also be achieved by engineering different EFLs 805 using "dummy" substrates in a manner similar to that illustrated in Figure 8B, with the exception that all of the substrates have lenses elements on them in each optical channel. The lens elements, however, have different prescriptions in order to allow different EFLs. Accordingly, any of a variety of configurations of optics and

sensor size, and/or light sensing element size can be utilized with an array camera in accordance with embodiments of the invention to achieve different FOVs.

Capturing Video Images

[00162] In one embodiment, the camera array generates high frame image sequences. The imagers in the camera array can operate independently to capture images. Compared to conventional image sensors, the camera array may capture images at the frame rate up to N time (where N is the number of imagers). Further, the frame period for each imager may overlap to improve operations under low-light conditions. To increase the resolution, a subset of imagers may operate in a synchronized manner to produce images of higher resolution. In this case, the maximum frame rate is reduced by the number of imagers operating in a synchronized manner. The high-speed video frame rates can enables slow-motion video playback at a normal video rate.

[00163] In one example, two luma imagers (green imagers or near-IR imagers), two blue imagers and two green imagers are used to obtain high-definition 1080p images. Using permutations of four luma imagers (two green imagers and two near-IR imagers or three green imagers and one near-IR imager) together with one blue imager and one red imager, the chroma imagers can be upsampled to achieve 120 frames/sec for 1080p video. For higher frame rate imaging devices, the number of frame rates can be scaled up linearly. For Standard-Definition (480p) operation, a frame rate of 240 frames/sec may be achieved using the same camera array.

[00164] Conventional imaging devices with a high-resolution image sensor (e.g., 8 Megapixels) use binning or skipping to capture lower resolution images (e.g., 1080p30, 720p30 and 480p30). In binning, rows and columns in the captured images are interpolated in the charge, voltage or pixel domains in order to achieve the target video resolutions while reducing the noise. In skipping, rows and columns are skipped in order to reduce the power consumption of the sensor. Both of these techniques result in reduced image quality.

[00165] In one embodiment, the imagers in the camera arrays are selectively activated to capture a video image. For example, 9 imagers (including one near-IR imager) may be used to obtain 1080p (1920 x 1080 pixels) images while 6 imagers (including one near-IR imager) may be used to obtain 720p (1280 x 720 pixels) images or 4 imagers (including one near-IR imager) may be used to obtain 480p (720 x 480 pixels) images. Because there is an accurate

one-to-one pixel correspondence between the imager and the target video images, the resolution achieved is higher than traditional approaches. Further, since only a subset of the imagers is activated to capture the images, significant power savings can also be achieved. For example, 60% reduction in power consumption is achieved in 1080p and 80% of power consumption is achieved in 480p.

[00166] Using the near-IR imager to capture video images is advantageous because the information from the near-IR imager may be used to denoise each video image. In this way, the camera arrays of embodiments exhibit excellent low-light sensitivity and can operate in extremely low-light conditions. In one embodiment, super-resolution processing is performed on images from multiple imagers to obtain higher resolution video imagers. The noise-reduction characteristics of the super-resolution process along with fusion of images from the near-IR imager results in a very low-noise images.

[00167] In one embodiment, high-dynamic-range (HDR) video capture is enabled by activating more imagers. For example, in a 5 x 5 camera array operating in 1080p video capture mode, there are only 9 cameras active. A subset of the 16 cameras may be overexposed and underexposed by a stop in sets of two or four to achieve a video output with a very high dynamic range.

Other Applications for Multiple Imagers

[00168] In one embodiment, the multiple imagers are used for estimating distance to an object in a scene. Since information regarding the distance to each point in an image is available in the camera array along with the extent in x and y coordinates of an image element, the size of an image element may be determined. Further, the absolute size and shape of physical items may be measured without other reference information. For example, a picture of a foot can be taken and the resulting information may be used to accurately estimate the size of an appropriate shoe.

[00169] In one embodiment, reduction in depth of field is simulated in images captured by the camera array using distance information. The camera arrays according to the present invention produce images with greatly increased depth of field. The long depth of field, however, may not be desirable in some applications. In such case, a particular distance or several distances may be selected as the "in best focus" distance(s) for the image and based on the distance (z) information from parallax information, the image can be blurred pixel-by-

pixel using, for example, a simple Gaussian blur. In one embodiment, the depth map obtained from the camera array is utilized to enable a tone mapping algorithm to perform the mapping using the depth information to guide the level, thereby emphasizing or exaggerating the 3D effect.

[00170] In one embodiment, apertures of different sizes are provided to obtain aperture diversity. The aperture size has a direct relationship with the depth of field. In miniature cameras, however, the aperture is generally made as large as possible to allow as much light to reach the camera array. Different imagers may receive light through apertures of different sizes. For imagers to produce a large depth of field, the aperture may be reduced whereas other imagers may have large apertures to maximize the light received. By fusing the images from sensor images of different aperture sizes, images with large depth of field may be obtained without sacrificing the quality of the image.

[00171] In one embodiment, the camera array according to the present invention refocuses based on images captured from offsets in viewpoints. Unlike a conventional plenoptic camera, the images obtained from the camera array of the present invention do not suffer from the extreme loss of resolution. The camera array according to the present invention, however, produces sparse data points for refocusing compared to the plenoptic camera. In order to overcome the sparse data points, interpolation may be performed to refocus data from the spare data points.

[00172] In one embodiment, each imager in the camera array has a different centroid. That is, the optics of each imager are designed and arranged so that the fields of view for each imager slightly overlap but for the most part constitute distinct tiles of a larger field of view. The images from each of the tiles are panoramically stitched together to render a single high-resolution image.

[00173] In one embodiment, camera arrays may be formed on separate substrates and mounted on the same motherboard with spatial separation. The lens elements on each imager may be arranged so that the corner of the field of view slightly encompasses a line perpendicular to the substrate. Thus, if four imagers are mounted on the motherboard with each imager rotated 90 degrees with respect to another imager, the fields of view will be four slightly overlapping tiles. This allows a single design of WLO lens array and imager chip to be used to capture different tiles of a panoramic image.

[00174] In one embodiment, one or more sets of imagers are arranged to capture images that are stitched to produce panoramic images with overlapping fields of view while another imager or sets of imagers have a field of view that encompasses the tiled image generated. This embodiment provides different effective resolution for imagers with different characteristics. For example, it may be desirable to have more luminance resolution than chrominance resolution. Hence, several sets of imagers may detect luminance with their fields of view panoramically stitched. Fewer imagers may be used to detect chrominance with the field of view encompassing the stitched field of view of the luminance imagers.

[00175] In one embodiment, the camera array with multiple imagers is mounted on a flexible motherboard such that the motherboard can be manually bent to change the aspect ratio of the image. For example, a set of imagers can be mounted in a horizontal line on a flexible motherboard so that in the quiescent state of the motherboard, the fields of view of all of the imagers are approximately the same. If there are four imagers, an image with double the resolution of each individual imager is obtained so that details in the subject image that are half the dimension of details that can be resolved by an individual imager. If the motherboard is bent so that it forms part of a vertical cylinder, the imagers point outward. With a partial bend, the width of the subject image is doubled while the detail that can be resolved is reduced because each point in the subject image is in the field of view of two rather than four imagers. At the maximum bend, the subject image is four times wider while the detail that can be resolved in the subject is further reduced.

Offline Reconstruction and Processing

[00176] The images processed by the imaging system 400 may be previewed before or concurrently with saving of the image data on a storage medium such as a flash device or a hard disk. In one embodiment, the images or video data includes rich light field data sets and other useful image information that were originally captured by the camera array. Other traditional file formats could also be used. The stored images or video may be played back or transmitted to other devices over various wired or wireless communication methods.

[00177] In one embodiment, tools are provided for users by a remote server. The remote server may function both as a repository and an offline processing engine for the images or video. Additionally, applets mashed as part of popular photo-sharing communities such as Flikr, Picasaweb, Facebook etc. may allow images to be manipulated interactively, either

individually or collaboratively. Further, software plug-ins into image editing programs may be provided to process images generated by the imaging device 400 on computing devices such as desktops and laptops.

[00178] Various modules described herein may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, application specific integrated circuits (ASICs), or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus. Furthermore, the computers referred to in the specification may include a single processor or may be architectures employing multiple processor designs for increased computing capability.

[00179] While particular embodiments and applications of the present invention have been illustrated and described herein, it is to be understood that the invention is not limited to the precise construction and components disclosed herein and that various modifications, changes, and variations may be made in the arrangement, operation, and details of the methods and apparatuses of the present invention without departing from the spirit and scope of the invention as it is defined in the appended claims.

What is claimed:

1. An imaging device comprising:

at least one imager array, and each imager in the array comprises a plurality of light sensing elements and a lens stack including at least one lens surface, where the lens stack is configured to form an image on the light sensing elements;

control circuitry configured to capture images formed on the light sensing elements of each of the imagers; and

a super-resolution processing module configured to generate at least one higher resolution super-resolved image using a plurality of the captured images.

2. The imaging device of claim 1, wherein:

a spectral filter is provided within each imager and is configured to pass a specific spectral band of light; and

spectral filters that pass different spectral bands are provided within at least two of the imagers.

3. The imaging device of claim 2, wherein the spectral filter is selected from the group consisting of an organic color filter, an absorptive material, a dielectric coating, an interference filter, a multilayer coating, and combinations thereof.

4. The imaging device of claim 2, wherein at least one of the imagers further comprises a polarizing filter.

5. The imaging device of claim 2, wherein the construction of the lens stack within an imager differs based upon the specific spectral band of light passed by the spectral filter within the imager such that chromatic aberrations are reduced.

6. The imaging device of claim 5, wherein the prescription of at least one surface of the lens stack within an imager is a function of the specific spectral band of light passed by the spectral filter within the imager.

7. The imaging device of claim 6, wherein the at least one surface of the lens stack is configured so that the back focal length of each lens stack in the imager array are the same independent of the spectral band.

8. The imaging device of claim 2, wherein a combination of high and low Abbe number materials is used in the construction of each of the lens stacks to reduce chromatic aberrations.

9. The imaging device of claim 2, wherein each lens stack includes at least one aperture stop positioned in front of the light sensing element, and the spectral filter is positioned in proximity to the aperture stop.

10. The imaging device of claim 9, wherein the at least one aperture stop is formed by a light blocking material selected from the group consisting of metal materials, oxide materials, black particle filled photoresists and combinations thereof.

11. The imaging device of claim 2, wherein:

at least one lens surface in the optical stack of an imager differs based upon the specific spectral band of light passed by the spectral filter within the imager; and

each lens surface is selected from the group consisting of diffractive, Fresnel, refractive and combinations thereof.

12. The imaging device of claim 11, wherein the radii of curvature of the lens surfaces differ based upon the specific spectral band of light passed by the spectral filter within the imager.

13. The imaging device of claim 11, wherein the lens stacks of each of the imagers have the same back focal length.

14. The imaging device of claim 1, wherein the light sensing elements are disposed to detect an image in a backside imaging mode.

15. The imaging device of claim 14, wherein a separate negative lens element is disposed in close proximity to the light sensing elements of an imager and in optical alignment with the lens stack of the imager so that the field curvature of the lens stack is corrected.

16. The imaging device of claim 1, wherein a separate negative lens element is disposed in close proximity to the light sensing elements of an imager and in optical alignment with the lens stack of the imager so that the field curvature of the lens stack is corrected.

17. The imaging device of claim 1, wherein at least two of the imagers in the imager array have different fields of view so that different scene sizes can be captured by the imagers.

18. The imaging device of claim 17, wherein the lens stacks of the at least two imagers have different focal lengths.

19. The imaging device of claim 17, wherein the light sensing elements in each of at least two imagers have different sizes.

20. The imaging device of claim 17, wherein the at least two imagers include different numbers of light sensing elements.

21. The imaging device of claim 1, further comprising a mechanical zoom mechanism within the lens stack of an imager for smoothly transitioning between different fields of view.

22. The imaging device of claim 1, wherein at least one of the imagers is designed to image light in the near-infrared spectrum.

23. The imaging device of claim 1, wherein at least one imager is configured to take a measurement of the visible light spectrum, and wherein the control circuitry is

configured to use said measurement to control the imaging characteristics of the other imagers in said imaging device.

24. The imaging device of claim 1, wherein the imaging device includes at least two camera arrays.

25. The imaging device of claim 24, wherein the at least two camera arrays operate in conjunction during imaging to provide stereo images.

26. The imaging device of claim 24, wherein the at least two camera arrays are spatially separated one from the other in at least one plane.

27. The imaging device of claim 24, wherein each of the camera arrays comprise a different combination of imagers each combination of imagers having different imaging characteristics.

28. The imaging device of claim 1, wherein at least one camera array comprises an N x M array of imagers, where at least one of N and M is greater than 2, and each of said imagers comprising at least two light sensing elements.

29. The imaging device of claim 1, wherein the control circuitry is configured to control the imaging characteristics of each imager.

30. The imaging device of claim 29, wherein the controllable imaging characteristics include exposure time, gain, and black level offset.

31. The imaging device of claim 1, wherein the control circuitry is configured to trigger each of said imagers in accordance with a desired sequence.

32. The imaging device of claim 31, wherein the control circuitry operates the imagers in a staggered sequence.

33. The imaging device of claim 1, wherein:

an initial master setting for the imaging characteristics of each imager is set by the control circuitry;

predefined deviations from the initial master settings are also set by the control circuitry; and

the deviations include functions selected from the group consisting of ISO settings, high dynamic range, gain settings, integration time settings, exposure settings, digital processing settings and combinations thereof.

34. The imaging device of claim 1, wherein the camera arrays are fabricated using techniques consisting of wafer level optics techniques, injection molding, glass molding and combinations thereof.

35. The imaging device of claim 1, wherein each of the plurality of imagers are optically separated from each other.

36. The imaging device of claim 35, wherein each of the imagers is optically separated from the other imagers by at least two opaque surfaces located in front of the light sensing elements and having openings arranged in axial alignment with the lens stack of the imager.

37. The imaging device of claim 35, wherein the imagers are optically separated from each other by opaque walls disposed at the boundaries between the imagers.

38. The imaging device of claim 37, wherein the opaque walls are cavities between the imagers filled with light blocking material.

39. The imaging device of claim 35, wherein:

the lens stack includes spacers; and

the spacers are constructed from an opaque material.

40. The imaging device of claim 35, wherein:

the lens stack includes spacers; and

the spacers are coated with an opaque material.

41. The imaging device of claim 1, wherein the control circuitry is configured to perform normalization of a captured low resolution image using a one dimensional space filling curve to describe a normalization plane.

42. The imaging device of claim 41, wherein the one dimensional space filling curve is expressed as the coefficients of a polynomial.

43. The imaging device of claim 1, wherein the control circuitry is configured to capture multiple low resolution images using different imagers having different exposure times.

44. The imaging device of claim 43, wherein the light sensing elements of at least one of the imagers used to capture an image are high dynamic range light sensing elements.

45. The imaging device of claim 44, wherein at least one of the imagers used to capture a low resolution image is configured to capture a near-IR low resolution image.

46. The imaging device of claim 1, wherein the super-resolution module is configured to generate a depth map for the super-resolution image.

47. The imaging device of claim 46, wherein the super-resolution module is configured to select at least one distance as a focal plane and to apply blurring to pixels with depths that are not proximate a focal plane.

48. The imaging device of claim 1, wherein the super-resolution processing module is configured to perform temperature normalization with respect to the captured images.

49. The imaging device of claim 48, wherein:

the point spread functions of the lens stacks vary with temperature; and

the super-resolution processing module is configured to perform temperature normalization by selecting a point spread functions from temperature calibration data corresponding to the point spread functions of the lens stacks during the capture of the images.

50. The imaging device of claim 1, wherein the super-resolution processing module is configured to computationally correct color differences between the captured images.

51. The imaging device of claim 1, wherein the super-resolution processing module is configured to computationally correct geometric distortion differences between the captured images.

52. A lens stack array, comprising:

lens elements formed on substrates separated by spacers, where the lens elements, substrates and spacers are configured to form a plurality of optical channels;

at least one aperture located within each optical channel;

at least one spectral filter located within each optical channel, where each spectral filter is configured to pass a specific spectral band of light; and

light blocking materials located within the lens stack array to optically isolate the optical channels.

53. The lens stack array of claim 52, wherein the light blocking materials are selected from the group consisting of opaque materials, reflective materials and combinations thereof.

54. The lens stack array of claim 52, wherein:

spectral filters that pass different spectral bands are provided within at least two of the imagers.

55. The lens stack array of claim 54, wherein each spectral filter is selected from the group consisting of an organic color filter, an absorptive material, a dielectric coating, an interference filter, a multilayer coating, and combinations thereof.

56. The lens stack array of claim 54, further comprising at least one polarizing filter located within each optical channel.

57. The lens stack array of claim 54, wherein the construction of each optical channel differs based upon the specific spectral band of light passed by the spectral filter within the imager so that chromatic aberrations are reduced.

58. The lens stack array of claim 54, wherein the prescription of at least one surface of a lens within each optical channel is a function of the specific spectral band of light passed by the spectral filter within the optical channel.

59. The lens stack array of claim 58, wherein the back focal lengths of each optical channel in the lens stack array are the same irrespective of the spectral band of light passed by the spectral filter within the optical channel.

60. The lens stack array of claim 54, wherein a combination of high and low Abbe number materials is used in the construction of each of the lens elements in an optical channel to reduce chromatic aberrations.

61. The lens stack array of claim 54, further comprising:

at least one aperture stop located within each optical channel;

wherein each spectral filter is located within each optical channel so that the spectral filter is proximate the aperture stop.

62. The lens stack array of claim 61, wherein each aperture stop is formed by a light blocking material selected from the group consisting of metal materials, oxide materials, black particle filled photoresists and combinations thereof.

63. The lens stack array of claim 54, wherein:

the at least one lens surface of a lens in each optical channel differs based upon the specific spectral band of light passed by the spectral filter within the optical channel; and

each lens surface is selected from the group consisting of diffractive, Fresnel, refractive and combinations thereof.

64. The lens stack array of claim 63, wherein the radii of curvature of the lens surfaces differ based upon the specific spectral band of light passed by the spectral filter within the optical channel.

65. The lens stack array of claim 63, wherein each of the optical channels have the same back focal length.

66. The lens stack array of claim 52, wherein at least one of the lens elements in an optical channel is a negative lens element, and the negative lens element is proximate the image formed by the optical channel.

67. The lens stack array of claim 52, wherein at least two of the optical channels have different focal lengths.

68. The lens stack array of claim 52, further comprising a mechanical zoom mechanism within an optical channel configured to smoothly transition between different fields of view.

69. The lens stack array of claim 52, wherein the lens stack array comprises an N x M array of optical channels, where at least one of N and M is greater than 2.

70. The lens stack array of claim 52, wherein the lens stack array is fabricated using techniques consisting of wafer level optics techniques, injection molding, glass molding and combinations thereof.

71. The lens stack array of claim 52, wherein the light blocking materials located within the lens stack array to optically separate the optical channels comprise at least two opaque surfaces located on a substrate within an optical channel, where the two opaque surfaces have openings arranged in axial alignment with the optical channel.

72. The lens stack array of claim 52, wherein the light blocking materials located within the lens stack array to optically separate the optical channels comprise opaque walls disposed at the boundaries between the optical channels.

73. The lens stack array of claim 72, wherein the opaque walls are cavities between the optical channels filled with light blocking material.

74. The lens stack array of claim 52, wherein a plurality of the spacers are constructed from light blocking materials and are located within the lens stack array to optically separate the optical channels.

75. The lens stack array of claim 52, wherein a plurality of the spacers are coated in light blocking materials and are located within the lens stack array to optically isolate the optical channels.

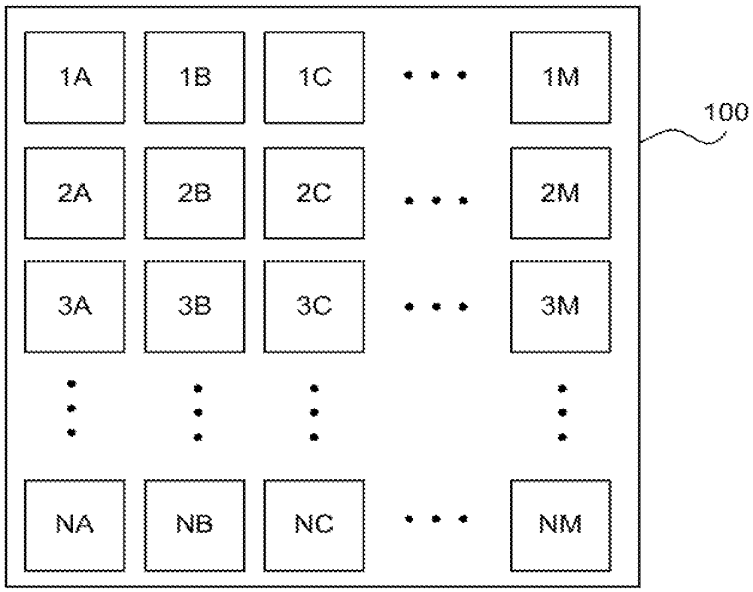

1A
1B
1C
1M
2A
2B
2C
2M
3A
3B
3C
3M
NA
NB
NC
NM
100

FIG. 1

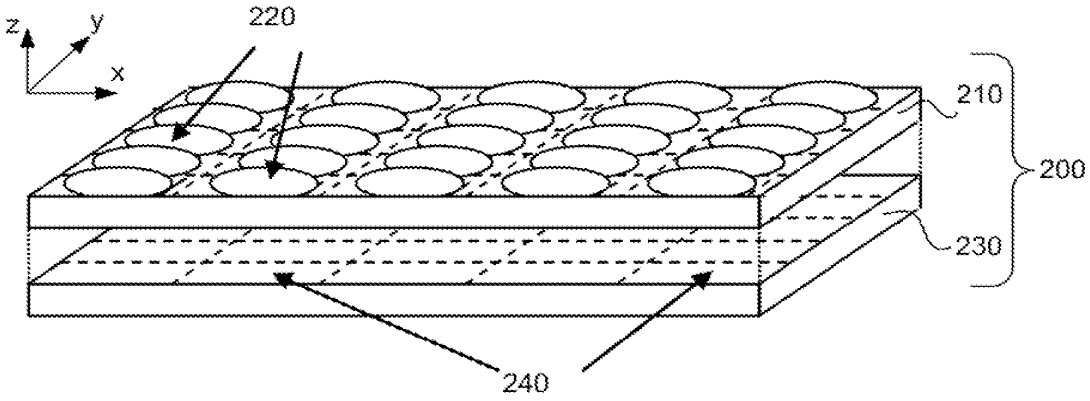

z
y
x
220
210
200
230
240

FIG. 2A

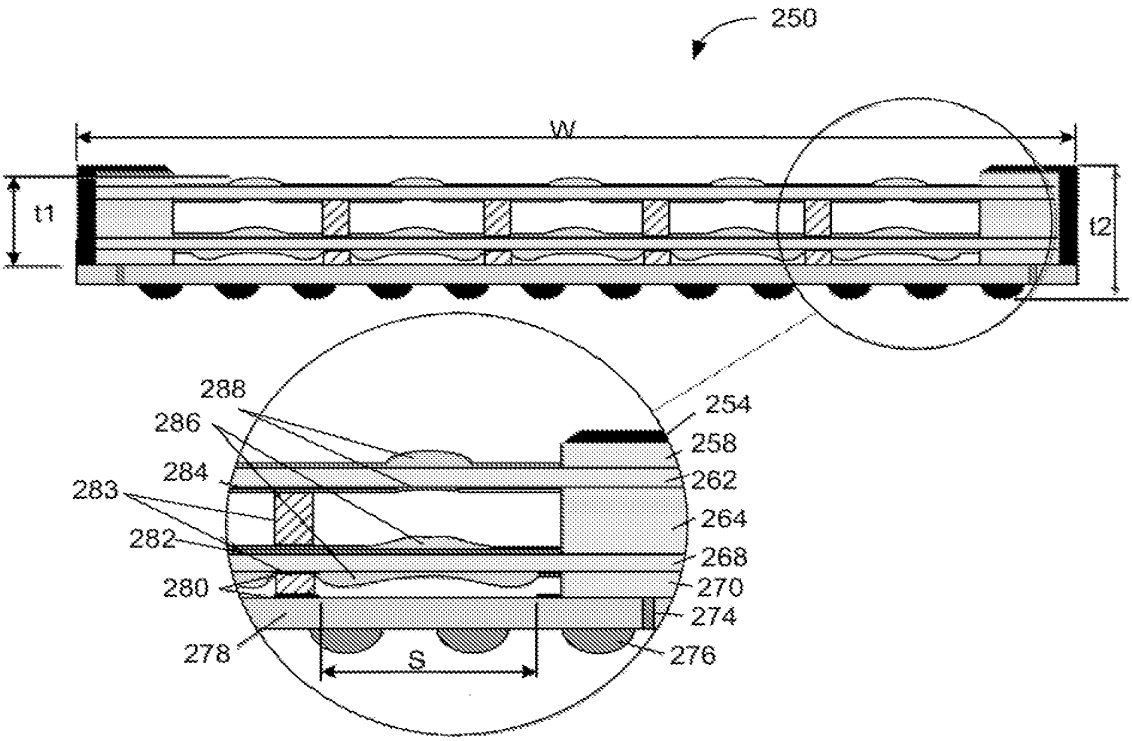


FIG. 2B

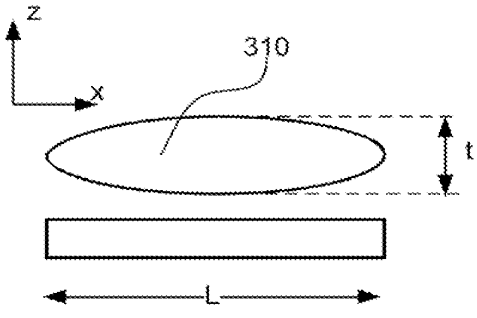


FIG. 3A

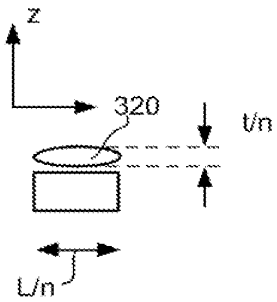


FIG. 3B

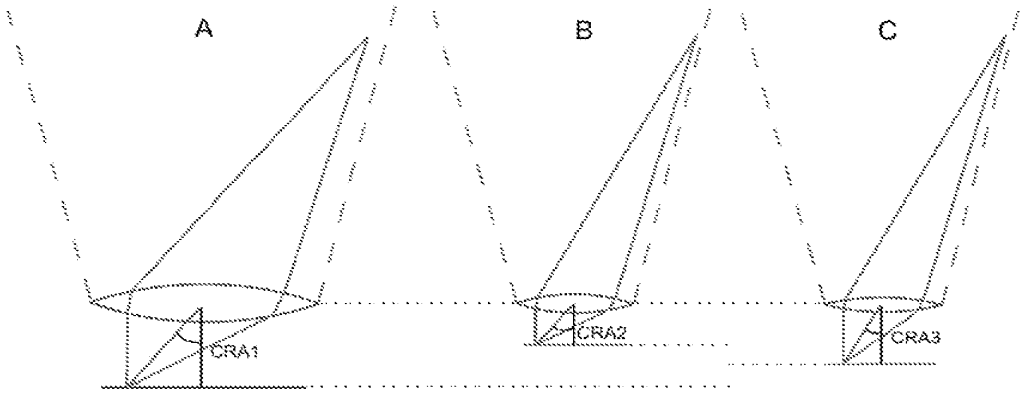

A
B
C
CRA1
CRA2
CRA3

FIG. 3C

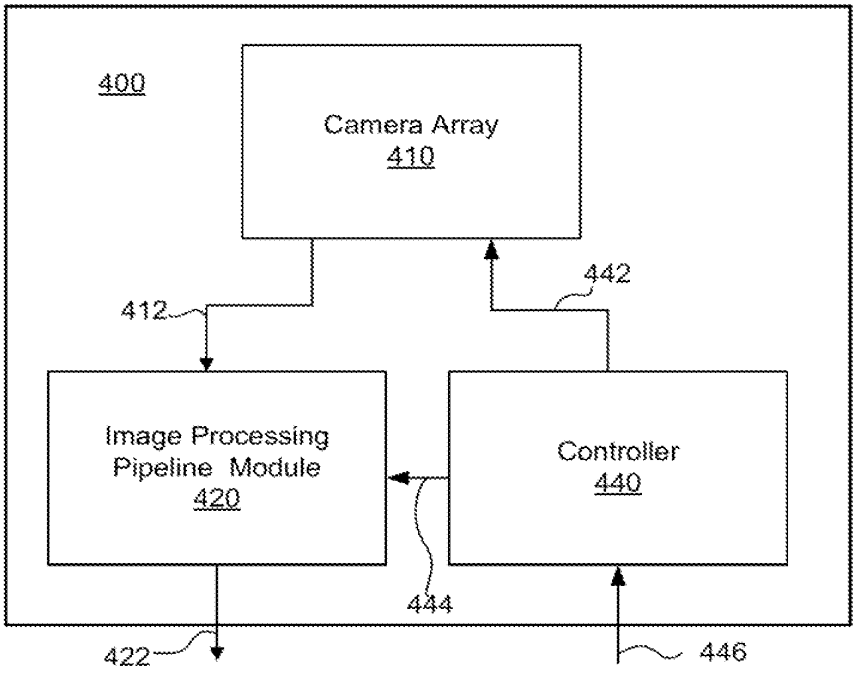

400
Camera Array
410
412
442
Image Processing
Pipeline Module
420
Controller
440
444
422
446

FIG. 4

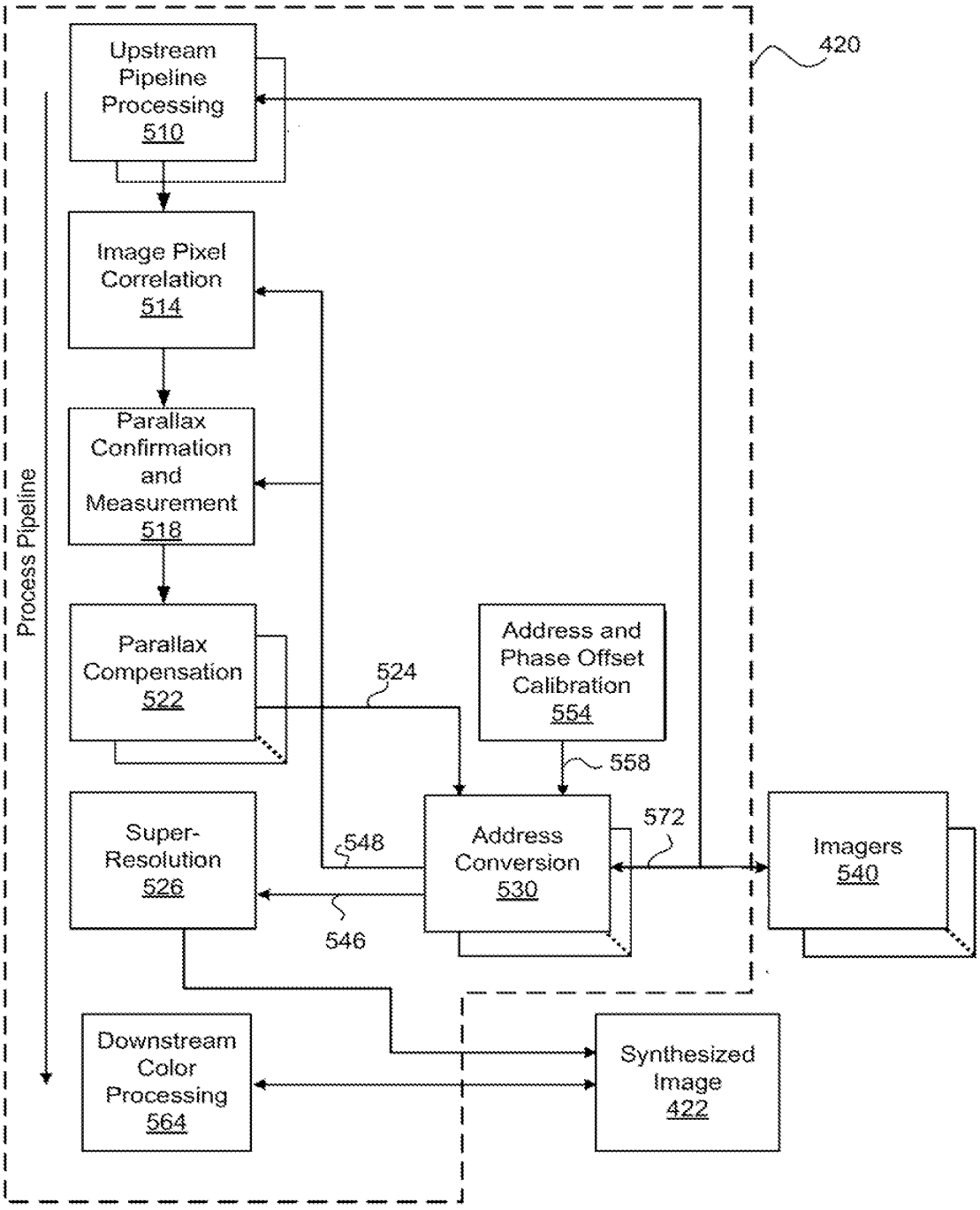

420
Upstream Pipeline Processing 510
Image Pixel Correlation 514
Parallax Confirmation and Measurement 518
Parallax Compensation 522
524
Address and Phase Offset Calibration 554
558
Super-Resolution 526
548
Address Conversion 530
572
Imagers 540
546
Process Pipeline
Downstream Color Processing 564
Synthesized Image 422

FIG. 5

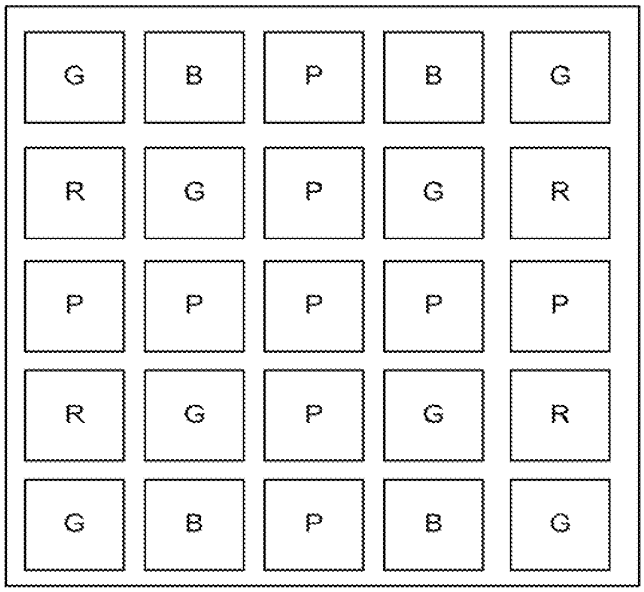


FIG. 6A

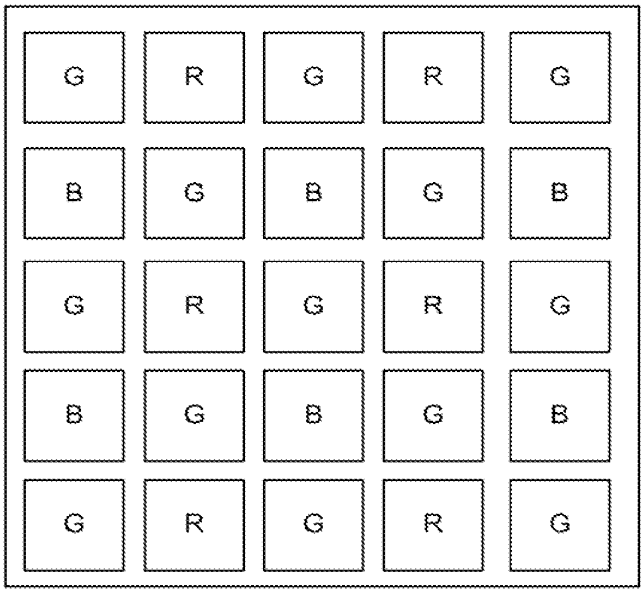

G R G R G
B G B G B
G R G R G
B G B G B
G R G R G

FIG. 6B

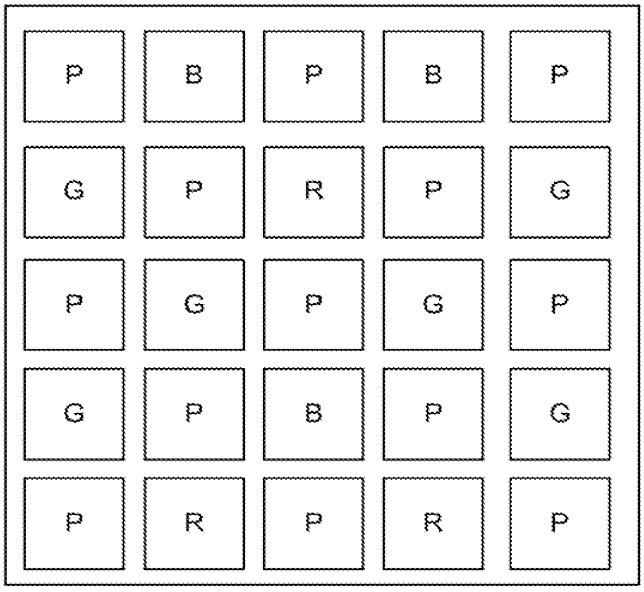

P B P B P
G P R P G
P G P G P
G P B P G
P R P R P

FIG. 6C

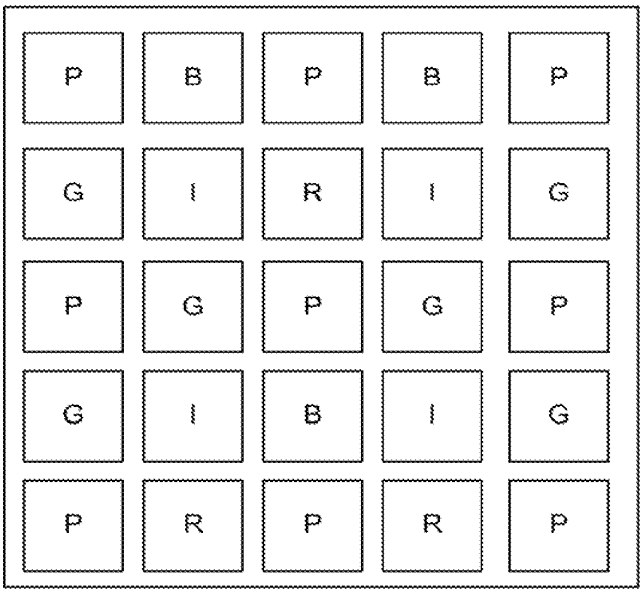

P B P B P
G I R I G
P G P G P
G I B I G
P R P R P

FIG. 6D

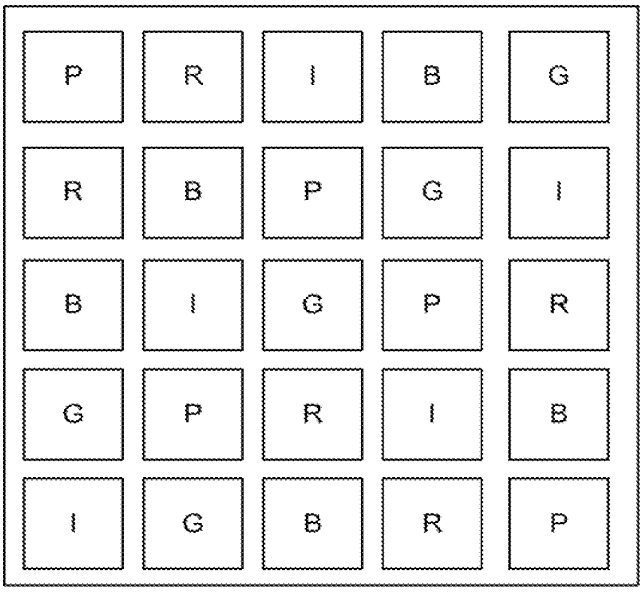

P R I B G
R B P G I
B I G P R
G P R I B
I G B R P

FIG. 6E

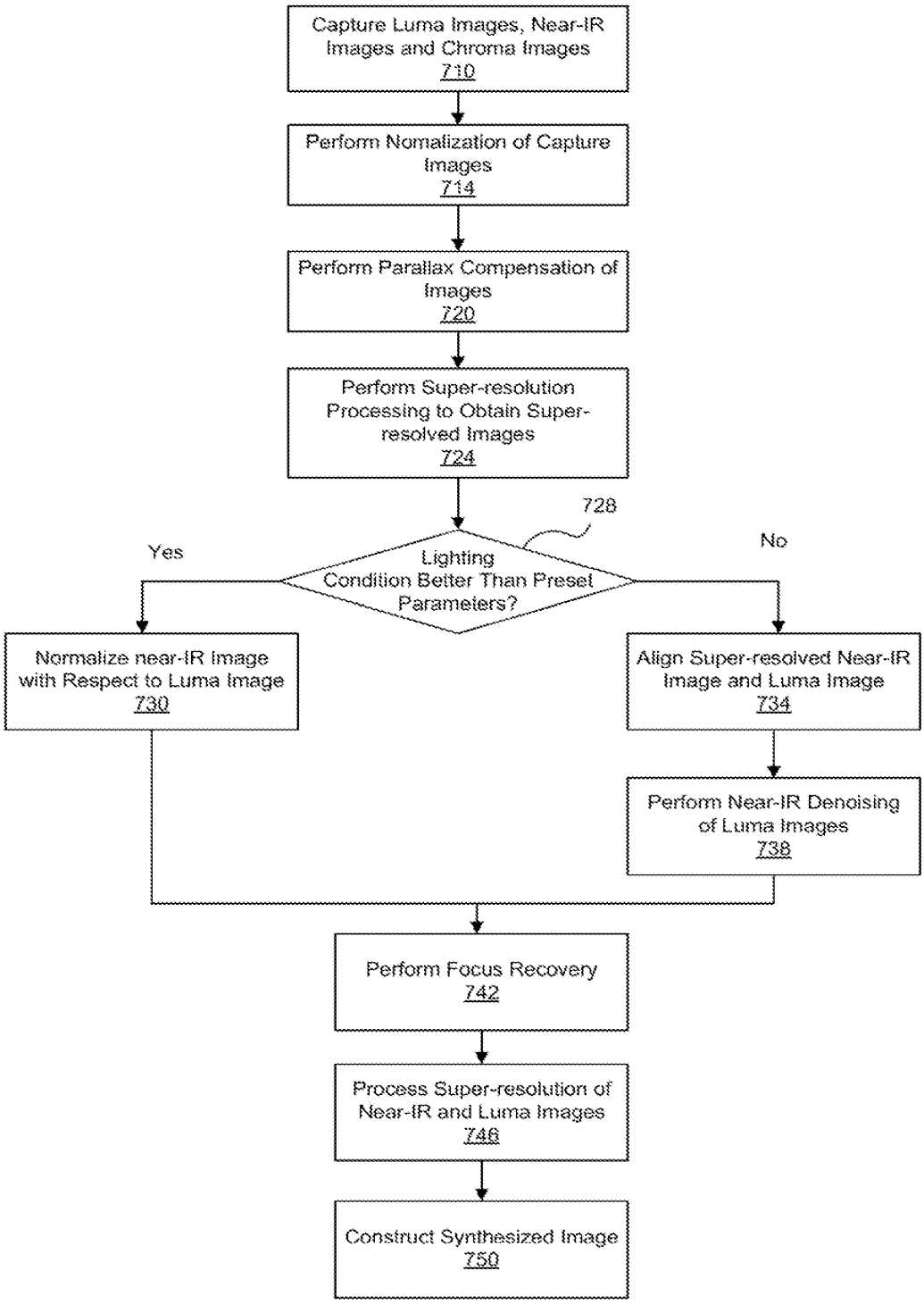

Capture Luma Images, Near-IR Images and Chroma Images
710
Perform Nomalization of Capture Images
714
Perform Parallax Compensation of Images
720
Perform Super-resolution Processing to Obtain Super-resolved Images
724
728
Lighting Condition Better Than Preset Parameters?
Yes
No
Normalize near-IR Image with Respect to Luma Image
730
Align Super-resolved Near-IR Image and Luma Image
734
Perform Near-IR Denoising of Luma Images
738
Perform Focus Recovery
742
Process Super-resolution of Near-IR and Luma Images
746
Construct Synthesized Image
750

FIG. 7

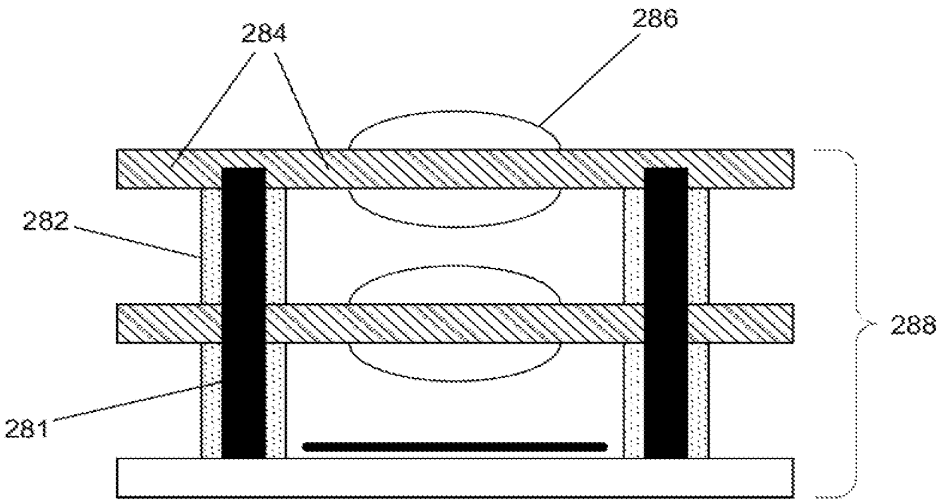


FIG. 2C

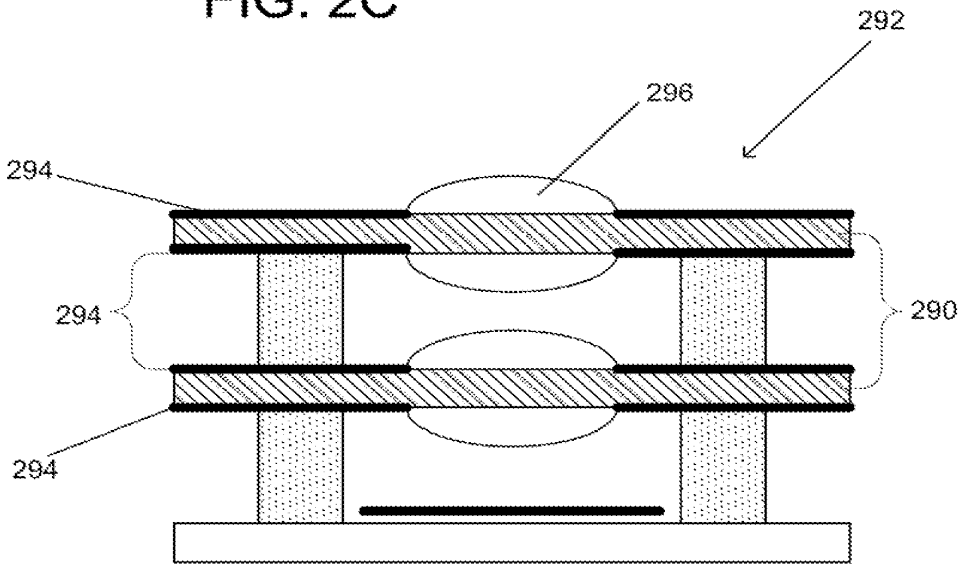


FIG. 2D

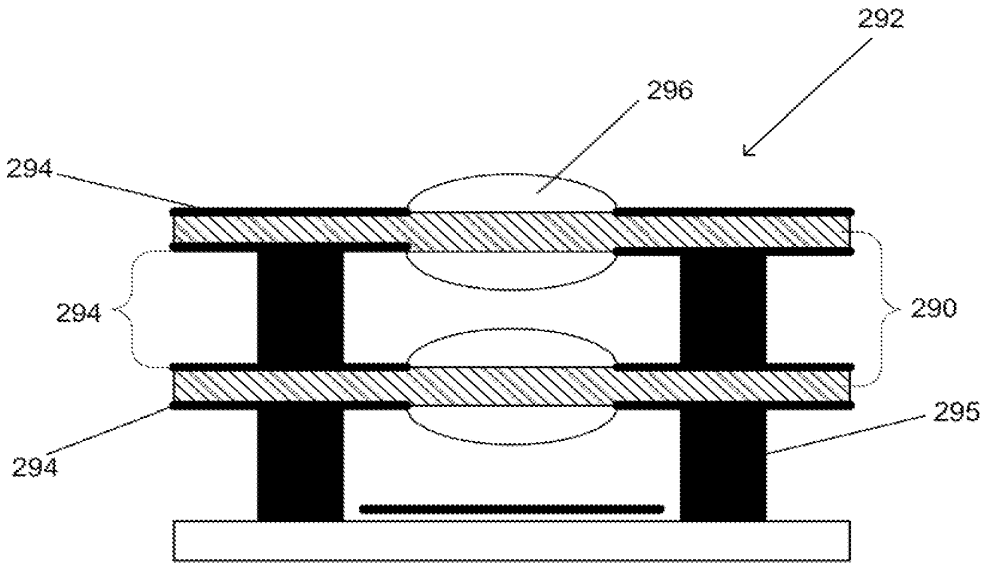


FIG. 2E

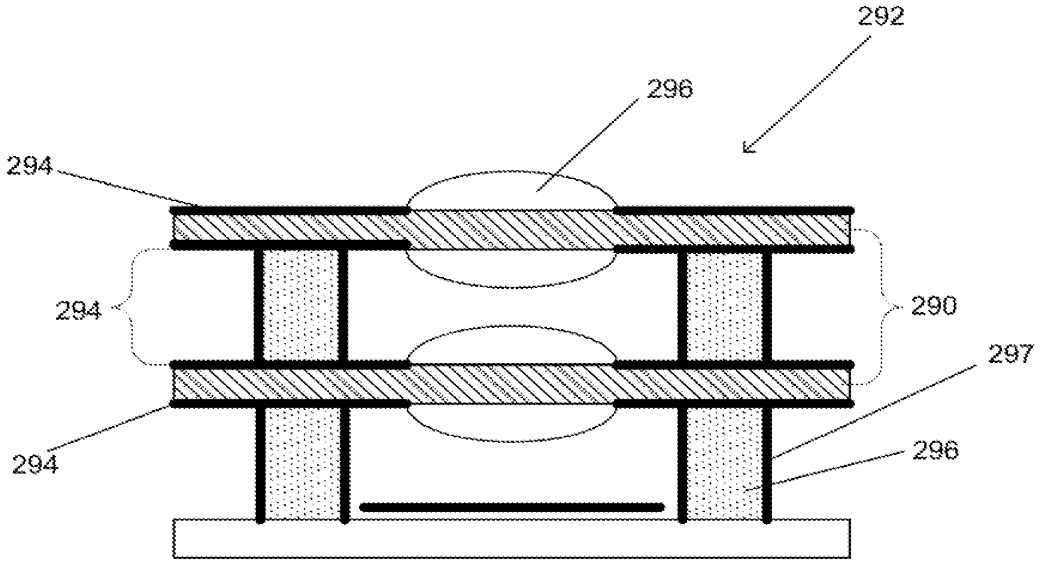


FIG. 2F

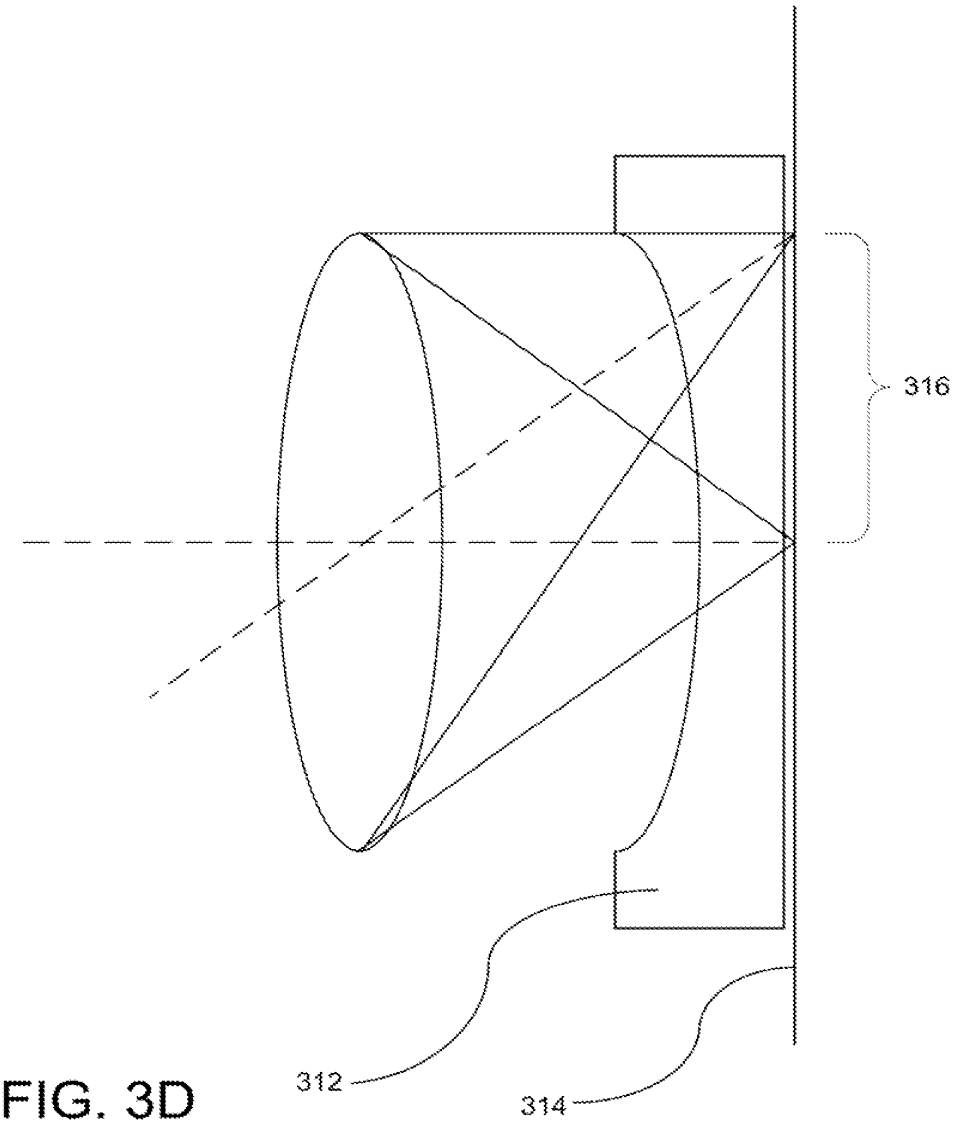


FIG. 3D


G B G B G
R G G G R
G G G G G
R G G G R
G B G B G

FIG. 6F

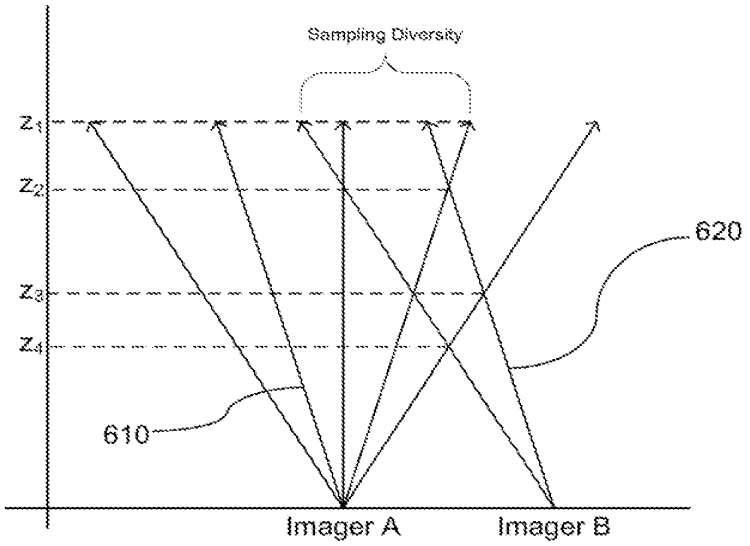

Sampling Diversity
z_1
z_2
z_3
z_4
620
610
Imager A
Imager B

FIG. 6G

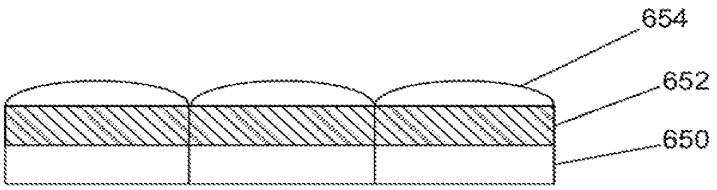


FIG. 6H

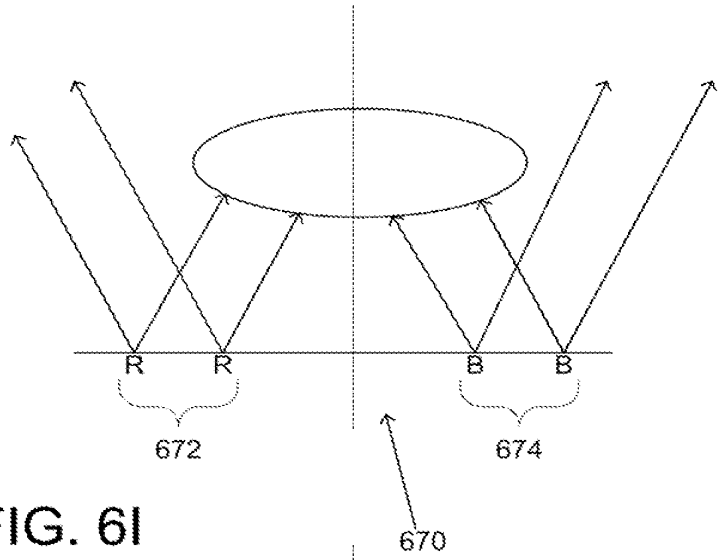


FIG. 6I

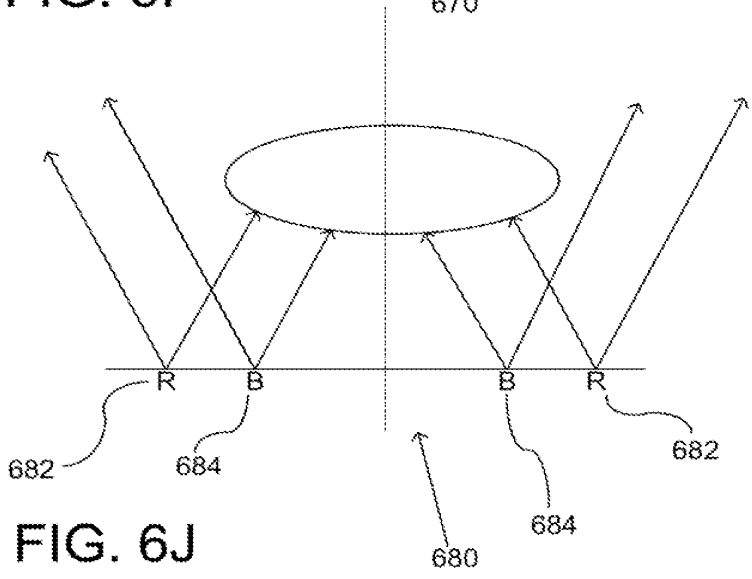


FIG. 6J

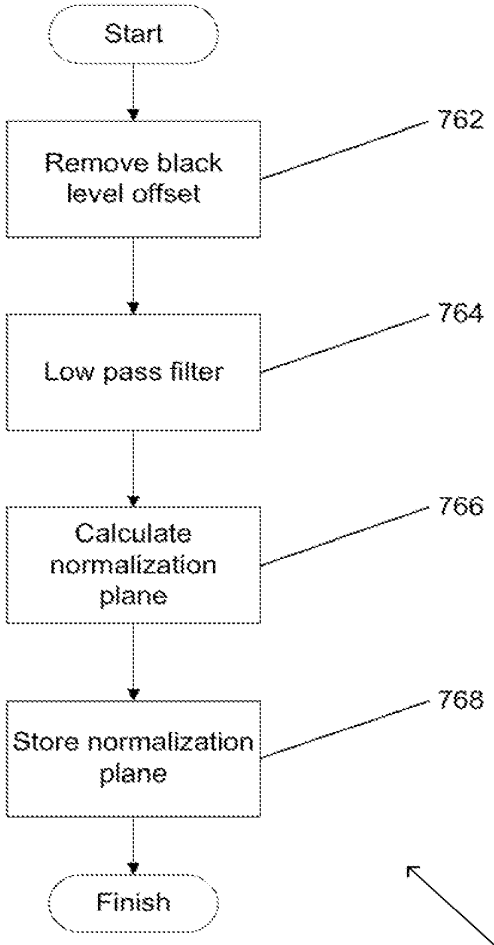

Start
Remove black level offset
762
Low pass filter
764
Calculate normalization plane
766
Store normalization plane
768
Finish
760

FIG. 7A

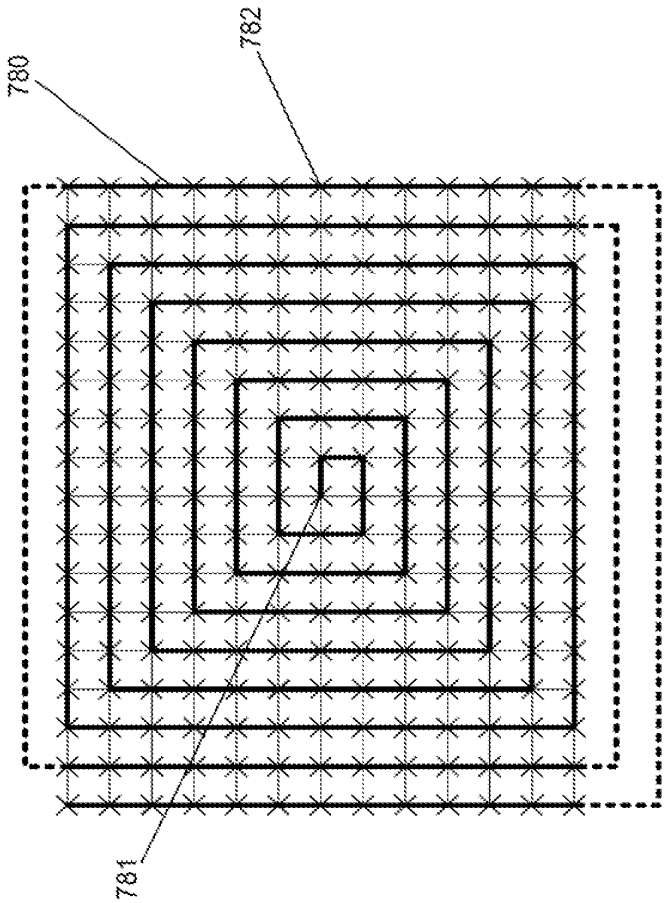


FIG. 7B

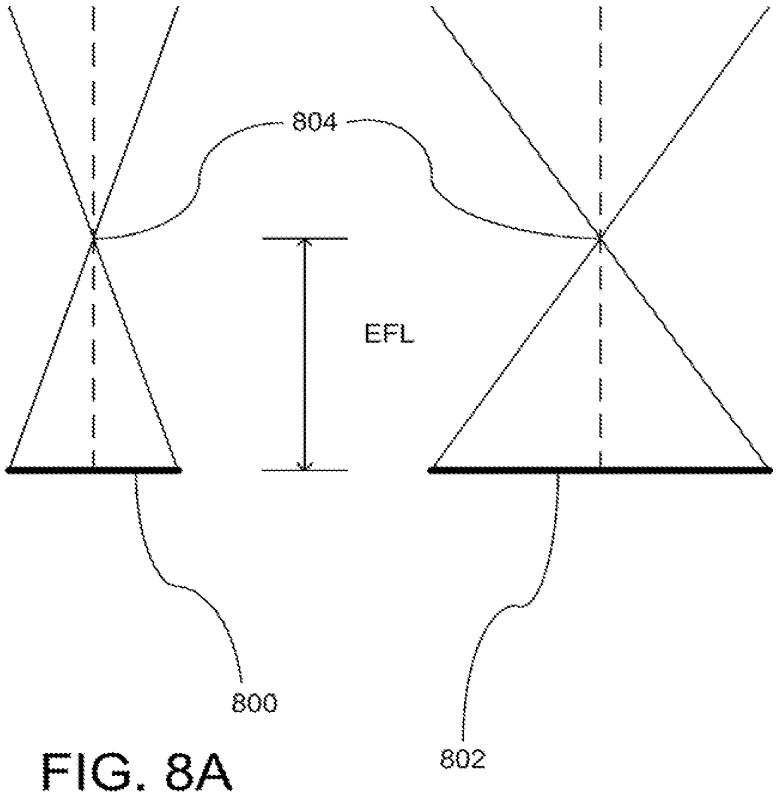


FIG. 8A

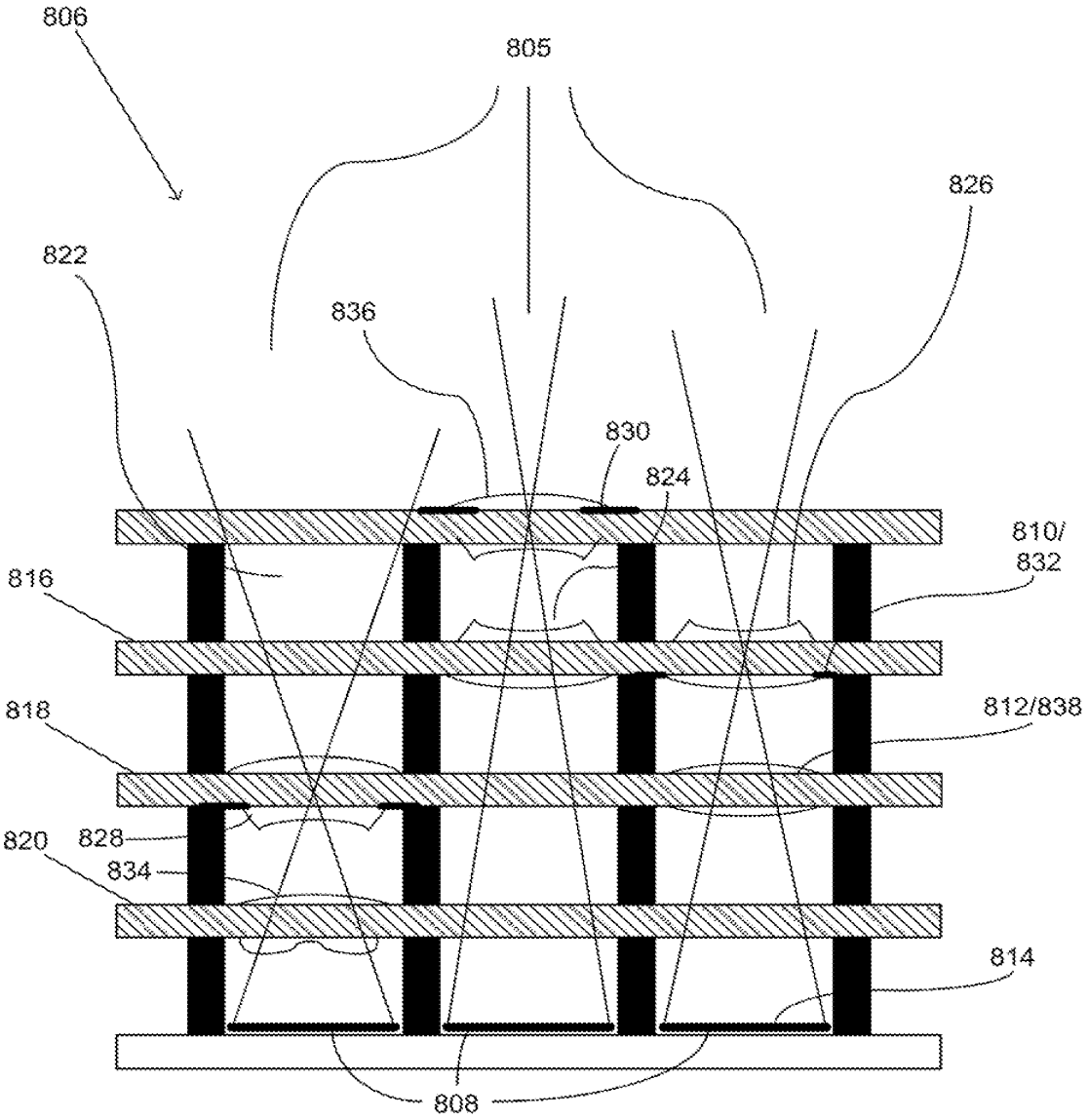

806
805
826
822
836
830
824
810/
832
816
818
812/838
820
828
834
814
808

FIG. 8B

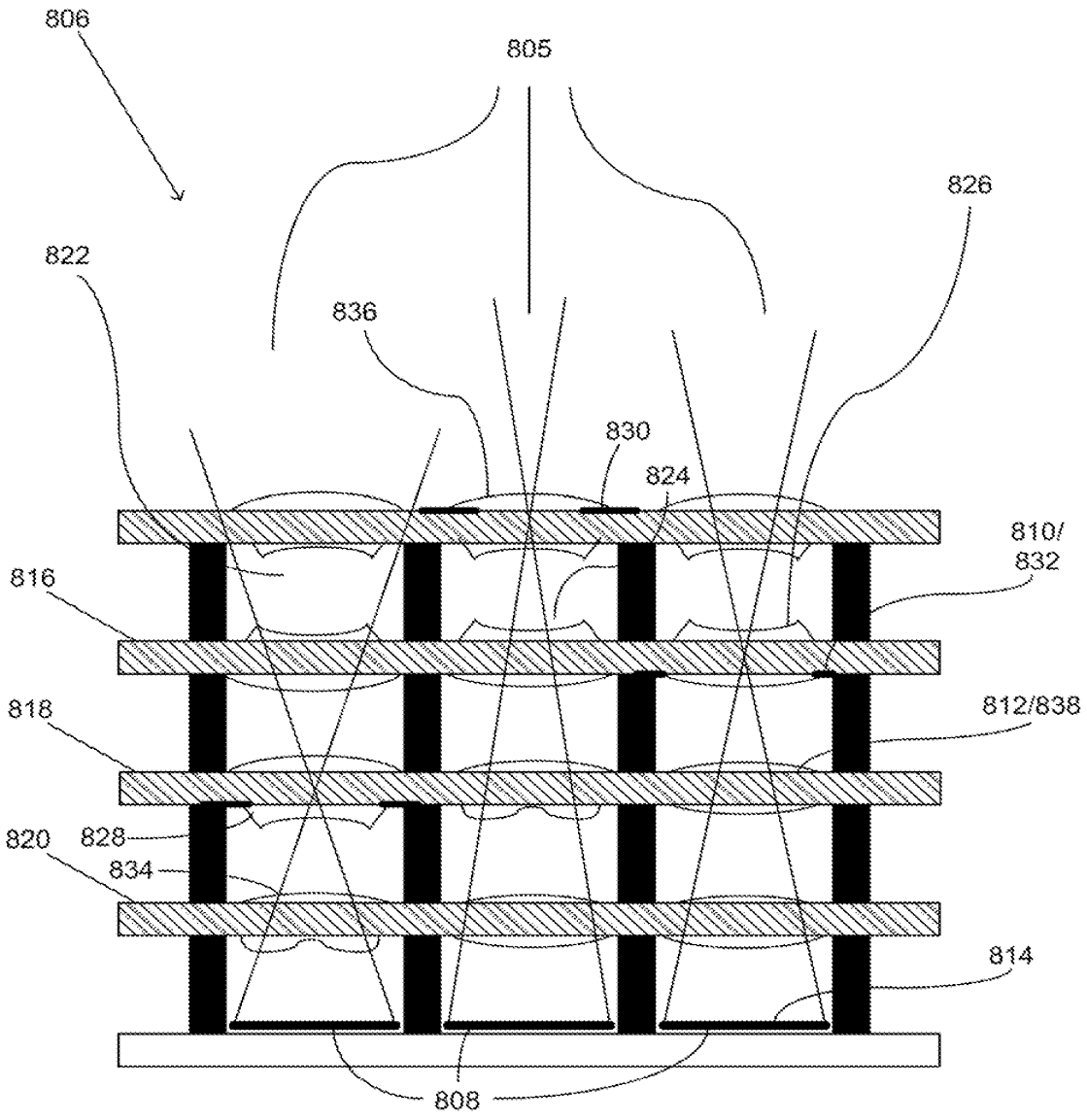

806
805
826
822
836
830
824
810/
832
816
818
812/838
820
828
834
814
808

FIG. 8C

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H04N 5/45 (2011.01)

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(74) Agents: **NISHIKAWA, Takashi** et al.; Nishishinjukukimuraya Building 9F, 5-25, Nishi-Shinjuku 7-chome, Shinjuku-ku, Tokyo, 1600023 (JP).

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

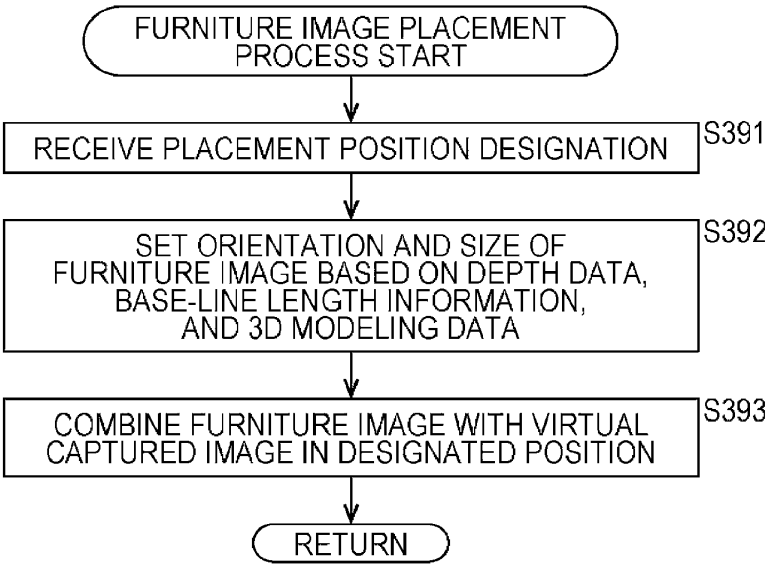
[Continued on next page]

WO 2015/037211 A1

(54) Title: IMAGE PROCESSING DEVICE AND METHOD

(57) Abstract: An image processing apparatus including circuitry configured to initiate a setting of an object for display within a background image in accordance with a modeling condition associated with a position at which the object is set, based on depth data and base-line length information associated with the background image and modeling data of the object.

FIG. 34



(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, ST, 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, KM, ML, MR, NE, SN, TD, TG).

Published:

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

Description

Title of Invention: IMAGE PROCESSING DEVICE AND METHOD

Technical Field

[0001] The present disclosure relates to image processing devices and methods, and more particularly, relates to an image processing device and a method that are designed to increase the user-friendliness of a service that uses multiview images.

[0002] <CROSS REFERENCE TO RELATED APPLICATIONS>

This application claims the benefit of Japanese Priority Patent Applications JP 2013-188409 filed on September 11, 2013 and JP 2014-174173 filed on August 28, 2014, the entire contents of which are incorporated herein by reference.

Background Art

[0003] There is a known technique to measure distances to a measuring object (a subject) by using images with different viewpoints. For example, a distance calculation method that uses a technique called "stereo matching" has been suggested (see Patent Document 1, for example).

[0004] With the stereo matching technique, depth data that indicates a distance to a subject in a multiview image is calculated from the multiview image formed with images having different viewpoints from one another. With the depth data, multiview images are superimposed on one another to generate an image to be provided to a user.

Citation List

Patent Literature

[0005] PTL 1: JP 2011-171858 A

Summary of Invention

Technical Problem

[0006] However, there is a demand for an increase in user-friendliness of such a multiview-image using service.

[0007] The present disclosure is made in view of those circumstances, and is to increase the user-friendliness of the service that uses multiview images.

Solution to Problem

[0008] An image processing apparatus according to an embodiment of the present technique includes circuitry configured to initiate a setting of an object for display within a background image in accordance with a modeling condition associated with a position at which the object is set, based on depth data and base-line length information associated with the background image and modeling data of the object.

[0009] An image processing method according to an embodiment includes: setting an object for display within a background image in accordance with a modeling condition associated with a position at which the object is set, based on depth data and base-line length information associated with the background image and modeling data of the object; and placing the set object to be displayed at the position within the background image.

[0010] An image processing device according to an embodiment of the present technique includes an object placement unit that sets the orientation and the size of an object in a position in which the object is to be placed in a background image, and places the object having the set orientation and the set size in the designated position in the background image, the orientation and the size being set based on depth data, base-line length information, and the three-dimensional modeling data of the object, the depth data indicating the distance to a subject in the background image, the base-line length information being information indicating a reference length in the background image.

[0011] When another position is designated after the object is placed in the background image, the object placement unit may set the orientation and the size of the object in the another position, and place the object having the set orientation and the set size in the another position in the background image.

[0012] When there is a change in the position or the orientation of the viewpoint of the background image, the object placement unit may set the orientation and the size of the object in the position in which the object was placed before the change in the position or the orientation of the viewpoint in the background image not yet having the change in the position or the orientation of the viewpoint, and place the object having the set orientation and the size in the position in which the object was placed before the change in the position or the orientation of the viewpoint in the background image having the change in the position or the orientation of the viewpoint.

[0013] The object placement unit may move the object, to bring the object having the set orientation and the set size into contact with the floor.

[0014] The object placement unit may measure the length of a designated area in the background image.

[0015] The object placement unit may simulate lighting in the background image based on light source parameters and the depth data, and cause the background image to reflect the simulated lighting, the light source parameters being parameters related to the light source.

[0016] The object placement unit may identify a portion that satisfies line-of-flow conditions in the background image having the object placed therein, and emphasize the identified portion in the background image having the object placed therein.

[0017] The object placement unit may set the orientation and the size of a person in a

position in which an image of the person is to be placed in a background having the object placed therein, and place the image of the person having the set orientation and the set size in the designated position in the background image having the object placed therein, the orientation and the size of the person being set based on the depth data, the base-line length information, and the three-dimensional modeling data of the image of the person.

[0018] The object placement unit may set the orientation and the size of the object selected from candidates for the object in the position in which the object selected from the candidates for the object is to be placed in the background image, and place the object selected from the candidates for the object having the set orientation and the set size in the designated position in the background image, the orientation and the size of the selected object being set based on the depth data, the base-line length information, and the three-dimensional modeling data of the object selected from the candidates for the object.

[0019] The object placement unit may identify objects that can be placed in the background image, and select the object to be placed in the background image from the identified objects, the objects being identified based on the depth data, the base-line length information, and the three-dimensional modeling data.

[0020] The image processing device may further include: an imaging unit that captures an image of the subject, and obtains the captured image as the background image; and a depth data generation unit that generates the depth data of the captured image obtained by the imaging unit.

[0021] The captured image may be a multiview image formed with images having different viewpoints from one another, the depth data generation unit may generate the depth data of the multiview image, and the image processing device may further include a virtual captured image generation unit that generates a virtual captured image as the background image based on the multiview image and the depth data, the virtual captured image being obtained by imaging the subject of the multiview image.

[0022] The object may be an image of furniture.

[0023] The image processing device may further include a purchase processing unit that performs a purchase process to purchase the furniture that is placed in the background image by the object placement unit.

[0024] The image processing device may further include a transmission unit that transmits multiview image data as the data of a multiview image and the depth data of the multiview image, the multiview image being formed with images having different viewpoints from one another and used for generating the background image.

[0025] The image processing device may further include a combined image data generation unit that generates the image data of the background image having the object placed

therein by the object placement unit. The transmission unit may further transmit the combined image data generated by the combined image data generation unit.

[0026] The image processing device may further include an application parameter generation unit that generates application parameters that are parameters related to combining of the background image and the object. The transmission unit may further transmit the application parameters generated by the application parameter generation unit.

[0027] The image processing device may further include a metadata generation unit that generates metadata about the multiview image. The transmission unit may further transmit the metadata generated by the metadata generation unit.

[0028] The metadata may include the base-line length information.

[0029] An image processing method according to an embodiment of the present technique includes: setting the orientation and the size of an object in a position in which the object is to be placed in a background image, the orientation and the size being set based on depth data, base-line length information, and the three-dimensional modeling data of the object, the depth data indicating the distance to a subject in the background image, the base-line length information being information indicating a reference length in the background image; and placing the object having the set orientation and the set size in the designated position in the background image.

[0030] In an embodiment of the present technique, the orientation and the size of an object in a position in which the object is to be placed in a background image are set based on depth data indicating the distance to a subject in the background image, base-line length information indicating a reference length in the background image, and the three-dimensional modeling data of the object. The object having the set orientation and the set size is then placed in the designated position in the background image.

Advantageous Effects of Invention

[0031] According to an embodiment of the present technique, images can be processed. According to an embodiment of the present technique, the user-friendliness of a service that uses multiview images can also be increased.

Brief Description of Drawings

[0032] [fig.1]Fig. 1 is a diagram for explaining an example of a multiview-image using service platform.

[fig.2]Fig. 2 is a diagram for explaining an example of an application that uses multiview images.

[fig.3]Fig. 3 is a diagram showing a typical example structure of a multiview-image using service providing system.

[fig.4]Fig. 4 is a block diagram showing a typical example structure of the terminal

device.

[fig.5]Fig. 5 is a diagram for explaining the outline of the imaging unit.

[fig.6]Fig. 6 is a diagram showing a typical example structure of the server.

[fig.7]Fig. 7 is a functional block diagram for explaining the functions of the terminal device and the server.

[fig.8]Fig. 8 is a diagram showing an example of the information being managed by the server.

[fig.9]Fig. 9 is a flowchart showing an example flow of a multiview-image using service providing process.

[fig.10]Fig. 10 is a diagram showing an example of a multiview image and depth data.

[fig.11]Fig. 11 is a diagram showing a typical example structure of a multiview image file.

[fig.12]Fig. 12 is a diagram for explaining an example of a camera array.

[fig.13]Fig. 13 is a diagram for explaining an example of metadata.

[fig.14]Fig. 14 is a flowchart for explaining an example flow of a depth detection process.

[fig.15]Fig. 15 is a diagram showing another typical example structure of a multiview-image using service providing system.

[fig.16]Fig. 16 is a diagram showing a typical example structure of the application providing server.

[fig.17]Fig. 17 is a functional block diagram for explaining the functions of the terminal device, the server, and the application providing server.

[fig.18]Fig. 18 is a flowchart showing another example flow of a multiview-image using service providing process.

[fig.19]Fig. 19 is a diagram showing examples of displayed information.

[fig.20]Fig. 20 is a diagram showing yet another typical example structure of a multiview-image using service providing system.

[fig.21]Fig. 21 is a diagram for explaining an example flow of virtual lens processing.

[fig.22]Fig. 22 is a functional block diagram for explaining the functions of the terminal device and the server.

[fig.23]Fig. 23 is a flowchart showing yet another example flow of a multiview-image using service providing process.

[fig.24]Fig. 24 is a diagram for explaining an example of virtual lens selection.

[fig.25]Fig. 25 is a flowchart for explaining an example flow of the virtual lens processing.

[fig.26]Fig. 26 is a diagram for explaining an example of a lens profile.

[fig.27]Fig. 27 is a diagram showing yet another typical example structure of a multiview-image using service providing system.

[fig.28]Fig. 28 is a diagram for explaining an example furniture layout.

[fig.29]Fig. 29 is a diagram for explaining another example layout.

[fig.30]Fig. 30 is a functional block diagram for explaining the functions of the terminal device, the server, and the furniture sales server.

[fig.31]Fig. 31 is a flowchart showing yet another example flow of a multiview-image using service providing process.

[fig.32]Fig. 32 is a flowchart showing yet another example flow of a multiview-image using service providing process, continued from Fig. 31.

[fig.33]Fig. 33 is a flowchart showing yet another example flow of a multiview-image using service providing process, continued from Fig. 32.

[fig.34]Fig. 34 is a flowchart for explaining an example flow of a furniture image placement process.

[fig.35]Fig. 35 is a diagram showing examples of furniture layout updates.

[fig.36]Fig. 36 is a flowchart for explaining an example flow of a furniture placement updating process.

[fig.37]Fig. 37 is a diagram for explaining an example of floor contact determination.

[fig.38]Fig. 38 is a flowchart for explaining an example flow of a floor contact determination process.

[fig.39]Fig. 39 is a diagram for explaining an example of measurement.

[fig.40]Fig. 40 is a flowchart for explaining an example flow of a measurement process.

[fig.41]Fig. 41 is a diagram for explaining an example of a lighting simulation.

[fig.42]Fig. 42 is a flowchart for explaining an example flow of a lighting process.

[fig.43]Fig. 43 is a diagram for explaining an example of presentation of a line of flow.

[fig.44]Fig. 44 is a flowchart for explaining an example flow of a line-of-flow presentation process.

[fig.45]Fig. 45 is a diagram for explaining an example of human image placement.

[fig.46]Fig. 46 is a flowchart for explaining an example flow of a human image placement process.

[fig.47]Fig. 47 is a flowchart for explaining an example flow of a furniture list restriction process.

Description of Embodiments

[0033] The following is a description of modes for embodying this disclosure (hereinafter referred to as the embodiments). Explanation will be made in the following order.

1. First Embodiment (Multiview-Image Using Service Platform)
2. Second Embodiment (Management of Multiview Images)
3. Third Embodiment (Application Sales)

4. Fourth Embodiment (Virtual Lens Processing)

5. Fifth Embodiment (Sales Support)

6. Others

[0034] <1. First Embodiment>

<Multiview-Image Using Service Platform>

Fig. 1 is a diagram for explaining an example of a multiview-image using service platform. The multiview-image using service platform 100 shown in Fig. 1 is a basic structure/environment that provides a user with services using multiview images each formed with images having different viewpoints. The multiview-image using service platform 100 has functions such as a cloud storage 101 and an application market 102.

[0035] The cloud storage 101 is a service that stores and manages multiview image data 111 that is data of multiview images. For example, a user who is registered in the multiview-image using service platform operates a multiview imaging device 121 to capture images of a subject, and obtains captured images with difference viewpoints as a multiview image. The user then operates the multiview imaging device 121 to supply the multiview image data to the multiview-image using service platform 100. The cloud storage 101 stores the supplied multiview image data, and manages the multiview image data for the user.

[0036] Based on the multiview image data and the like, the cloud storage 101 can also generate data related to the multiview image data, where necessary. Furthermore, the cloud storage 101 can provide the multiview image data being managed therein to the terminal device being operated by the user or the later described application, in response to a request from the user or the like.

[0037] The application market 102 is a service that performs some processing by using the multiview image data, provides a user with an application 112, sells the application 112 to the user, or executes the application 112. The application 112 is for providing the user with multiview-image using services. This application 112 may be executed by the multiview-image using service platform 100 or by a terminal device.

[0038] As this application 112 is executed, the user is provided with various highly-useful services such as games using multiview images, space combining, lens simulations, space recognitions, and sales supports.

[0039] The services to be provided by the application 112 may be of any kinds as long as they use multiview images. For example, a lens simulation is a service that simulates a virtual optical system, and generates a virtual image of a subject captured by the virtual optical system, using a multiview image. In that case, the application 112 sets a virtual lens 150 as shown in Fig. 2A, and simulates a ray vector 151 that is light incident on the virtual lens 150 from the subject, a ray vector 152 that is the incident light after passing through the virtual lens 150, a virtual image sensor 153 that obtains a virtual

captured image from the ray vector 152, and the like. Based on the above simulations, the application 112 generates a virtual captured image from a multiview image, and provides the user with the virtual captured image. The application 112 can also select or sell the virtual lens 150 that is set in the above manner, for example.

[0040] Through a lens simulation, a virtual lens can be set. Accordingly, an optical system of any type can be simulated. That is, through a lens simulation, an actual optical system or an unrealistic optical system can be simulated. As such a service is provided, the user can reproduce captured images obtained with various kinds of optical systems. For example, through such a lens simulation, the user can readily obtain an image captured with an optical system having a larger aperture than that of an optical system that obtains the respective captured images forming a multiview image. Also, through such a lens simulation, the user can more readily obtain an image with higher resolution than that of the respective images forming a multiview image, an image with a wide field of view, an image with a narrow field of view and a long focal length, or the like. Furthermore, through such a lens simulation, it is possible to readily obtain an image captured with a high-grade lens or an image captured with an unrealistic optical system, for example. In other words, the user can obtain various kinds of captured images at low costs.

[0041] A sales support is a service to support product sales by using multiview images, for example. Any products may be sold, and any measures may be taken to provide the support. For example, in this service, the product to be sold may be furniture, and images of furniture may be virtually arranged in a captured image as shown in Fig. 2B. In this case, the application 112 generates a captured image by superimposing the respective captured images of a multiview image on one another, arranges the images of furniture in the captured image by using three-dimensional modeling data (also referred to as 3D modeling data) and depth data indicating the distances to the subject in the multiview image, and provides the user with the combined image. The application 112 also sets the positions of the pieces of furniture to be arranged based on an operation of the user.

[0042] By virtue of such a service, the user can capture an image of his/her own room, and arrange images of furniture in desired positions in the captured image (or the image of his/her own room). Accordingly, the user can accurately assume the layout prior to the purchase. Specifically, through such a service, the user can reduce the pre-purchase anxiety that "the purchased furniture might be too big for my room", "the purchased furniture might not fit in my room", or the like. Accordingly, the user can be motivated to purchase. In this manner, the application 112 can support furniture sales.

[0043] As described above, the multiview-image using service platform 100 can not only generate and provide an image from a multiview image, but also manage data related

to the user and multiview images, sell applications, and provide services using applications. Accordingly, various services that are very useful to the user can be provided. That is, the multiview-image using service platform 100 can increase the user-friendliness of the multiview-image using service.

[0044] Although a multiview image is formed with captured images in the above description, the number of images forming a multiview image is not fixed. Also, some or all of the images forming a multiview image may be unrealistic, or each of the images may be partially or entirely unrealistic like an artificially-drawn computer graphic image (that is, a multiview image may include an image that is not a captured image).

[0045] Also, the terminal device to which the multiview-image using service platform 100 is to provide services may be the multiview imaging device 121 being operated by the user owning a multiview image, may be a terminal device other than the multiview imaging device 121 being operated by the user, or may be a terminal device being operated by another user authorized to use the multiview image by the user.

[0046] Further, the multiview-image using service platform 100 may have any physical structure. For example, the multiview-image using service platform 100 may be formed with one server, or may be formed with more than one server. Also, some or all of the functions of the multiview-image using service platform 100 may be shared with other devices over a network, and be executed in cooperation with the other devices over a network, to realize a cloud computing structure. Furthermore, some or all of the functions of the multiview-image using service platform 100 may be executed by a terminal device.

[0047] Examples of services to be provided by the multiview-image using service platform 100 are described below in detail.

[0048] <2. Second Embodiment>

<Management of Multiview Images>

As described above in the first embodiment, the multiview-image using service platform 100 has the function of the cloud storage 101, and can provide a service to store and manage multiview image data. In this embodiment, the management of multiview images is described.

[0049] <Multiview-Image Using Service Providing System>

Fig. 3 is a diagram showing a typical example structure of a multiview-image using service providing system. The multiview-image using service providing system 200 shown in Fig. 3 is an example of a system to which the present technique is applied. In this system, a server 202 provides a multiview-image using service to a terminal device 201 connected thereto via a network 210. That is, the multiview-image using service providing system 200 is an example of a structure that realizes the multiview-image using service platform 100.

[0050] Fig. 3 shows an example of a structure related to the provision of a service related to management of multiview images among the services to be provided by the multiview-image using service platform 100. In Fig. 3, the multiview-image using service providing system 200 includes the terminal device 201 and the server 202 that are connected to the network 210.

[0051] The network 210 is a network such as the Internet or a local area network. The network 210 is formed with one or more wired and/or wireless networks. The terminal device 201 and the server 202 are connected to the network 210 in a wired or wireless manner.

[0052] The terminal device 201 captures images of a subject to perform multiview imaging and obtain a multiview image that is formed with captured images having different viewpoints from one another. The terminal device 201 then encodes the multiview image data, to generate multiview encoded data. The terminal device 201 transmits the generated multiview encoded data to the server 202.

[0053] The server 202 manages users that are registered in advance. The server 202 also acquires the transmitted multiview image encoded data, and detects the depth of the multiview image, to generate depth data. The server 202 further turns the data related to the multiview image into a file, to generate a multiview image file. The server 202 stores (saves) the generated multiview image file, and manages the stored file. The multiview image file being managed by the server 202 is provided to the terminal device 201 or an application to be executed, where necessary.

[0054] <Terminal Device>

Fig. 4 is a block diagram showing a typical example structure of the terminal device 201. As shown in Fig. 4, in the terminal device 201, a CPU (Central Processing Unit) 221, a ROM (Read Only Memory) 222, and a RAM (Random Access Memory) 223 are connected to one another via a bus 224.

[0055] An input/output interface 230 is also connected to the bus 224. An input unit 231, an output unit 232, a storage unit 233, a communication unit 234, and a drive 235 are connected to the input/output interface 230.

[0056] The input unit 231 is formed with an input device that receives external information such as a user input. The input unit 231 includes operation buttons, a touch panel, a microphone, and an input terminal, for example. The input unit 231 may also include various kinds of sensors, such as an acceleration sensor, an optical sensor, and a temperature sensor. The output unit 232 is formed with an output device that outputs information such as images and sound. The output unit 232 includes a display, a speaker, and an output terminal, for example.

[0057] The storage unit 233 is formed with a hard disk, a RAM disk, a nonvolatile memory, or the like. The communication unit 234 is formed with a network interface, for

example. The drive 235 drives a removable medium 241 such as a magnetic disk, an optical disk, a magnetooptical disk, or a semiconductor memory.

[0058] The CPU 221 performs various kinds of processes by loading a program stored in the storage unit 233 into the RAM 223 via the input/output interface 230 and the bus 224, and executing the program. Necessary data for the CPU 221 to perform various kinds of processes and the like are also stored in the RAM 223 as appropriate.

[0059] The program to be executed by the CPU 221 can be recorded on the removable medium 241 as a packaged medium, for example, and be provided to the terminal device 201. In this case, the program can be installed into the storage unit 233 via the input/output interface 230 when the removable medium 241 is mounted in the drive 235.

[0060] Alternatively, the program can be provided to the terminal device 201 via a wired or wireless transmission medium such as a LAN, the Internet, or digital satellite broadcasting. In this case, the program can also be received by the communication unit 234 via a wired or wireless transmission medium, and be installed into the storage unit 233.

[0061] Also, the program can be installed in the ROM 222 or the storage unit 233 in advance.

[0062] An imaging unit 236 is further connected to the input/output interface 230. Under the control of the CPU 221, for example, the imaging unit 236 captures images of a subject to perform multiview imaging and obtain a multiview image formed with captured images having different viewpoints from one another. The imaging unit 236 includes camera modules 242-1 through 242-N. N is an integer that is 2 or greater. The camera modules 242-1 through 242-N have the same structures as one another, and perform the same processes as one another. Hereinafter, the cameral modules 242-1 through 242-N will be referred to simply as the camera modules 242, as long as there is no need to distinguish them from one another.

[0063] The camera modules 242 are modules that include optical systems having image sensors (imaging elements), and obtain captured images by capturing images of a subject. The respective camera modules 242 are arranged in different positions from one another on a flat surface or a curved surface, such as positions C11, C12, C13, C21, C22, C23, C31, C32, and C33 shown in Fig. 5. That is, the camera modules 242-1 through 242-N capture images of a subject, and obtain captured images having different viewpoints from one another.

[0064] Under the control of the CPU 221, for example, the imaging unit 236 captures images of a subject by using the camera modules 242-1 through 242-N, and obtains N (more than one)captured images having different viewpoints from one another. The imaging unit 236 obtains the captured images as a multiview image (multiview image

data). That is, the imaging unit 236 performs multiview imaging by using the camera modules 242.

[0065] Under the control of the CPU 221, for example, the imaging unit 236 supplies the obtained multiview image data to the CPU 221 and the RAM 223 via the input/output interface 230, the bus 224, and the like, supplies and stores the obtained multiview image data into the storage unit 233 via the input/output interface 230, supplies the obtained multiview image data to the output unit 232 to output the multiview image data, or supplies the obtained multiview image data to the communication unit 234 to supply the multiview image data to the outside.

[0066] The angles of view and the imaging directions of the respective camera modules 242 may or may not be the same as one another. For example, in one of the camera modules 242, the angle of view and/or the imaging direction may differ from those of the other camera modules 242. Alternatively, the angles of view and the imaging directions of all the camera modules 242 may differ from one another. However, as will be described later, multiview captured images are to be superimposed on one another to generate an image. Therefore, at least some portions of the imaging ranges of the respective camera modules 242 (or the subject of the respective camera modules 242) preferably overlap with one another.

[0067] In multiview imaging, imaging conditions, such as the imaging timing, the exposure, and the aperture value, may or may not be the same among the camera modules 242. Also, the multiview image (or the respective captured images forming a multiview image) obtained by multiview imaging may be a still image or may be a moving image.

[0068] The imaging unit 236 may be provided as one component on the housing of the terminal device 201 at the time of the manufacture thereof, or may be designed as a module that is independent of the terminal device 201 but can be connected to the terminal device 201. For example, the imaging unit 236 may be an external component that is connected to an external terminal of the terminal device 201 and operates under the control of the terminal device 201. Further, the imaging unit 236 may be a device that is independent of the terminal device 201. For example, the imaging unit 236 may be an imaging device such as a camera that is independent of the terminal device 201, be connected to the terminal device 201 by a wired or wireless communication, and supply a multiview image obtained by multiview imaging to the terminal device 201.

[0069] <Server>

Fig. 6 is a block diagram showing a typical example structure of the server 202. As shown in Fig. 6, in the server 202, a CPU 251, a ROM 252, and a RAM 253 are connected to one another via a bus 254.

[0070] An input/output interface 260 is also connected to the bus 254. An input unit 261, an

output unit 262, a storage unit 263, a communication unit 264, and a drive 265 are connected to the input/output interface 260.

[0071] The input unit 261 is formed with an input device that receives external information such as a user input. The input unit 261 includes operation buttons, a touch panel, a microphone, a camera, and an input terminal, for example. The input unit 261 may also include various kinds of sensors, such as an acceleration sensor, an optical sensor, and a temperature sensor. The output unit 262 is formed with an output device that outputs information such as images and sound. The output unit 262 includes a display, a speaker, and an output terminal, for example.

[0072] The storage unit 263 is formed with a hard disk, a RAM disk, a nonvolatile memory, or the like. The communication unit 264 is formed with a network interface, for example. The drive 265 drives a removable medium 271 such as a magnetic disk, an optical disk, a magnetooptical disk, or a semiconductor memory.

[0073] The CPU 251 performs various kinds of processes by loading a program stored in the storage unit 263 into the RAM 253 via the input/output interface 260 and the bus 254, and executing the program. Necessary data for the CPU 251 to perform various kinds of processes and the like are also stored in the RAM 253 as appropriate.

[0074] The program to be executed by the CPU 251 can be recorded on the removable medium 271 as a packaged medium, for example, and be provided to the server 202. In this case, the program can be installed into the storage unit 263 via the input/output interface 260 when the removable medium 271 is mounted in the drive 265.

[0075] Alternatively, the program can be provided to the server 202 via a wired or wireless transmission medium such as a LAN, the Internet, or digital satellite broadcasting. In this case, the program can also be received by the communication unit 264 via a wired or wireless transmission medium, and be installed into the storage unit 263.

[0076] Also, the program can be installed in the ROM 252 or the storage unit 263 in advance.

[0077] <Functional Blocks>

The terminal device 201 has functions shown as functional blocks in Fig. 7A, as the CPU 221 executes a predetermined program. As shown in Fig. 7A, the CPU 221 has functional blocks such as an imaging control unit 281, a metadata generation unit 282, an encoding unit 283, and a transmission control unit 284.

[0078] The imaging control unit 281 performs a process related to multiview imaging control. The metadata generation unit 282 performs a process related to generation of metadata of a multiview image obtained by multiview imaging. The encoding unit 283 performs a process related to encoding of a multiview image. The transmission control unit 284 performs a process related to transmission control for multiview image data and the like.

[0079] Meanwhile, the server 202 has functions shown as functional blocks in Fig. 7B, as the CPU 251 executes a predetermined program. As shown in Fig. 7B, the CPU 251 has functional blocks such as a user management unit 291, an acquisition control unit 292, a depth detection unit 293, a file generation unit 294, and a data management unit 295.

[0080] The user management unit 291 performs a process related to management of users to whom multiview-image using services are to be provided. For each user, the user management unit 291 stores and manages, in the storage unit 263, user management information 301 shown in Fig. 8A, for example. As shown in Fig. 8A, the user management information 301 includes a user ID as the identification information about a user, the past purchases by the user, file management information identification information as the identification information for the file management information associated with the user (or registered with the user), preference setting predictions that are information predictive of the settings preferred by the user based on a statistical analysis or the like, the points (or money) held by the user, comments sent to/from other users, and the like. The user management information 301 may of course include any information. Some of the above described information may be excluded, or information other than the above described information may be included.

[0081] The acquisition control unit 292 performs a process related to control on acquisition of information such as multiview image data and the like transmitted from the terminal device 201. The depth detection unit 293 performs a process related to detection of the depth value of a multiview image. The file generation unit 294 performs a process related to generation of a multiview image file from various kinds of data including multiview image data.

[0082] The data management unit 295 performs a process related to management of data such as a multiview image file. For each multiview image file, the data management unit 295 stores and manages, in the storage unit 263, file management information 302 shown in Fig. 8B, for example. As shown in Fig. 8B, the file management information 302 includes multiview image file identification information that is the identification information for a multiview image file, edit result image identification information that is associated with the multiview image file and is the identification information for an edit result image as the result of editing of a multiview image, application parameter identification information as the identification information for an application parameter that is associated with the multiview image file and is the history of application execution using the multiview image, and the like. The file management information 302 may of course include any information. Some of the above described information may be excluded, or information other than the above described information may be included.

[0083] <Flow of a Multiview-Image Using Service Providing Process>

The terminal device 201 and the server 202 of the multiview-image using service providing system having the above described structure perform a multiview-image using service providing process to provide a service using multiview images, or provide a service such as management of multiview images in this embodiment. Referring now to the flowchart shown in Fig. 9, an example flow of the multiview-image using service providing process to be performed by those devices is described.

[0084] In step S101, the imaging control unit 281 of the terminal device 201 controls the imaging unit 236 to perform multiview imaging on a subject and obtain a multiview image. For example, the imaging control unit 281 performs multiview imaging to obtain a multiview image 311 formed with captured images having different viewpoints from one another as shown in Fig. 10A.

[0085] Referring back to Fig. 9, after multiview image data is obtained by the multiview imaging, the metadata generation unit 282 in step S102 generates metadata of the multiview image data. As will be described later in detail, the metadata include array information indicating the relative positional relationship among the respective viewpoints of the multiview image, and viewpoint number information indicating the number of viewpoints of the multiview image. That is, the metadata generation unit 282 generates metadata including the array information and the viewpoint number information, and associates the multiview image data with the information.

[0086] In step S103, the encoding unit 283 encodes the multiview image data by a predetermined encoding method, to generate multiview image encoded data. The encoding method may be any method, as long as image data is encoded by the method. For example, the encoding method may be an existing encoding method such as JPEG (Joint Photographic Experts Group) or MPEG (Moving Picture Experts Group), or may be a novel encoding method designed for multiview images. After the encoding of the multiview image data, the above described metadata (such as the array information and the viewpoint number information) of the multiview image data is associated with the multiview image encoded data (or is turned into metadata of the multiview image encoded data) by the metadata generation unit 282.

[0087] In step S104, the transmission control unit 284 controls the communication unit 234 to transmit the multiview image encoded data generated in step S103, as well as the metadata generated in step S102, to the server 202. For example, the transmission control unit 284 transmits the multiview image encoded data and the metadata as a bit stream or auxiliary information about a bit stream.

[0088] In step S111, the acquisition control unit 292 of the server 202 controls the communication unit 264, to acquire the multiview image encoded data and its metadata transmitted from the terminal device 201 in step S104.

[0089] In step S112, the depth detection unit 293 decodes the multiview image encoded data acquired in step S111 by a decoding method compatible with the encoding method used in step S103.

[0090] In step S113, the depth detection unit 293 detects the depth of the multiview image to generate depth data, using the multiview image data obtained by decoding the multiview image encoded data in step S112. For example, the depth detection unit 293 generates a depth map 312 as the depth data showing the distances to the subject with degrees of luminance and colors on a pixel-to-pixel basis as shown in Fig. 10B. The depth detection will be described later in detail.

[0091] Referring back to Fig. 9, after generating the depth data, the depth detection unit 293 in step S114 encodes the multiview image data from which the depth has been detected, to generate multiview image encoded data. The encoding method may be any method, as long as image data is encoded by the method. For example, the encoding method may be an existing encoding method such as JPEG or MPEG, or may be a novel encoding method designed for multiview images. The encoding method may or may not be the same as the encoding method used in step S103. The depth detection unit 293 associates the generated depth data with the multiview image encoded data.

[0092] The depth detection (the depth data generation) may be performed in a device other than the server 202. For example, the depth detection may be performed in the terminal device 201. In that case, the CPU 221 of the terminal device 201 further includes the necessary functional block such as the depth detection unit 293 as appropriate. In such a case, the depth detection unit 293 detects a depth prior to the encoding of the multiview image data by the encoding unit 283 (prior to the processing in step S103). In step S103, the encoding unit 283 encodes the multiview image data, as described above. The depth detection unit 293 then associates the depth data with the multiview image encoded data, and the metadata generation unit 282 associates the metadata (such as the array information and the viewpoint number information) with the multiview image encoded data.

[0093] In step S115, the file generation unit 294 generates a multiview image file containing the multiview image encoded data generated in step S114, the meta data, and the depth data generated in step S113. The format of the multiview image file may be of any type. In a case where the multiview image is a still image, for example, the multiview image may be turned into a file in the Exif (Exchangeable image file format) file format. In a case where the multiview image is a moving image, for example, the multiview image may be turned into a file in the MP4 (MPEG-4 Part 14) file format. It is of course possible to use a file format other than the above.

[0094] The file generation unit 294 generates a multiview image file 321 having the structure shown in Fig. 11, for example. In the example shown in Fig. 11, the

multiview image file 321 contains multiview image encoded data 331, depth data 332, and metadata 333.

[0095] The multiview image encoded data 331 is the multiview image encoded data generated in step S114. The depth data 332 is the depth data generated in step S113, and is the depth data of the multiview image of the multiview image encoded data 331. The metadata 333 is the metadata generated in step S102, and is the metadata of the multiview image encoded data 331.

[0096] As shown in Fig. 11, the metadata 333 includes camera module information 341, camera array information 342, viewpoint number information 343, calibration information 344, and base-line length information 345, for example.

[0097] The camera module information 341 is the information related to imaging performed to obtain the multiview image, or is the information about the respective camera modules 242 of the imaging unit 236. In a case where N camera modules 242 are provided in the imaging unit 236, for example, the metadata 333 includes N pieces of camera module information 341. As shown in Fig. 11, the camera module information 341 includes information such as resolution, focal lengths, ISO sensitivity, imaging directions, shutter speeds, F values, and angles of view. The camera module information 341 may of course have any structure. Some of the information may be excluded, or information other than the above may be included.

[0098] The camera array information 342 is the information that indicates the relative positional relationship among the respective camera modules 242. That is, the camera array information 342 is the information that indicates the relative positional relationship among the respective viewpoints of the multiview image. As shown in Fig. 12, the camera array information 342 includes the distances L_x (x = 1 to 8 in the example shown in Fig. 12) from the reference camera module C_0 to the other camera modules C_x (or the distances L_x from the reference viewpoint to the respective viewpoints), and the directions R_x from the reference camera module C_0 toward the other camera modules C_x (or the directions R_x from the reference viewpoint to the respective viewpoints), for example.

[0099] The viewpoint number information 343 is the information that indicates the number of the camera modules 242 (the number of the viewpoints). The calibration information 344 is the information that indicates variations of the respective camera modules 242. The base-line length information 345 is the information that indicates the reference length in the multiview image.

[0100] The metadata 333 may have any structure. Some of the information may be excluded, or information other than the above may be included.

[0101] Fig. 13 is a diagram showing example structures of the respective data in the metadata. As shown in Fig. 13A, the camera module information 341 may include in-

formation such as the resolution, the focal length, the ISO sensitivity, the imaging direction, the shutter speed, the F value, and the angle of view of each of the camera modules 242.

[0102] If those parameters of the respective camera modules 242 have different values from one another, the selection of the captured images to be superimposed on one another, the mixture ratios of the captured images, and are controlled in accordance with the values of the parameters when the respective captured images of the multiview image are superimposed on one another. In this manner, an image with higher quality can be obtained. For example, only captured images having those parameters closer to desired values are superimposed on one another, or captured images having those parameters closer to the desired values are combined at higher rates (the combination ratios of those captured images are made higher), so that an image having those parameters closer to the desired values can be easily obtained. As a result, unnecessary image processing to change the parameters can be reduced. Accordingly, image quality degradation due to the image processing can be reduced (an image with higher quality can be obtained).

[0103] Also, as the respective captured images have various values as the parameters, a captured image having parameters closer to the desired values can be obtained, regardless of the values of the parameters of the image obtained as a result of the superimposition. That is, an image with higher quality can be obtained, regardless of the values of the parameters.

[0104] The camera array information 342 may indicate the array of the camera modules 242 with the relative positional relationship (C_N, L_N, R_N) as in the example shown in Fig. 11, or may indicate a predetermined type of array such as "X type" as in the example shown in Fig. 13A. The degree of freedom of the array can be increased in the example shown in Fig. 11. An increase in the amount of information in the metadata can be reduced in the example shown in Fig. 13.

[0105] The viewpoint number information 343 is shown as a number as in the example shown in Fig. 13A.

[0106] The calibration information 344 may be formed with the information that indicates the positions of the respective viewpoints of the multiview image, for example. In the example shown in Fig. 13A, the calibration information 344 is formed with the coordinate information about the respective camera modules 242 (or the information indicating the central coordinates of the respective camera modules 242). Alternatively, the calibration information 344 may be formed with information that corrects the degrees of luminance of the respective images of the multiview image, for example. In the example shown in Fig. 13B, the calibration information 344 is formed with luminance correction data information about the respective camera modules 242.

[0107] The base-line length information 345 may include the information that indicates the distances from the reference viewpoint to the respective viewpoints of the multiview image, for example. In the example shown in Fig. 13C, the base-line length information 345 includes the information that indicates the distances from the reference camera module 242 to the other camera modules 242.

[0108] Referring back to Fig. 9, in step S116, the data management unit 295 supplies and stores the multiview image file generated in step S115 into the storage unit 263, and generates and manages the file management information 302 about the multiview image file. Also, the user management unit 291 updates the user management information 301 about the user stored in the storage unit 263, and registers the multiview image file associated with the user.

[0109] When the processing in step S116 is finished, the multiview-image using service providing process comes to an end.

[0110] As such a multiview-image using service providing process is performed, a user can more easily register multiview image data obtained by multiview imaging in the server 202. Also, the multiview image data and the data related to the multiview image (such as depth data and metadata) are turned into a file and are then managed. Accordingly, the user can more easily use the multiview image data he/she has registered. That is, the multiview-image using service providing system 200 (the multiview-image using service platform 100) can increase the user-friendliness of the multiview-image using service.

[0111] In the above description, multiview imaging is performed by using the imaging unit 236 including the camera modules 242, to generate a multiview image (multiview image data). However, a multiview image (multiview image data) may be generated by any method. For example, a multiview image may be generated by performing imaging (capturing a moving image or capturing still images) while moving the imaging position and the imaging direction (or the viewpoint) by using an imaging unit including a single imaging element and an optical system (or an imaging unit including a single camera module 242). In that case, the information about the changes in the imaging position and the imaging direction (or the viewpoint) is preferably associated as metadata with multiview image data (multiview image encoded data).

[0112] Also, in the above description, the multiview image file generated by the file generation unit 294 is stored and managed in the storage unit 263 of the server 202. However, a multiview image file may be managed in any other site. For example, a multiview image file may be stored and managed in a device other than the server 202 (such as a file management server (not shown)). In that case, the file generation unit 294 transmits the generated multiview image file as a bit stream or auxiliary information about a bit stream to the device via the communication unit 264, for

example. In that case, the device includes a communication unit that acquires the multiview image file by communicating with the server 202, a storage unit that stores the acquired multiview image file, and a data management unit as the functional block that manages the multiview image file stored in the storage unit, updates the multiview image file or supplies the multiview image file to another device such as the terminal device 201 or the server 202 where necessary.

[0113] Further, in the above description, a multiview image file is generated in the server 202. However, a multiview image file may be generated in any device. For example, a multiview image file may be generated in the terminal device 201. In that case, the CPU 221 of the terminal device 201 further includes the necessary functional block such as the file generation unit 294 as appropriate. In such a case, the file generation unit 294 generates a multiview image file after multiview image data is encoded by the encoding unit 283 (or after the processing in step S103). In step S104, the transmission control unit 284 transmits the multiview image file as a bit stream or auxiliary information about a bit stream to the server 202, for example. In step S111, the acquisition control unit 292 controls the communication unit 264, to acquire the multiview image file.

[0114] <Flow of the Depth Detection Process>

Referring now to the flowchart in Fig. 14, an example flow of the depth detection process to be performed in step S113 in Fig. 9 is described.

[0115] When the depth detection process is started, the depth detection unit 293 acquires the metadata 333 in step S131. In step S132, the depth detection unit 293 corrects the resolution of each of the captured images in accordance with the resolution and the like of each of the camera modules 242.

[0116] In step S133, the depth detection unit 293 corrects the luminance of each of the captured images in accordance with the shutter speed and the like of each of the camera modules 242. In step S134, the depth detection unit 293 sets the area to be used in the depth calculation in accordance with the angle of view of each of the camera modules 242.

[0117] In step S135, the depth detection unit 293 corrects the shift length at the time of disparity evaluation based on the base-line length information 345 and the like. In step S136, the depth detection unit 293 determines the reference camera, the matching axis, the image interpolation method, and the like based on the camera array, the number of viewpoints, and the like.

[0118] In step S137, the depth detection unit 293 corrects each of the captured images based on the calibration information 344. In step S138, the depth detection unit 293 estimates the depth by repeating stereo matching or the like, and detects depth data.

[0119] After the depth data is detected, the process returns to the process shown in Fig. 9.

[0120] As the depth detection process is performed in the above described manner, a user can generate and use depth data more easily.

[0121] <3. Third Embodiment>

<Application Sales>

As described above in the first embodiment, the multiview-image using service platform 100 can provide a service to sell the application 112 through the application market 102, for example. In this embodiment, the sales of the application are described.

[0122] <Multiview-Image Using Service Providing System>

Fig. 15 is a diagram showing a typical example structure of a multiview-image using service providing system. The multiview-image using service providing system 200 shown in Fig. 15 is an example of a system to which the present technique is applied. In this system, a server 202 provides a multiview-image using service to a terminal device 401 connected thereto via a network 210. That is, the multiview-image using service providing system 200 is an example of a structure that realizes the multiview-image using service platform 100.

[0123] Fig. 15 shows an example of a structure related to the provision of a service related to sales or provision of the application 112 among the services to be provided by the multiview-image using service platform 100. In Fig. 15, the multiview-image using service providing system 200 includes the terminal device 401, the server 202, and an application providing server 402 that are connected to the network 210.

[0124] The terminal device 401 connected to the network 210 in a wired or wireless manner communicates with the server 202, to carry out the procedure to purchase the application 112. The terminal device 401 may be the same as the terminal device 201, or may differ from the terminal device 201. The terminal device 401 basically has the same structure as the terminal device 201. Therefore, the structure illustrated in Fig. 4 can also be applied to the terminal device 401. In the case of the terminal device 401, however, the functions related to imaging are unnecessary. Therefore, the imaging unit 236 can be omitted.

[0125] The application providing server 402 is the server that provides the application 112 to the multiview-image using service platform 100 (the application market 102). The server 202 sells or provides the application provided by the application providing server 402 to (the user of) the terminal device 401.

[0126] <Server>

Fig. 16 is a block diagram showing a typical example structure of the application providing server 402. As shown in Fig. 16, in the application providing server 402, a CPU 411, a ROM 412, and a RAM 413 are connected to one another via a bus 414.

[0127] An input/output interface 420 is also connected to the bus 414. An input unit 421, an

output unit 422, a storage unit 423, a communication unit 424, and a drive 425 are connected to the input/output interface 420.

[0128] The input unit 421 is formed with an input device that receives external information such as a user input. The input unit 421 includes operation buttons, a touch panel, a microphone, a camera, and an input terminal, for example. The input unit 421 may also include various kinds of sensors, such as an acceleration sensor, an optical sensor, and a temperature sensor. The output unit 422 is formed with an output device that outputs information such as images and sound. The output unit 422 includes a display, a speaker, and an output terminal, for example.

[0129] The storage unit 423 is formed with a hard disk, a RAM disk, a nonvolatile memory, or the like. The communication unit 424 is formed with a network interface, for example. The drive 425 drives a removable medium 431 such as a magnetic disk, an optical disk, a magnetooptical disk, or a semiconductor memory.

[0130] The CPU 411 performs various kinds of processes by loading a program stored in the storage unit 423 into the RAM 413 via the input/output interface 420 and the bus 414, and executing the program. Necessary data for the CPU 411 to perform various kinds of processes and the like are also stored in the RAM 413 as appropriate.

[0131] The program to be executed by the CPU 411 can be recorded on the removable medium 431 as a packaged medium, for example, and be provided to the application providing server 402. In this case, the program can be installed into the storage unit 423 via the input/output interface 420 when the removable medium 431 is mounted in the drive 425.

[0132] Alternatively, the program can be provided to the application providing server 402 via a wired or wireless transmission medium such as a LAN, the Internet, or digital satellite broadcasting. In this case, the program can also be received by the communication unit 424 via a wired or wireless transmission medium, and be installed into the storage unit 423.

[0133] Also, the program can be installed in the ROM 412 or the storage unit 423 in advance.

[0134] <Functional Blocks>

The terminal device 401 has a function shown as a functional block in Fig. 17A, as the CPU 221 executes a predetermined program. As shown in Fig. 17A, the CPU 221 has a functional block such as an application purchase processing unit 441.

[0135] The application purchase processing unit 441 controls respective components such as the input unit 231, the output unit 232, the storage unit 233, and the communication unit 234, communicates with the server 202, and performs a process related to application purchases by displaying images and receiving user instructions.

[0136] Meanwhile, the server 202 has functions shown as functional blocks in Fig. 17B, as

the CPU 251 executes a predetermined program. As shown in Fig. 17B, the CPU 251 has functional blocks such as a user management unit 451, an application sales processing unit 452, and a data management unit 453.

[0137] Like the user management unit 291, the user management unit 451 performs a process related to management of users to whom multiview-image using services are to be provided. The application sales processing unit 452 controls the communication unit 264 to communicate with the terminal device 401 or the like, and performs a process related to application sales. Like the data management unit 295, the data management unit 453 performs a process related to management of data such as a multiview image file. The data management unit 453 also performs a process related to management of the application supplied from the application providing server 402.

[0138] Further, the application providing server 402 has a function shown as a functional block in Fig. 17C, as the CPU 411 executes a predetermined program. As shown in Fig. 17C, the CPU 411 has a functional block such as an application provision processing unit 461.

[0139] The application provision processing unit 461 controls the communication unit 424 to communicate with the server 202 or the like, and performs a process related to the provision of the application to the server 202.

[0140] <Flow of a Multiview-Image Using Service Providing Process>

The terminal device 401, the server 202, and the application providing server 402 of the multiview-image using service providing system having the above described structure perform a multiview-image using service providing process to provide a service using multiview images, or provide a service such as application sales in this embodiment. Referring now to the flowchart shown in Fig. 18, an example flow of the multiview-image using service providing process to be performed by those devices is described.

[0141] In step S171, the application provision processing unit 461 of the application providing server 402 controls the communication unit 424, to supply the application to be provided to the server 202 and register the application therein.

[0142] In step S161, the data management unit 453 of the server 202 controls the communication unit 264 or the like to acquire the application supplied from the application providing server 402, stores the application into the storage unit 263, and manages the application so that the application can be sold to the terminal device 401.

[0143] In step S151, the application purchase processing unit 441 of the terminal device 401 controls the communication unit 234, to request an application purchase from the server 202.

[0144] In step S162, the application sales processing unit 452 of the server 202 controls the communication unit 264 or the like, to acquire the request.

[0145] In step S163, the application sales processing unit 452 cooperates with the user management unit 451 and the data management unit 453, to create a list of applications that can be sold to the user. The application sales processing unit 452 then controls the communication unit 264 or the like, to provide the application list to the terminal device 401.

[0146] In step S152, the application purchase processing unit 441 of the terminal device 401 acquires the application list. The application purchase processing unit 441 controls the output unit 232 or the like, to display the application list on a monitor or the like, so that the application list is presented to the user, and an instruction is received from the user.

[0147] For example, the GUI (Graphical User Interface) 471 shown in Fig. 19A is displayed on the monitor of the terminal device 401. Based on such a GUI, the user selects a desired application from a number of applications. In a case where an application for lens simulations is selected, for example, the GUI 472 shown in Fig. 19B is displayed, and a virtual lens is selected. In a case where an application for editing images is selected, for example, the GUI 473 shown in Fig. 19C is displayed, and an editing function such as a decorating stamp is selected.

[0148] Referring back to Fig. 18, when the user selects the application to be purchased from the list, the application purchase processing unit 441 in step S153 receives the selection instruction, and controls the communication unit 234 or the like, to supply control information for selecting the application to be purchased to the server 202.

[0149] In step S164, the application sales processing unit 452 of the server 202 controls the communication unit 264 or the like, to acquire the control information. In step S165, the application sales processing unit 452 cooperates with the user management unit 451 and the data management unit 453, and associates the user management information 301 about the user with the selected application (the application designated by the user in the instruction to purchase), so that the selected application is registered with the user.

[0150] In step S166, the application sales processing unit 452 performs a payment process related to the sale of the application. The user management unit 451 causes the user management information 301 about the user to reflect the payment information. (The points equivalent to the price or fee are subtracted from the points or money owned by the user, for example. This sale is added to the past purchases of the application.)

[0151] When the processing in step S166 is finished, the multiview-image using service providing process comes to an end.

[0152] As such a multiview-image using service providing process is performed, a user can more easily purchase an application by performing a process using multiview images. Also, as the purchased applications are registered with the user and are managed in the

server 202, the user can more easily use the applications he/she has purchased. That is, the multiview-image using service providing system 200 (the multiview-image using service platform 100) can increase the user-friendliness of the multiview-image using service.

[0153] Applications may not be sold, and may be provided for free. In that case, the payment process can be skipped.

[0154] <4. Fourth Embodiment>

<Virtual Lens Processing>

By performing an application provided to a user as described above, the multiview-image using service platform 100 can provide various services using multiview images to the user.

[0155] In this embodiment, execution of an application for performing the lens simulation (virtual lens processing) described in the first embodiment is described as an example of the application.

[0156] <Multiview-Image Using Service Providing System>

Fig. 20 is a diagram showing a typical example structure of a multiview-image using service providing system. The multiview-image using service providing system 200 shown in Fig. 20 is an example of a system to which the present technique is applied. In this system, a server 202 provides a multiview-image using service to a terminal device 401 connected thereto via a network 210. That is, the multiview-image using service providing system 200 is an example of a structure that realizes the multiview-image using service platform 100.

[0157] Fig. 20 shows an example of a structure related to the provision of a service related to a lens simulation (virtual lens processing) among the services to be provided by the multiview-image using service platform 100. In Fig. 20, the multiview-image using service providing system 200 includes the terminal device 401 and the server 202 that are connected to the network 210.

[0158] The terminal device 401 connected to the network 210 in a wired or wireless manner communicates with the server 202, to select the multiview image to be used in the lens simulation, select the virtual lens to be simulated, and set user designated parameters that are imaging-related parameters having values designated by a user, such as a focusing position and a depth of field.

[0159] Based on those processes, the server 202 performs virtual lens processing to simulate a virtual lens, and generates virtual captured image data obtained by imaging with the use of the virtual lens. The server 202 also saves (stores, and manages) the virtual captured image data. Further, the server 202 generates and saves (stores, and manages) history information as application parameters of the application for performing the lens simulation. The history information indicates what value has been set for which

parameter, what kind of operation (instruction) has been performed by the user, what kind of processing has been performed, and the like.

[0160] <Outline of the Virtual Lens Processing>

Next, an outline of virtual lens processing is described. In the virtual lens processing, a virtual lens 150 designated by a user as shown in Fig. 2A is set, and a ray vector 151 that is light incident on the virtual lens 150 from a subject, a ray vector 152 that is the incident light after passing through the virtual lens 150, a virtual image sensor 153 that obtains a virtual captured image from the ray vector 152, and the like are simulated, and a virtual captured image is generated from a multiview image based on the simulations.

[0161] For example, the interpolating images 502 and the depth data 503 shown in Fig. 21B are generated from the multiview image 501 shown in Fig. 21A, for example, and a virtual captured image 504 obtained by imaging with the use of the virtual lens 150 (the virtual optical system shown in Fig. 2A) as shown in Fig. 21C is generated by using the interpolating images 502 and the depth data 503.

[0162] In the above manner, the virtual captured image 504 that is larger than the respective captured images of the multiview image 501, and reflects the optical effects given by the virtual lens 150 is obtained. An optical system such as the virtual lens 150 is simulated by using profile information unique to the virtual optical system. The profile information is formed with parameters for reproducing the optical effects of the virtual optical system. Therefore, the server 202 can readily reproduce various optical systems that range from existing ones to unrealistic ones. In short, a user can obtain various kinds of captured images at low costs through this service. That is, the multiview-image using service providing system 200 (the multiview-image using service platform 100) can increase the user-friendliness of the multiview-image using service.

[0163] <Functional Blocks>

The terminal device 401 has functions shown as functional blocks in Fig. 22A, as the CPU 221 executes a predetermined program. As shown in Fig. 22A, the CPU 221 has functional blocks such as a user instruction reception processing unit 511, a display control unit 512, and a transmission control unit 513.

[0164] The user instruction reception processing unit 511 controls the input unit 231 or the like, to perform a process related to reception of a user instruction. The display control unit 512 controls the output unit 232 or the like, to perform a process related to display control to display an image such as a GUI or a guide on a monitor. The transmission control unit 513 controls the communication unit 234 or the like, to perform a process related to transmission of various kinds of information such as a user instruction received by the user instruction reception processing unit 511.

[0165] Meanwhile, the server 202 has functions shown as functional blocks in Fig. 22B, as

the CPU 251 executes a predetermined program. As shown in Fig. 22B, the CPU 251 has functional blocks such as a user management unit 521, an application selection processing unit 522, an image selection processing unit 523, a lens selection processing unit 524, a user designated parameter setting unit 525, a virtual lens processing unit 526, and a data management unit 527.

[0166] Like the user management unit 291, the user management unit 521 performs a process related to management of users to whom multiview-image using services are to be provided. The application selection processing unit 522 controls the communication unit 264 to communicate with the terminal device 401 or the like, and performs a process related to selection of the application to be executed. The image selection processing unit 523 controls the communication unit 264 to communicate with the terminal device 401 or the like, and performs a process related to selection of a multiview image to be the current multiview image in the lens simulation (virtual lens processing). The lens selection processing unit 524 controls the communication unit 264 to communicate with the terminal device 401 or the like, and performs a process related to selection of profile information about the virtual lens to be simulated. The user designated parameter setting unit 525 controls the communication unit 264 to communicate with the terminal device 401 or the like, and performs a process related to the setting of user designated parameters transmitted from the terminal device 401. The virtual lens processing unit 526 performs a process related to the simulation of a virtual optical system. Like the data management unit 295, the data management unit 527 performs a process related to management of data such as a multiview image file, and management of an application and data related to the application.

[0167] <Flow of a Multiview-Image Using Service Providing Process>

The terminal device 401 and the server 202 of the multiview-image using service providing system having the above described structure perform a multiview-image using service providing process to provide a service using multiview images, or provide a service such as a lens simulation in this embodiment. Referring now to the flowchart shown in Fig. 23, an example flow of the multiview-image using service providing process to be performed by those devices is described.

[0168] In step S201, the user instruction reception processing unit 511 of the terminal device 401 controls the input unit 231 or the like, to receive an instruction to request startup of an application from a user. The transmission control unit 513 controls the communication unit 234 or the like, to supply the application startup request received by the user instruction reception processing unit 511 to the server 202.

[0169] In step S221, the application selection processing unit 522 of the server 202 controls the communication unit 264 or the like, to acquire the request. In step S222, the application selection processing unit 522, in response to the request, generates a list of

applications that can be used by the user based on the user management information being managed by the user management unit 521, and controls the communication unit 264 or the like, to supply the list to the terminal device 401.

[0170] In step S202, the transmission control unit 513 of the terminal device 401 controls the communication unit 234 or the like, to acquire the list. The display control unit 512 controls the output unit 232, to display the acquired list as an image on a monitor. The user then selects the application to be started from the list.

[0171] In step S203, the user instruction reception processing unit 511 controls the input unit 231 or the like, to receive an instruction as to the selection of the application to be started from the user. The transmission control unit 513 controls the communication unit 234 or the like, to supply the application-to-start selection instruction received by the user instruction reception processing unit 511 to the server 202.

[0172] In step S223, the application selection processing unit 522 of the server 202 controls the communication unit 264 or the like, to acquire the selection instruction. In step S224, the image selection processing unit 523 generates a list of multiview images of the user based on the user management information being managed by the user management unit 521, and controls the communication unit 264 or the like, to supply the list to the terminal device 401.

[0173] In step S204, the transmission control unit 513 of the terminal device 401 controls the communication unit 234 or the like, to acquire the list. The display control unit 512 controls the output unit 232, to display the acquired list as an image on the monitor. The user then selects the multiview image to be the current multiview image from the list.

[0174] In step S205, the user instruction reception processing unit 511 controls the input unit 231 or the like, to receive an instruction as to the selection of the current image from the user. The transmission control unit 513 controls the communication unit 234 or the like, to supply the current image selection instruction received by the user instruction reception processing unit 511 to the server 202.

[0175] In step S225, the image selection processing unit 523 of the server 202 controls the communication unit 264 or the like, to acquire the selection instruction. In step S226, the lens selection processing unit 524 generates a list of the lenses registered with the user based on the user management information being managed by the user management unit 521, and controls the communication unit 264 or the like, to supply the list to the terminal device 401.

[0176] In step S206, the transmission control unit 513 of the terminal device 401 controls the communication unit 234 or the like, to acquire the list. The display control unit 512 controls the output unit 232, to display the acquired list as an image on the monitor. The user then selects the virtual lens to be simulated from the list.

[0177] In step S207, the user instruction reception processing unit 511 controls the input unit 231 or the like, to receive a lens selection instruction from the user. The transmission control unit 513 controls the communication unit 234 or the like, to supply the lens selection instruction received by the user instruction reception processing unit 511 to the server 202.

[0178] In step S227, the lens selection processing unit 524 of the server 202 controls the communication unit 264 or the like, to acquire the selection instruction.

[0179] In step S208, the user instruction reception processing unit 511 of the terminal device 401 controls the input unit 231 or the like, to receive user designated parameters that are imaging-related parameters such as imaging conditions having values designated by the user. The transmission control unit 513 controls the communication unit 234 or the like, to supply the user designated parameters received by the user instruction reception processing unit 511 to the server 202.

[0180] In step S228, the user designated parameter setting unit 525 of the server 202 controls the communication unit 264 or the like, to acquire the user designated parameters.

[0181] In step S229, the virtual lens processing unit 526 performs virtual lens processing to generate a virtual captured image that is obtained by capturing an image of the subject in the multiview image selected in step S225 with the virtual lens selected in step S227 while using the multiview image data and the profile information including the parameters for reproducing the optical effects of a virtual optical system. In doing so, the virtual lens processing unit 526 reproduces the optical influence of the virtual lens with higher precision by using the user designated parameters acquired in step S228. Also, in doing so, the virtual lens processing unit 526 generates interpolating images for the multiview image in accordance with the camera array information 342, the viewpoint number information 343, and the depth data 332 included in the multiview image file of the multiview image selected in step S225. The virtual lens processing will be described later in detail.

[0182] In step S230, the virtual lens processing unit 526 controls the communication unit 264 or the like, to supply the data of the virtual captured image generated by the processing in step S229 to the terminal device 401.

[0183] In step S209, the transmission control unit 513 of the terminal device 401 acquires the data of the virtual captured image. The display control unit 512 controls the output unit 232, to display the acquired virtual captured image on the monitor. Based on the virtual captured image, the user determines whether to save the virtual captured image.

[0184] In step S210, the user instruction reception processing unit 511 controls the input unit 231 or the like, to receive an instruction to save the data of the virtual captured image from the user. The transmission control unit 513 controls the communication unit 234

or the like, to supply the virtual captured image data saving instruction received by the user instruction reception processing unit 511 to the server 202.

[0185] In step S231, the data management unit 527 of the server 202 controls the communication unit 264 or the like, to acquire the virtual image data saving instruction. In step S232, the data management unit 527 generates application parameters about this lens simulation. The data management unit 527 stores and manages the data and the application parameters of the virtual captured image generated by the processing in step S229, and also registers the data and the application parameters with the user (or updates the user management information about the user).

[0186] When the processing in step S232 is finished, the multiview-image using service providing process comes to an end.

[0187] As such a multiview-image using service providing process is performed, a user can perform a virtual lens simulation more easily by using a multiview image (or generate a virtual captured image obtained by imaging with the use of a virtual lens). Also, as the generated virtual captured image data is registered with the user and is managed in the server 202, the user can use the virtual captured image data more readily. Furthermore, as the virtual captured image data is managed in association with the multiview image, the application parameters, and the like used in generating the virtual captured image, the user can more readily use the virtual captured image data as well as the other related data. That is, the multiview-image using service providing system 200 (the multiview-image using service platform 100) can increase the user-friendliness of the multiview-image using service.

[0188] <Example of a Screen>

Fig. 24 is a schematic view of an example of a setting GUI displayed on the display unit 531.

[0189] The screen shown in Fig. 24 displays a setting GUI as well as a preview image Pv. In the example shown in Fig. 24, development parameters are formed with the design information about the lens, the shape of the aperture, and the focus position.

[0190] In this case, a lens unit selection portion DL, an aperture shape selection portion DA, and a focus position selection portion DF are superimposed on the preview image Pv, and are displayed as the setting GUI on the display unit 531.

[0191] The lens unit selection portion DL displays figures that represent lens units based on selection candidates for the design information about a lens in the development parameters. The aperture shape selection portion DA displays figures that represent selection candidates for the aperture shape in the development parameters. The focus position selection portion DF displays a setting bar Fb that indicates the position of a selection candidate for the focus position.

[0192] The user touches, with a finger U, the figure that represents a desired lens unit

displayed in the lens unit selection portion DL, to select a selection candidate for the design information about the lens corresponding to the lens unit. The user also touches, with the finger U, the figure that represents a desired aperture shape displayed in the aperture shape selection portion DA, to select a selection candidate for the aperture shape.

[0193] The user also touches, with the finger U, the setting bar Fb in the focus position selection portion DF, and moves the finger U up and down, to move the setting bar Fb to the position corresponding to a desired focus position. In this manner, the user can select a selection candidate in a desired focus position.

[0194] The setting bar Fb may not be moved by the user moving the finger U after touching the setting bar Fb with the finger U. Instead, the setting bar Fb may be moved to a desired position in the focus position selection portion DF by the user touching the desired position. Also, a selection candidate for the focus position may not be displayed. Instead, the selection candidate for the focus position closest to the subject in the position touched with the finger U in the screen may be selected.

[0195] In the example shown in Fig. 24, the lens unit selection portion DL is located in the upper left corner of the preview image Pv, the aperture shape selection portion DA is located in the lower left corner, and the focus position selection portion DF is located on the right side. However, the positions of the respective portions are not limited to the above.

[0196] Although not shown in the drawing, selection candidates for other development parameters related to white balance, exposure correction, and the like may be displayed as well as the lens unit selection portion DL, the aperture shape selection portion DA, the focus position selection portion DF, and the like.

[0197] In the second embodiment, the display unit 531 is formed integrally with a touch panel. In a case where the display unit 531 is not formed integrally with a touch panel, however, a user moves a pointer displayed in the screen by operating a mouse or the like (not shown), to perform a selecting operation that is equivalent to a touch panel operation.

[0198] <Flow of the Virtual Lens Processing>

Referring now to the flowchart shown in Fig. 25, an example flow of the virtual lens processing performed in step S229 in Fig. 23 is described in detail.

[0199] When the virtual lens processing is started, the virtual lens processing unit 526 in step S251 acquires the selected multiview image file from the storage unit 263. In step S252, the virtual lens processing unit 526 acquires the profile information about the selected lens from the storage unit 263.

[0200] The site where multiview image files and profile information are stored and managed is not fixed, and may not be the storage unit 263. For example, multiview image files

and profile information may be stored and managed in a device other than the server 202, such as the terminal device 401. In that case, the virtual lens processing unit 526 controls the communication unit 264, for example, to acquire a multiview image file and profile information from the device in which the file and the information are stored. The site where multiview image files are stored and the site where profile information is stored may differ from each other.

[0201] Profile information is formed with parameters for reproducing the optical effects of a virtual optical system, and is unique to the virtual optical system. The profile information includes the PSF (Point Spread Function) data of the respective colors of RGB, an aperture shape, interpolation number designation information, and the like.

[0202] The PSF data is also referred to as a point spread function or a point-image distribution function, and is the function that indicates responses of the virtual lens included in the virtual optical system to a point light source. In other words, the PSF data is the data that indicates the influence of a virtual lens on light rays of RGB passing through the virtual lens. Fig. 26A shows an example of the PSF data. In this example, the PSF data in accordance with distances to the focusing point (or the point light source) are shown for the respective colors (in the respective rows).

[0203] The aperture shape is the information that indicates the shape of the virtual aperture included in the virtual optical system. This aperture shape may be an actually existing aperture shape, or may be an unrealistic shape such as a round shape, the shape of a star, or the shape of an X shown in the left portion of Fig. 26B. The aperture shape can be designated by any method. For example, a predetermined shape may be designated by identification information (ID) or the like. The aperture shape may be expressed by an intensity distribution 542 as shown in the right portion of Fig. 26B, for example. The size of the intensity distribution (the number of intensities) depends on the number of interpolating images (the interpolation number) designated by the interpolation number designation information. Where the interpolation number is N, for example, the aperture shape is expressed by the N x N intensity distribution 542.

[0204] The interpolation number designation information is the information that designates the number of interpolating images to be generated when a virtual captured image is generated. That is, in the virtual lens processing, the virtual lens processing unit 526 generates the number of interpolating images as designated by the interpolation number designation information. Where the number of interpolating images is larger, a virtual captured image with higher definition can be obtained. Normally, where the virtual lens has a higher grade (higher performance), the number of interpolating images is larger.

[0205] As described above, the lens profile information is formed with the information that indicates the features of the virtual lens. The contents of the lens profile information

are not fixed. Some of the above described information may be excluded, or information other than the above described information may be included. For example, the physical design information about the lens to be used for emulating the virtual lens may be included in the lens profile information.

[0206] Referring back to Fig. 25, in step S253, the virtual lens processing unit 526 sets the user designated parameters acquired in step S228 in Fig. 23.

[0207] The user designated parameters are imaging-related parameters that have values designated by the user. In accordance with the user designated parameters, the virtual lens processing unit 526 generates a virtual captured image. For example, the user designated parameters include focusing position designation information, a depth-of-field designation information, super-resolution processing instruction information, and the like.

[0208] The focusing position designation information (focus position designation information) is the information that designates an area (or a point) where the subject on which the focus is to be put is located in the captured image. When the user designates a position in the captured image as the focusing position, a virtual captured image is generated so that the focal point is on the subject located in the focusing position.

[0209] The depth-of-field designation information is the information that designates a depth of field (an aperture size). The super-resolution processing instruction information is the information that includes instructions related to super-resolution processing, such as an instruction as to whether super-resolution processing is to be performed when the respective captured images of the multiview image are superimposed on one another to generate a virtual captured image, and an instruction as to in which area and to what extent the super-resolution processing is to be performed if it is determined to be performed. The super-resolution processing at the time of the superimposition of the respective captured images of the multiview image is performed based on the super-resolution processing instruction information.

[0210] The contents of the user designated parameters are of course not fixed. Some of the above described information may be excluded, or information other than the above described information may be included.

[0211] In step S254, the virtual lens processing unit 526 determines the reference camera, the matching axis, the image interpolation method, and the like based on the camera array information, the viewpoint number information, and the like included in the metadata associated with the current multiview image data.

[0212] In step S255, the virtual lens processing unit 526 determines the combination ratios of the respective images to be used in image interpolation (or the respective images to be superimposed) in accordance with the positions of the interpolating images to be generated.

[0213] In step S256, the virtual lens processing unit 526 generates interpolating images in accordance with the depth data and the various kinds of parameters that are set in the above described manner. For example, the virtual lens processing unit 526 generates interpolating image by superimposing an image of the reference viewpoint determined in step S254 and the images designated by the interpolation method determined in step S254 by using the matching axis determined in step S254, in accordance with the depth data. The virtual lens processing unit 526 generates the number of interpolating images as designated by the interpolation number designation information in the profile information.

[0214] In step S257, the virtual lens processing unit 526 causes each of the interpolating images to reflect the aperture shape data in the profile information.

[0215] In step S258, based on the depth data, the virtual lens processing unit 526 calculates the depth value of the focusing position (the focus position) designated by the user. Specifically, in the virtual captured image to be generated, the virtual lens processing unit 526 calculates the depth value of the subject (the distance to the subject) located in the position (coordinates) designated by the focusing position designation information (the focus position designation information) included in the user designated parameters acquired in step S228, for example.

[0216] In step S259, the virtual lens processing unit 526 sets the depth of field designated by the depth-of-field designation information in the user designated parameters.

[0217] In step S260, the virtual lens processing unit 526 generates a virtual captured image by superimposing the multiview image and the interpolating images by repeating stereo matching or the like. In doing so, the virtual lens processing unit 526 reflects the PSF data of the virtual lens in accordance with the depth data (the depth value of the subject). Also, the virtual lens processing unit 526 generates the virtual captured image so that the focus is achieved at the depth value (distance) calculated in step S258. Furthermore, the virtual lens processing unit 526 causes each of the interpolating images to reflect the aperture shape data in step S257, so that the virtual captured image can reflect the virtual aperture shape. Also, the virtual lens processing unit 526 generates the virtual captured image so that the depth of field set in step S259 is achieved.

[0218] In step S261, the virtual lens processing unit 526 performs super-resolution processing on the virtual captured image in accordance with the super-resolution processing instruction information in the user designated parameters. In a case where the super-resolution processing instruction information instructs not to perform the super-resolution processing, for example, the virtual lens processing unit 526 does not perform the super-resolution processing. In a case where the super-resolution processing instruction information instructs to perform the super-resolution processing, for example, the virtual lens processing unit 526 performs the super-resolution

processing.

[0219] The super-resolution processing may be performed on the entire virtual captured image, or may be performed only on the predetermined area that has the depth value of the focusing position. Even if the super-resolution processing is performed on the area of the subject on which any focus is put, the effect to be achieved (an increase in image quality) is small. Therefore, the super-resolution processing is performed only on the area that has a depth value equal or similar to the depth value of the focusing position, so that the processing load can be reduced while image quality degradation is suppressed. The area where the super-resolution processing is to be performed may also be designated by the super-resolution processing instruction information.

[0220] When the processing in step S261 is finished, the virtual lens processing comes to an end, and returns to the process shown in Fig. 23.

[0221] As the virtual lens processing is performed in the above described manner, a user can obtain a virtual captured image more readily.

[0222] The virtual lens processing described above may not be performed by the server 202, but may be performed by some other device. For example, the CPU 221 of the terminal device 401 may have the virtual lens processing unit 526 or the like to perform the virtual lens processing in the terminal device 401. In that case, the virtual lens processing can be performed basically in the same manner as in the above described example. The information that is to be used in the virtual lens processing and is stored (managed) in the server 202, such as a multiview image file and the profile information about a virtual lens, may be transmitted to the terminal device 401 where necessary.

[0223] <5. Fifth Embodiment>

<Sales Support>

In this embodiment, execution of an application for performing the sales support described in the first embodiment is described as another example of the application. In this embodiment, an application for supporting sales of furniture as described in the first embodiment is described as an example of the sales support.

[0224] <Multiview-Image Using Service Providing System>

Fig. 27 is a diagram showing a typical example structure of a multiview-image using service providing system. The multiview-image using service providing system 200 shown in Fig. 27 is an example of a system to which the present technique is applied. In this system, a server 202 provides a multiview-image using service to a terminal device 201 connected thereto via a network 210. That is, the multiview-image using service providing system 200 is an example of a structure that realizes the multiview-image using service platform 100.

[0225] Fig. 27 shows an example of a structure related to the provision of a service related to the sales support (furniture sales support) among the services to be provided by the

multiview-image using service platform 100. In Fig. 27, the multiview-image using service providing system 200 includes the terminal device 201, the server 202, and a furniture sales server 601 that are connected to the network 210.

[0226] The terminal device 201 captures images of a subject to perform multiview imaging and obtain a multiview image. The terminal device 201 also detects the depth of the multiview image obtained through the multiview imaging. Furthermore, the terminal device 201 generates a virtual captured image by using the multiview imaging. The terminal device 201 also performs a process related to the placement of a furniture image in the virtual captured image. The terminal device 201 further turns the multiview image data and the like into a file, to generate a multiview image file.

[0227] The terminal device 201 and the server 202 that are connected to the network 210 in a wired or wireless manner communicate with each other, to perform processes such as selection of furniture data, transmission of three-dimensional modeling data (3D modeling data), furniture purchase procedures, and transmission of various kinds of data.

[0228] The server 202 performs processes such as saving of various kinds of data supplied from the terminal device 201.

[0229] The server 202 and the furniture sales server 601 that are connected to the network 210 in a wired or wireless manner communicate with each other, to perform processes such as provision of three-dimensional modeling data (3D modeling data) and furniture purchase procedures.

[0230] The furniture sales server 601 is the server that performs processes related to sales of furniture or sales support. Specifically, the furniture sales server 601 processes payment in sales of furniture, and provides the furniture image and the 3D modeling data thereof to be used in the sales support, and the like, as described above. The furniture sales server 601 has basically the same structure as the application providing server 402. Therefore, the structure illustrated in Fig. 15 can also be applied to the furniture sales server 601.

[0231] <Furniture Sales Support>

Next, a sales support method in a furniture sales support service to be provided by the above described multiview-image using service providing system 200 is described in detail. A product support service to be provided by the multiview-image using service platform 100 to which the present technique is applied is a service that virtually places an object as an image of the product being currently promoted in a desired background image, to cause a user to envision a situation where the product is actually used. The furniture sales support service to be provided by the multiview-image using service providing system 200 shown in Fig. 27 uses an image of the furniture being currently promoted (furniture image) as an example of the object, and uses a virtual

captured image as an example of the background image. That is, this furniture sales support service is a service that places a furniture image in a virtual captured image, to cause a user to envision a situation where the furniture is actually placed in a room or the like. In doing so, the furniture sales support service not only combines the virtual captured image with the furniture image, but also sets the size and the orientation of the furniture image in accordance with the placement position of the furniture image by using the depth data of the virtual captured image. Accordingly, it is possible to cause the user to envision a more accurate situation.

[0232] More specifically, the terminal device 201 generates the virtual captured image 611 shown in Fig. 28A from a multiview image obtained by multiview imaging. For example, the user performs multiview imaging on the room to be furnished with the furniture to be purchased, and generates the virtual captured image 611 of the room. The terminal device 201 also generates the depth data (depth map) 612 of the virtual captured image 611 as shown in Fig. 28B from the multiview image obtained by the multiview imaging.

[0233] The terminal device 201 then acquires the image (the furniture image) of the furniture being sold by the furniture sales server 601 and the 3D modeling data thereof from the server 202, and places the furniture image in the virtual captured image 611 (the room image) as in the combined image 613 shown in Fig. 28C. Here, the 3D modeling data may be a data to display three dimensional shape of the object such as furniture. The 3D modeling data can be information related with coordinates which indicate height, width, and depth of each position organizing external shape of the object, or the 3D modeling data can be set of polygons to organize external surfaces of the object, or set of free form curve lines based on the coordinates, and the like. Or more specifically, 3D modeling data could be information just indicating height, width, and depth of whole object. Further, 3D modeling data could include information defining color, texture, design pattern, reflectance or transparence of each surface organizing the external shape of the object. The placing of the furniture image is performed by using the depth data 612, and the size and the orientation of the furniture image are appropriately set in accordance with the distance to the placement position of the furniture image in the depth direction and the like. Specifically, for example, the terminal device 201 determines a modeling condition at the placement position in the virtual captured image 611 based on the acquired 3D modeling data. Here, the modeling condition may be a condition of the 3D modeling data applied the size and the orientation based on the placement position when the 3D modeling data is placed. Further, for example, the terminal device can also determine the modeling condition as a change of the color or the texture associated with light source and the placement position, or a change of a shape if the object could be changed in shape in response to

the placement position.

[0234] Also, the depth-direction positional relationship (the degree of overlapping) with other subjects in the image can be accurately reproduced in accordance with the distance to the placement position in the depth direction, as in the image shown in Fig. 29B, which shows a Christmas tree placed behind the person shown in the image in Fig. 29A.

[0235] Further, the placement position can be designated by the user, and the user can freely move the furniture image in the room displayed as the virtual captured image 611. The movement of furniture can be performed by set modeling condition based on the 3D modelling data again, in response to change of the condition of the designated furniture such as the position or the orientation. The user can also select the furniture image to be placed from the furniture images being provided to users by the furniture sales server 601 (the server 202). For example, the user can change colors and sizes of furniture. Also, types of furniture can be changed. For example, a chair can be replaced with a sofa.

[0236] Here, user can remove an object which has already been placed in the room as the displayed virtual captured image 611, and place a designated furniture image at the place where the removed object had been placed. Specifically, the terminal device 201 can discriminate particular object in the virtual captured image 511 by analyzing the virtual captured image. The discrimination can be preformed based on a change of contrast in the virtual captured image, depth data (depth map), and the like, and for example the wall, the column, or the shelf described in the figure 28 are identified as individual object each other. User can designate each identified object, and the terminal device can generate an image which is the virtual captured image without the designated object, in response to user instruction for the designated object. The place where the removed object has been placed in the virtual captured image can be represented as an extended plane of the floor or the wall simulated based on the depth data (depth map) 612, or represented by change of the condition of the object to display translucent condition. So that user can confirm a situation of the room, the designated object of which is removed, or is replaced to designated furniture after the removal.

[0237] The number of pieces of furniture to be combined with the virtual captured image is not fixed, and may be one or more. The terminal device 201 can also cause the server 202 or the like to record the image data of the combined image showing the result of the placement of the furniture image. Accordingly, the user can readily recheck the result of the placement of the furniture image later.

[0238] As the furniture sales support application is executed in the terminal device 201, for example, the user can receive the furniture sales support service. That is, before purchasing the furniture, the user can virtually place virtual furniture (a furniture

image) in the place (such as a room) to be furnished with the furniture (or can simulate placement of the furniture). Accordingly, the user can eliminate the anxiety about the purchase of the furniture before actually purchasing, and the motivation to purchase can be increased. In short, the multiview-image using service providing system 200 can support sales of furniture by providing the above described furniture sales support service.

[0239] <Functional Blocks>

The terminal device 201 has functions shown as functional blocks in Fig. 30A, as the CPU 221 executes a predetermined program. As shown in Fig. 30A, the CPU 221 has functional blocks such as a user instruction reception processing unit 651, a display control unit 652, an imaging control unit 653, a metadata generation unit 654, a depth detection unit 655, a virtual captured image generation unit 656, a furniture image placement processing unit 657, a purchase processing unit 658, a file generation unit 659, a combined image data generation unit 660, an application parameter generation unit 661, and a transmission control unit 662.

[0240] The user instruction reception processing unit 651 controls the input unit 231 or the like, to perform a process related to reception of a user instruction. The display control unit 652 controls the output unit 232 or the like, to perform a process related to display control to display an image such as a GUI or a guide on a monitor. The imaging control unit 653 performs a process related to multiview imaging control. The metadata generation unit 654 performs a process related to generation of metadata of a multiview image obtained by multiview imaging. The depth detection unit 655 performs a process related to detection of the depth of the multiview image. The virtual captured image generation unit 656 performs a process related to generation of a virtual captured image. The furniture image placement processing unit 657 performs a process related to the placement of a furniture image in the virtual captured image. The purchase processing unit 658 performs a process related to a purchase of furniture. The file generation unit 659 performs a process related to generation of a multiview image file. The combined image data generation unit 660 performs a process related to generation of combined image data in which the furniture image is combined with the virtual captured image. The application parameter generation unit 661 performs a process related to generation of application parameters about the application. The transmission control unit 662 controls the communication unit 234 or the like, to perform a process related to transmission of various kinds of information.

[0241] Meanwhile, the server 202 has functions shown as functional blocks in Fig. 30B, as the CPU 251 executes a predetermined program. As shown in Fig. 30B, the CPU 251 has functional blocks such as a user management unit 671, an application selection unit 672, a furniture data selection unit 673, a purchase processing unit 674, an acquisition

control unit 675, and a data management unit 676.

[0242] Like the user management unit 291, the user management unit 671 performs a process related to management of users to whom multiview-image using services are to be provided. The application selection unit 672 controls the communication unit 264 to communicate with the terminal device 201 or the like, and performs a process related to selection of the application to be executed. The furniture data selection unit 673 controls the communication unit 264 or the like to communicate with the terminal device 201, and performs a process related to selection of the furniture (furniture image) to be placed in a virtual captured image. The purchase processing unit 674 controls the communication unit 264 or the like to communicate with the terminal device 201 and the furniture sales server 601, and performs a process related to a purchase of furniture. The acquisition control unit 675 controls the communication unit 264 or the like, to perform a process related to acquisition of various kinds of data transmitted from the terminal device 201 or the like. Like the data management unit 295, the data management unit 676 performs a process related to management of data such as a multiview image file, and management of an application and data related to the application.

[0243] Further, the furniture sales server 601 has functions shown as functional blocks in Fig. 30C, as the CPU 411 executes a predetermined program. As shown in Fig. 30C, the CPU 411 has functional blocks such as a furniture data provision unit 681 and a purchase processing unit 682.

[0244] The furniture data provision unit 681 performs a process related to provision of the data to be used in the furniture sales support, such as a furniture image and 3D modeling data. The purchase processing unit 682 controls the communication unit 424 or the like to communicate with the server 202, and performs a process related to a furniture purchase procedure.

[0245] <Flow of a Multiview-Image Using Service Providing Process>

The terminal device 201, the server 202, and the furniture sales server 601 of the multiview-image using service providing system having the above described structure perform a multiview-image using service providing process to provide a service using multiview images, or provide a product sales support service in this embodiment. Referring now to the flowchart shown in Figs. 31 through 33, an example flow of the multiview-image using service providing process to be performed by those devices is described.

[0246] In step S321, the furniture data provision unit 681 of the furniture sales server 601 supplies the image data of a furniture image and the 3D modeling data thereof to the server 202, and registers the image data and the 3D modeling data therein. In step S311, the data management unit 676 of the server 202 acquires those data, and

registers and manages those data as the data of the furniture being promoted.

[0247] In step S301, the user instruction reception processing unit 651 of the terminal device 201 controls the input unit 231 or the like, to receive an instruction to request startup of an application from a user. The transmission control unit 662 controls the communication unit 234 or the like, to supply the application startup request received by the user instruction reception processing unit 651 to the server 202.

[0248] In step S312, the application selection unit 672 of the server 202 controls the communication unit 264 or the like, to acquire the request. In step S313, the application selection unit 672, in response to the request, generates a list of applications that can be used by the user based on the user management information being managed by the user management unit 671, and controls the communication unit 264 or the like, to supply the list to the terminal device 201.

[0249] In step S302, the transmission control unit 662 of the terminal device 201 controls the communication unit 234 or the like, to acquire the list. The display control unit 652 controls the output unit 232, to display the acquired list as an image on a monitor. The user then selects the application to be started from the list.

[0250] In step S303, the user instruction reception processing unit 651 controls the input unit 231 or the like, to receive an instruction as to the selection of the application to be started from the user. The transmission control unit 662 controls the communication unit 234 or the like, to supply the application-to-start selection instruction received by the user instruction reception processing unit 651 to the server 202.

[0251] In step S314, the application selection unit 672 of the server 202 controls the communication unit 264 or the like, to acquire the selection instruction. In step S315, the furniture data selection unit 673 generates a product list that is a list of the pieces of furniture that can be sold to the user based on the user management information being managed by the user management unit 671, and controls the communication unit 264 or the like, to supply the list to the terminal device 201.

[0252] In step S304, the transmission control unit 662 of the terminal device 201 controls the communication unit 234 or the like, to acquire the list. The display control unit 652 controls the output unit 232, to display the acquired list as an image on a monitor. The user then selects the furniture (furniture data) to be the current furniture data from the list.

[0253] In step S305, the user instruction reception processing unit 651 controls the input unit 231 or the like, to receive a furniture data selection instruction from the user. The transmission control unit 662 controls the communication unit 234 or the like, to supply the furniture data selection instruction received by the user instruction reception processing unit 651 to the server 202.

[0254] In step S316, the furniture data selection unit 673 of the server 202 controls the com-

munication unit 264 or the like, to acquire the selection instruction.

[0255] In step S306, the imaging control unit 653 of the terminal device 201 that has supplied the furniture data selection instruction controls the imaging unit 236 to perform multiview imaging. In step S307, the metadata generation unit 654 generates the metadata to be associated with the multiview image generated in step S306. The contents of the metadata are not fixed, but the metadata may include information such as the camera array information 342 and the viewpoint number information 343 as described above with reference to Fig. 11.

[0256] In step S308, the depth detection unit 655 detects the depth value of the multiview image, and generates depth data (a depth map). The depth detection unit 655 generates the depth data by performing the depth detection process described above with reference to Fig. 14, for example. In step S309, the virtual captured image generation unit 656 generates a virtual captured image by using the multiview image.

[0257] Referring now to Fig. 32, when the image data of the furniture image and the 3D modeling data thereof are updated, the furniture data provision unit 681 of the furniture sales server 601 in step S351 controls the communication unit 424 or the like, to supply those data to the server 202 by a background transfer as appropriate. In step S341, the data management unit 676 of the server 202 acquires those data, and updates the registered information.

[0258] In step S342, in accordance with the furniture data selection instruction acquired in step S316, the furniture data selection unit 673 of the server 202 controls the communication unit 264 or the like, to provide the image data of the selected furniture and the 3D modeling data thereof to the terminal device 201. In step S331, the transmission control unit 662 of the terminal device 201 controls the communication unit 234, to acquire the image data of the furniture and the 3D modeling data.

[0259] In step S343, the furniture data selection unit 673 of the server 202 also selects a piece of furniture (in a different color or a different size) highly related to the furniture indicated by the furniture data provided in step S342, and controls the communication unit 264 or the like, to supply a furniture image of the selected furniture, the 3D modeling data thereof, and the like to the terminal device 201 by a background transfer as appropriate. In step S332, the transmission control unit 662 of the terminal device 201 controls the communication unit 234, to acquire the image data of the furniture and the 3D modeling data thereof.

[0260] As the furniture-related data is transmitted to the terminal device 201 by a background process without a request from the terminal device 201, the user of the terminal device 201 can replace the furniture image placed in a virtual captured image with an image of a highly-related piece of furniture, without a time lag in the communication for data acquisition.

[0261] In step S333, the furniture image placement processing unit 657 of the terminal device 201 performs a furniture image placement process to place the furniture image that is an example of an object in the virtual captured image that is an example of a background image. In doing so, the furniture image placement processing unit 657 sets the size and the orientation of the furniture image in accordance with the placement position of the furniture image. If the furniture image and the 3D modeling data need to be changed, or a furniture image and 3D modeling data need to be added as a result of the furniture image placement process, the furniture image placement processing unit 657 in step S334 controls the communication unit 234 or the like, to request the server 202 to change furniture images and 3D modeling data or add a furniture image and 3D modeling data.

[0262] In step S344, the furniture data selection unit 673 of the server 202 controls the communication unit 264 or the like, to acquire the request. In step S345, in response to the request, the furniture data selection unit 673 controls the communication unit 264 or the like, to provide an image data of the selected furniture and the 3D modeling data thereof to the terminal device 201. In step S335, the transmission control unit 662 of the terminal device 201 controls the communication unit 234, to acquire the image data of the furniture and the 3D modeling data thereof.

[0263] In step S345, the furniture data selection unit 673 of the server 202 also selects a piece of furniture (in a different color or a different size) highly related to the furniture indicated by the furniture data provided in step S344, and controls the communication unit 264 or the like, to supply a furniture image of the selected furniture, the 3D modeling data thereof, and the like to the terminal device 201 by a background transfer as appropriate. In step S336, the transmission control unit 662 of the terminal device 201 controls the communication unit 234, to acquire the image data of the furniture and the 3D modeling data.

[0264] As the furniture-related data is transmitted to the terminal device 201 by a background process without a request from the terminal device 201, the user of the terminal device 201 can replace the furniture image placed in a virtual captured image with an image of a highly-related piece of furniture, without a time lag in the communication for data acquisition.

[0265] Referring now to Fig. 33, the user of the terminal device 201 determines whether to purchase furniture based on the above described furniture placement simulation. In step S361, the user instruction reception processing unit 651 controls the input unit 231 or the like, to receive a user instruction, and determines which piece of furniture is to be purchased in accordance with the instruction.

[0266] In step S362, the purchase processing unit 658 of the terminal device 201 controls the communication unit 234 or the like to communicate with the server 202, and

performs a process related to the purchase, such as a payment process. In step S371, the purchase processing unit 674 of the server 202 controls the communication unit 264 or the like to communicate with the terminal device 201 and the furniture sales server 601, and performs a process related to the purchase, such as a payment process. In step S381, the purchase processing unit 682 of the furniture sales server 601 controls the communication unit 424 or the like to communicate with the terminal device 201 and the server 202, and performs a process related to the purchase, such as a payment process.

[0267] In step S363, the file generation unit 659 of the terminal device 201 generates a multiview image file. The format of the multiview image file may be of any type. In a case where the multiview image is a still image, for example, the multiview image may be turned into a file in the Exif file format. In a case where the multiview image is a moving image, for example, the multiview image may be turned into a file in the MP4 file format. It is of course possible to use a file format other than the above.

[0268] In step S364, the combined image data generation unit 660 generates the data of a combined image (combined image data) formed by placing and combining the furniture image with the virtual captured image in accordance with a user instruction.

[0269] In step S365, the application parameter generation unit 661 generates the application parameters of the application for performing the product sales support. The application parameters are history information that indicates which values have been set for which parameters, what kinds of operations (instructions) have been conducted by the user, and what kinds of processes have been performed in this furniture sales support.

[0270] In step S366, the transmission control unit 662 controls the communication unit 234, to supply the various kinds of data (the multiview image file (the multiview image data, the depth data, the metadata, and the like), the combined image data, the application parameters, and the like) generated in the above described manner, to the server 202.

[0271] In step S372, the acquisition control unit 675 of the server 202 controls the communication unit 264, to acquire the various kinds of data.

[0272] In step S373, the data management unit 676 stores the various kinds of data acquired in step S372, and registers the various kinds of data with the user (or causes the user management information to reflect the various kinds of data).

[0273] When the processing in step S373 is finished, the multiview-image using service providing process comes to an end.

[0274] As such a multiview-image using service providing process is performed, a user can perform a furniture placement simulation more easily by using a multiview image. Also, generated combined image data is registered with the user and is managed in the server 202. Accordingly, the user can readily recheck the result of furniture placement.

That is, the multiview-image using service providing system 200 (the multiview-image using service platform 100) can increase the user-friendliness of the multiview-image using service.

[0275] <Flow of the Furniture Image Placement Process>

Referring now to the flowchart shown in Fig. 34, an example flow of the furniture image placement process performed in step S333 in Fig. 32 is described in detail.

[0276] When the furniture image placement process is started, the furniture image placement processing unit 657 in step S391 controls the input unit 231, for example, to receive a placement position designation from the user or the like.

[0277] In step S392, the furniture image placement processing unit 657 sets the orientation and the size of the furniture image in the position where the furniture image is placed in the virtual captured image based on the depth data and the base-line length information about the virtual captured image (multiview image) as an example of a background image, and the 3D modeling data of the furniture image as an example of an object.

[0278] In step S393, the furniture image placement processing unit 657 places the furniture image having the orientation and the size set in step S392 in the position designated (by the placement position designation received in step S391, for example) in the virtual captured image, and combines the furniture image with the virtual captured image.

[0279] When the processing in step S393 is finished, the furniture image placement process comes to an end, and returns to the process shown in Fig. 32.

[0280] As the furniture image placement process is performed in the above described manner, a user can more readily perform a furniture placement simulation.

[0281] The above described furniture image placement process is not necessarily performed by the terminal device 201, but may be performed by some other device. For example, the furniture image placement process may be performed by the server 202. In that case, the CPU 251 of the server 202 includes the necessary functional blocks such as the furniture image placement processing unit 657. In that case, the furniture image placement process can be performed basically in the same manner as in the above described example. The information that is to be used in the furniture image placement process and is obtained by the terminal device 201, such as a multiview image file, is transmitted to the server 202 where necessary, under the control of the transmission control unit 662.

[0282] Likewise, the furniture image placement process may be performed in a device (such as the terminal device 401) other than the terminal device 201 that performs multiview imaging and the server 202, for example. In that case, the CPU of the device includes the necessary functional blocks such as the furniture image placement processing unit

657. In that case, the furniture image placement process can be performed basically in the same manner as in the above described example. The information that is to be used in the furniture image placement process and is obtained by the terminal device 201 or the server 202, such as a multiview image file and furniture data, is transmitted to the device where necessary, under the control of the transmission control unit 662, the furniture data selection unit 673, or the like.

[0283] <Furniture Placement Updating Process>

If the placement position designation is updated in the above described product sales support application, the furniture image combining position may be changed in accordance with the update. For example, as shown in Fig. 35A, in a case where the placement position designation for a furniture image 702A placed in a virtual captured image 701 is updated as indicated by a dashed arrow 703, the size and the orientation of the furniture image 702A are reset in accordance with the updated placement position (a furniture image 702B).

[0284] In a case where the viewpoint of a virtual captured image is updated, the position of the placed furniture image is not updated, and a condition of the furniture image having an appropriate size and an appropriate orientation is relocated in the original position in the virtual captured image with the new viewpoint. For example, as shown in Fig. 35B, a sofa 706 is placed in a virtual captured image formed by capturing an image of a room 704 from a viewpoint 705A. When the viewpoint of the virtual captured image is moved to a viewpoint 705B, the sofa 706 is also shown in the virtual captured image with the updated viewpoint. Therefore, the sofa 706 is placed in the original position in the virtual captured image with the updated viewpoint. At this point, the orientation and the size of the sofa 706 are adjusted appropriately in the virtual captured image with the updated viewpoint.

[0285] To realize such a function, the furniture image placement processing unit 657 performs a furniture placement updating process. Referring now to the flowchart shown in Fig. 36, an example flow of the furniture placement updating process is described. When the furniture placement updating process is started, the furniture image placement processing unit 657 in step S401 determines whether the designated placement position has been changed. If it is determined that a new placement position designation has been received from the user via the input unit 231, and the placement position designation has been changed, for example, the process moves on to step S402.

[0286] In step S402, the furniture image placement processing unit 657 sets the orientation and the size of the furniture image based on depth data and base-line length information as well as 3D modeling data. In step S403, the furniture image placement processing unit 657 combines the furniture image with the virtual captured image in

the updated designated position.

[0287] When the processing in step S403 is finished, the process moves on to step S404. If the designated placement position is determined not to have been changed in step S401, the process also moves on to step S404.

[0288] In step S404, the furniture image placement processing unit 657 determines whether the imaging position or direction has been changed. For example, in a case where a new virtual captured image is generated by new multiview imaging, or where multiview imaging is performed to capture a moving image while the operator is in motion, the imaging position or direction is determined to have been changed. In that case, the process moves on to step S405.

[0289] In step S405, the furniture image placement processing unit 657 updates the virtual captured image by re-creating a virtual captured image from a new multiview image. In step S406, the furniture image placement processing unit 657 identifies the position of the furniture image placed before the virtual captured image update in the updated virtual captured image. In step S407, the furniture image placement processing unit 657 sets the size and the orientation of the furniture image in the position specified in step S406 in the updated virtual captured image. In step S408, the furniture image placement processing unit 657 relocates the furniture image having the size and the orientation set in step S407 in the position specified in step S406 in the updated virtual captured image.

[0290] When the processing in step S408 is finished, the furniture placement updating process comes to an end. Also, if the imaging position or direction is determined not to have been changed in step S404, the furniture placement updating process comes to an end.

[0291] After a furniture image is placed in a virtual captured image, this furniture placement updating process is repeated until the furniture placement simulation is finished. Accordingly, a furniture image having an appropriate size and an appropriate orientation can be typically combined with a virtual captured image in an appropriate position.

[0292] <Floor Contact Determination>

As for the position of a furniture image, a check may be made to determine whether the furniture image is in contact with the floor or the like in a virtual captured image. For example, in the virtual captured image 711 shown in Fig. 37A, the position of a light stand 712 is designated in the position shown in Fig. 37A. In this case, the light stand 712 is at a distance from a floor 714 as indicated by a dashed double-headed arrow 713, and is placed in the air. This is not a realistic placement position, and is inappropriate and undesirable as a furniture placement simulation.

[0293] In such a case, the placement position of the light stand 712 may be changed so that the light stand 712 is brought into contact with the floor 714 in the virtual captured

image 711 as shown in Fig. 37B. Alternatively, the position may not be changed, but an alarm may be issued to the user or the like.

[0294] To realize such a function, the furniture image placement processing unit 657 performs a floor contact determination process. Referring now to the flowchart shown in Fig. 38, an example flow of the floor contact determination process is described.

[0295] When the floor contact determination process is started, the furniture image placement processing unit 657 in step S421 identifies the height of the designated placement position of the furniture from an area such as a floor on which furniture can be placed. In step S422, the furniture image placement processing unit 657 determines whether the furniture image is in contact with the area such as a floor on which furniture can be placed based on the 3D modeling data of the placed furniture image. If the furniture image is not in contact with the area, the process moves on to step S423.

[0296] In step S423, the furniture image placement processing unit 657 performs error processing. The contents of the error processing are not fixed, and any processing may be performed. For example, the furniture image may be moved so as to be in contact with the floor based on update of the modeling condition of the 3D modeling data, as described above. Alternatively, the placement position of the furniture image may not be updated, but an alarm may be issued to the user or the like, as described above.

[0297] When the processing in step S423 is finished, the floor contact determination process comes to an end. If the furniture image is determined to be in contact with the area such as a floor on which furniture can be placed in step S422, the floor contact determination process also comes to an end.

[0298] Every time furniture is placed, the floor contact determination process is performed. As a result, a user can perform a more realistic furniture placement simulation.

[0299] The placement position of an object may be adjusted not only in the vertical direction as described above, but also in the horizontal direction (including the transverse direction and the depth direction) of the object based on the contents of the background image (the positions of objects included in the background image).

[0300] For example, the background image (a virtual captured image) is an image of a room in which there is a large pillar in the front, there is a space behind the pillar, and there is a wall behind the space. In front of the wall (in the room), the area of the pillar is a placement prohibited area for objects (furniture images), and the space between the pillar and the wall is a placement allowed area for objects (furniture images). In a case where there is an instruction to place a furniture image in the placement prohibited area, the furniture image is moved to the space between the pillar and the wall, which is the placement allowed area, and is then placed therein. At this point, not only the size and the orientation of the furniture image are adjusted in accordance with the placement position after the move, but also part or all of the furniture image is

processed so as to be hidden behind the pillar and be combined with the virtual captured image, if necessary.

[0301] As a result, a user can perform a more realistic furniture placement simulation.

[0302] <Length Measurement>

Further, length measurement may be carried out in a virtual captured image. As shown in Fig. 39, in a virtual captured image 721, the width of a window is measured as indicated by a dashed double-headed arrow 722, for example. In the virtual captured image 721, the size of the window varies with the distance to the window in the depth direction. Therefore, a measured length may be corrected in accordance with the distance in the depth direction by using the depth data and the base-line length information about a multiview image, for example.

[0303] To realize such a function, the furniture image placement processing unit 657 performs a measurement process. Referring now to the flowchart shown in Fig. 40, an example flow of the measurement process is described.

[0304] When the measurement process is started, the furniture image placement processing unit 657 in step S441 receives a designation of an area in a virtual captured image. After an area is designated, the furniture image placement processing unit 657 in step S442 measures the length of the area based the depth data and the base-line length information about the multiview image used in generating the virtual captured image. When the processing in step S442 is finished, the measurement process comes to an end.

[0305] By this process, the length (the dashed double-headed arrow 722) of the window in the horizontal direction can be more accurately measured in the virtual captured image 721 in Fig. 39, for example. Accordingly, when curtains for this window are to be purchased, errors in the measurement of the size of the curtains can be reduced, and a decrease in the user's motivation to purchase can be prevented. That is, sales can be supported by such a service.

[0306] <Lighting Process>

Also, lighting (light rays) may be reproduced in a virtual captured image. As shown in Fig. 41, a situation where a floor lamp 732 placed in a virtual captured image 731 is on may be reproduced, for example.

[0307] To realize such a function, the furniture image placement processing unit 657 performs a lighting process. Referring now to the flowchart shown in Fig. 42, an example flow of the lighting process is described.

[0308] When the lighting process is started, the furniture image placement processing unit 657 in step S461 receives designations of light source parameters including parameters related to the light source, such as color, luminance, and direction. The values of the respective parameters included in the light source parameters may be designated by a

user, or may be provided as furniture data associated with an image of the furniture (a lighting device). In step S462, the furniture image placement processing unit 657 simulates lighting (light rays from the light source) in a virtual captured image based on the designated light source parameters. In step S463, the furniture image placement processing unit 657 causes the virtual captured image to reflect the result of the simulation. For example, the portion illuminated with light is made brighter, and the portion that is not illuminated with light is made darker or shaded.

[0309] As a result, a user can perform a more realistic lighting placement simulation. Accordingly, when a lighting device is purchased, inconvenient differences between the color and brightness of the actually purchased lighting device and estimated color and brightness of the product displayed in the store or shown in a catalog can be reduced. In this manner, a decrease in the user's motivation to purchase can be prevented. That is, sales can be supported by such a service.

[0310] <Line-of-Flow Presentation Process>

Also, portions to be lines of flow may be emphasized in a virtual captured image. As shown in Fig. 43, a table 742 is placed in a virtual captured image 741, and a portion 743 that satisfies line-of-flow conditions is identified, for example. This portion may be presented to the user. In the example shown in Fig. 43, the portion 743 that satisfies the line-of-flow conditions is emphasized by the shading. The line-of-flow conditions may be that a person can stand on the floor, and a large enough width to allow a person to walk through the place is ensured, for example.

[0311] The portion 743 satisfying the line-of-flow conditions may be indicated by a color or luminance, or may be indicated by a symbol or a figure such as an arrow or a star.

[0312] To realize such a function, the furniture image placement processing unit 657 performs a line-of-flow presentation process. Referring now to the flowchart shown in Fig. 44, an example flow of the line-of-flow presentation process is described.

[0313] When the line-of-flow presentation process is started, the furniture image placement processing unit 657 in step S481 identifies a floor portion having a width equal to or greater than a predetermined width in a virtual captured image, or a portion that satisfies the line-of-flow conditions, based on base-line length information. In step S482, the furniture image placement processing unit 657 emphasizes the identified portion with a pattern, a color, luminance, or the like. When the processing in step S482 is finished, the line-of-flow presentation process comes to an end.

[0314] In this manner, a user can simulate a furniture layout so as to secure a line of flow when placing furniture. Accordingly, inconvenience such as a space that is too narrow for a person to walk through due to large furniture can be prevented, for example. Also, a check can be made to determine whether a wide enough space for a wheel chair can be secured before the purchase of furniture, for example. Accordingly, the user's

motivation to purchase is increased by such a service, and sales can be supported.

[0315] <Human Image Placement>

When furniture is placed, a human image may be placed in a virtual captured image. As shown in Fig. 45, a chair 752 is placed in a virtual captured image 751, and a human image 753 may be placed in its vicinity, for example. This human image may be a captured image of an actual person, or may be an image of a fictional person. In either way, this human image is associated with the same 3D modeling data as that of a furniture image.

[0316] To realize such a function, the furniture image placement processing unit 657 performs a human image placement process. Referring now to the flowchart shown in Fig. 46, an example flow of the human image placement process is described.

[0317] When the human image placement process is started, the furniture image placement processing unit 657 in step S501 receives a position designation for the placement position of a human image from a user or the like via the input unit 231 or the like. In step S502, the furniture image placement processing unit 657 sets the size and the orientation of the human image in the designated position based on the base-line length information and the depth data of the captured image used in generating the virtual captured image, as in the case of a furniture image. In step S503, the furniture image placement processing unit 657 places the human image having the size and the orientation set in step S502 in the designated position (designated in step S501, for example). When the processing in step S503 is finished, the human image placement process comes to an end.

[0318] In this manner, a user can place not only a furniture image but also a human image in a virtual captured image. Accordingly, furniture placed in a position can be compared with the human image, and the size and the style of the furniture can be more accurately expressed. As a result, inconvenience such as differences in size and impression between the actually purchased furniture and expectations can be reduced, for example. Accordingly, the user's motivation to purchase is increased by such a service, and sales can be supported.

[0319] The position of the human image can be set in any appropriate manner. For example, the placement position of the human image may be determined in accordance with the position of the furniture image, and the human image may be placed on or near the furniture image. Alternatively, a user may designate a furniture image, and a human image may be placed in a position in accordance with the designated furniture image, for example. The human image to be placed may be an image of one person or an image of more than one person.

[0320] Here, a human image is an example of an image to be combined with (or placed in) a background image (a virtual captured image, for example), and is not an object (a

furniture image, for example) to be promoted. In other words, an image other than a human image may be placed in the same manner as in the above described case of a human image. For example, it is possible to use an image of an animal such as a dog or a cat (an animal image), an image of a product that is not being sold (promoted) (a product image), or an image of a person and an animal (a combination image).

[0321] Further, when an image is to be placed in the above manner, a user or the like may be allowed to select the image to be placed. For example, a user may be allowed to select a human image, an animal image, a product image, a combination image, or the like. Even more specific selection may be allowed. In the case of a human image, sex, age, posture (standing, sitting, or the like), clothes, the number of persons, and the like may be selected, for example. Likewise, in the case of an animal image, a product image, or a combination image, parameters such as category, sex, age, size, and color can be selected. An image is selected in any appropriate manner. For example, a user or the like may be allowed to select a desired image from candidates that are prepared in advance. Alternatively, a user or the like may create an image to be combined like the above described human image by processing an image or combining images.

[0322] <Restriction on a Furniture List>

As described above, a furniture list is presented when a user selects the furniture to be placed. At that point, a list of the pieces of furniture that can be placed in a virtual captured image may be presented to the user. Specifically, pieces of furniture that are not to be placed in a virtual captured image may be eliminated from the list, and a user or the like may select a furniture image to be placed in the virtual captured image (a background image) from the furniture images (objects) that can be placed in the virtual captured image.

[0323] To realize such a function, the furniture image placement processing unit 657 performs a furniture list restriction process. Referring now to the flowchart shown in Fig. 47, an example flow of the furniture list restriction process is described.

[0324] When the furniture list restriction process is started, the furniture image placement processing unit 657 in step S521 determines the sizes of furniture that can be placed in a virtual captured image from the base-line length information about the multiview image used in generating the virtual captured image. In step S522, the furniture image placement processing unit 657 identifies pieces of furniture that can be placed in the virtual captured image based on the 3D modeling data of the furniture images in a list supplied from the server 202. In step S523, the furniture image placement processing unit 657 creates a list of the pieces of furniture identified in step S522. The display control unit 652 controls the output unit 232, to display the list created by the furniture image placement processing unit 657 as an image on a monitor. When the processing in step S523 is finished, the furniture list restriction process comes to an end.

[0325] In this manner, unnecessary pieces of furniture can be eliminated from the list to be presented to the user. Accordingly, the user can select furniture by referring to the more useful list. Particularly, in a case where there are a large number of pieces of furniture being sold and a large number of kinds of furniture being sold, it might be difficult for a user to select a piece of furniture from the list. Therefore, it is preferable to eliminate the largest possible amount of unnecessary information from the list. Accordingly, furniture selection can be made easier for the user, a decrease in the motivation to purchase can be prevented, and sales can be supported.

[0326] In the above description, a virtual captured image obtained by multiview imaging and a furniture image are combined to form an example of a combined image. However, any images may be combined with each other. For example, captured images may be combined with each other, artificial images such as computer graphic images may be combined with each other, or a captured image and an artificial image may be combined with each other. Also, captured images that are partially artificial may be combined with each other. Further, moving images may be combined with each other, still images may be combined with each other, or a moving image and a still image may be combined with each other.

[0327] In the above description, in a product support service, an object is combined with a background image. However, the object may be of any kind, as long as it is an image of a product that can be promoted. The object may not have 3D modeling data. For example, 3D modeling data may be provided from a different site from the object. Also, instead of 3D modeling data, simplified information that indicates a size or the like may be used, for example.

[0328] A background image is an image in which an object is to be placed, and is not an image that indicates the superimposition relationship (positional relationship) with respect to the object. For example, the background image may include a foreground to be superimposed on the front side of an object. Also, the background image may be formed with only the foreground (that is, the entire background is to be superimposed on the front side of the object). Further, the background image may be the foreground or the background of the object, depending on the position in which the object is placed. That is, the background image may be formed with more than one image (or may be formed by superimposing images on each other). As described above, while the background image is formed with one captured image (a virtual captured image), the object and the background image may be processed as appropriate and be then combined, so that part of the background image comes in front of the object, depending on the placement position (particularly, the position in the depth direction) of the object (a furniture image).

[0329] <6. Others>

It should be noted that the above described series of processes may be performed by hardware or may be performed by software. In a case where the above described series of processes are performed by software, the program forming the software is installed from a network or a recording medium.

[0330] This recording medium is formed with a removable medium (such as the removable medium 241, the removable medium 271, or the removable medium 431) that is distributed for delivering the program to users independently of the device, and has the program recorded therein, as shown in Figs. 4, 6, and 16, for example. This removable medium may be a magnetic disk (a flexible disk) or an optical disk (a CD-ROM or a DVD). Further, the removable medium may be a magnetooptical disk (a MD (Mini Disc), a semiconductor memory, or the like.

[0331] In this case, the program can be installed into a storage unit via an input/output interface when the removable medium is mounted in the drive.

[0332] Alternatively, this program can be provided via a wired or wireless transmission medium such as a local area network, the Internet, or digital satellite broadcasting. In that case, the program can be received by the communication unit (the communication unit 234, the communication unit 264, or the communication unit 424, for example) of each device, and be installed into the storage unit (the storage unit 233, the storage unit 263, or the storage unit 423, for example) of each device.

[0333] Alternatively, this program can be installed into the ROM (the ROM 222, the ROM 252, or the ROM 412, for example) of each device, and be installed beforehand into the storage unit (the storage unit 233, the storage unit 263, or the storage unit 423, for example) of each device.

[0334] The programs to be executed by the computer may be programs for performing processes in chronological order in accordance with the sequence described in this specification, or may be programs for performing processes in parallel or performing a process when necessary, such as when there is a call.

[0335] In this specification, the steps written in the programs recorded in a recording medium include not only processes to be performed in chronological order in accordance with the sequence described herein, but also processes to be performed in parallel or independently of one another if not necessarily in chronological order.

[0336] The processing in each of the above described steps can be performed by each of the above described devices or any appropriate device other than the above described devices. In that case, the device that performs the processing include the above described necessary functions (such as functional blocks) for performing the processing. Also, the necessary information for the processing is transmitted to the device where necessary.

[0337] In this specification, a system means an assembly of components (devices, modules

(parts), and the like), and not all the components need to be provided in the same housing. In view of this, devices that are housed in different housings and are connected to each other via a network form a system, and one device having modules housed in one housing is also a system.

[0338] Also, in the above described examples, any structure described as one device (or one processing unit) may be divided into two or more devices (or processing units). Conversely, any structure described as two or more devices (or processing units) may be combined to form one device (or one processing unit). Also, it is of course possible to add a structure other than the above described ones to the structure of any of the devices (or any of the processing units). Further, as long as the structure and function of the entire system remain the same, part of the structure of a device (or a processing unit) may be incorporated into another device (or another processing unit).

[0339] Although embodiments of the present disclosure have been described above with reference to the accompanying drawings, the present disclosure is not limited to those examples. It is apparent that those who have ordinary skills in the art can make various changes or modifications within the scope of the technical spirit claimed herein, and it should be understood that those changes or modifications are within the technical scope of the present disclosure.

[0340] For example, the present technique can be embodied in a cloud computing structure in which one function is shared among devices via a network, and processing is performed by the devices cooperating with one another.

[0341] The respective steps described with reference to the above described flowcharts can be carried out by one device or can be shared among devices.

[0342] In a case where more than one process is included in one step, the processes included in the step can be performed by one device or can be shared among devices.

[0343] The image processing device according to the above described embodiments can be applied to various electronic devices including: transmitters and receivers for satellite broadcasting, cable broadcasting such as cable television, deliveries via the Internet, deliveries to terminals by cellular communications, and the like; recording devices that record images on media such as optical disks, magnetic disks, or flash memories; or reproducing devices that reproduce images from those storage media.

[0344] The present technique is not limited to the above, and can be applied to any component mounted on such a device or devices constituting a system, such as a processor as a system LSI (Large Scale Integration) or the like, a module using processors and the like, a module using processors and the like, a unit using modules and the like, or a set (as a component of a device) having functions as well as the functions of a unit.

[0345] The present technique can also be in the following forms.

(1) An image processing apparatus, including:
circuitry configured to initiate a setting of an object for display within a background image in accordance with a modeling condition associated with a position at which the object is set, based on depth data and base-line length information associated with the background image and modeling data of the object.
(2) The image processing apparatus of any of (1) and (3) through (22), wherein the circuitry is further configured to initiate a changing of a condition of the object to a condition corresponding to a second position, based on a change of position at which the object is set from a first position to the second position.
(3) The image processing apparatus of any of (1), (2) and (4) through (22), wherein the circuitry is further configured to initiate a changing of a condition of the object from a condition associated with a first viewpoint to a condition associated with a second view point, based on a changing of a viewpoint of the background image from the first viewpoint to the second viewpoint.
(4) The image processing apparatus of any of (1) through (3) and (5) through (22), wherein the circuitry is further configured to initiate a changing of a condition of the object from a condition associated with a first viewing direction to a condition associated with a second viewing direction, based on a changing of a direction of a viewpoint of the background image from the first viewing direction to the second viewing direction.
(5) The image processing apparatus of any of (1) through (4) and (6) through (22), wherein the circuitry is further configured to initiate a moving of the object, and repositioning of the object to have a condition of making contact with a plane of the background image.
(6) The image processing apparatus of any of (1) through (5) and (7) through (22), wherein the condition of making contact with the plane is determined based on a distance between the object and the plane.
(7) The image processing apparatus of any of (1) through (6) and (8) through (22), wherein a condition of the object is a condition associated with a position and an orientation of the object.
(8) The image processing apparatus of any of (1) through (7) and (9) through (22), wherein the circuitry is further configured to initiate a simulation of a lighting in the background image based on light source parameters and the depth data, the light source parameters being parameters related to a light source.
(9) The image processing apparatus of any of (1) through (8) and (10) through (22), wherein the circuitry is further configured to initiate an identification of a portion that satisfies line-of-flow conditions in the background image having the object placed therein, and initiates an emphasizing of the identified portion.

(10) The image processing apparatus of any of (1) through (9) and (11) through (22), wherein the circuitry is further configured to initiate a setting of an image of a person within the background image, in accordance with a modeling condition associated with a position at which the image of the person is set within the background image having the object placed therein, and based on the depth data, the base-line length information, and modeling data of the image of the person.

(11) The image processing apparatus of any of (1) through (10) and (12) through (22), wherein the object is selected from among one or more candidate objects, in accordance with a modeling condition of the selected object associated with a position at which the selected object is set in the background image, and based on the depth data, the base-line length information, and the modeling data of the selected object.

(12) The image processing apparatus of any of (1) through (11) and (13) through (22), wherein the one or more candidate objects are objects that can be placed within the background image.

(13) The image processing apparatus of any of (1) through (12) and (14) through (22), wherein the circuitry is further configured to initiate a control of a capturing of an image of a subject, initiate an obtaining of the captured image as the background image, and initiate a generation of depth data of the captured image.

(14) The image processing apparatus of any of (1) through (13) and (15) through (22), wherein the captured image is a multiview image formed with a plurality of images having different viewpoints from one another, and the circuitry is further configured to initiate a generation of depth data of the multiview image, and to initiate a generation of a virtual captured image as the background image based on the multiview image and the depth data, the virtual captured image being obtained by imaging a subject of the multiview image.

(15) The image processing apparatus of any of (1) through (14) and (16) through (22), wherein the object is an image of furniture.

(16)The image processing apparatus of any of (1) through (15) and (17) through (22), wherein the circuitry is further configured to initiate a performing of a purchase process to purchase the furniture that is placed within the background image.

(17) The image processing apparatus of any of (1) through (16) and (18) through (22), wherein the circuitry is further configured to initiate a transmission of multiview image data as data of a multiview image and depth data of the multiview image, the multiview image being formed with a plurality of images having different viewpoints from one another and used for generating the background image.

(18) The image processing apparatus of any of (1) through (17) and (19) through (22), wherein the circuitry is further configured to initiate a generation of image data of the background image having the object set therein, and initiate a transmission of the

generated image data.
(19) The image processing apparatus of any of (1) through (18) and (20) through (22), wherein the circuitry is further configured to initiate a generation of an application parameter that is a parameter related to a combining of the background image and the object, and initiate a transmission of the generated application parameter.
(20) The image processing apparatus of any of (1) through (19), (21) and (22), wherein the circuitry is further configured to initiate a generation of metadata about the multiview image, and initiate a transmission of the generated metadata.
(21) The image processing apparatus of any of (1) through (20) and (22), wherein the metadata includes the base-line length information.
(22) The image processing apparatus of any of (1) through (21), wherein the depth data indicates a distance of depth direction in the background image, and the base-line length information indicates a reference length associated with the background image.
(23) An image processing method including:
setting an object for display within a background image in accordance with a modeling condition associated with a position at which the object is set, based on depth data and base-line length information associated with the background image and modeling data of the object; and
placing the set object to be displayed at the position within the background image.
(24) An image processing device, including
an object placement unit that sets the orientation and the size of an object in a position in which the object is to be placed in a background image, and places the object having the set orientation and the set size in the designated position in the background image, the orientation and the size being set based on depth data, base-line length information, and the three-dimensional modeling data of the object, the depth data indicating the distance to a subject in the background image, the base-line length information being information indicating a reference length in the background image.
(25) The image processing device of any of (24) and (26) through (42), wherein, when another position is designated after the object is placed in the background image, the object placement unit sets the orientation and the size of the object in the another position, and places the object having the set orientation and the set size in the another position in the background image.
(26) The image processing device of any of (24), (25), and (27) through (42), wherein, when there is a change in the position or the orientation of the viewpoint of the background image, the object placement unit sets the orientation and the size of the object in the position in which the object was placed before the change in the position or the orientation of the viewpoint in the background image not yet having the change in the position or the orientation of the viewpoint, and places the object having the set

orientation and the size in the position in which the object was placed before the change in the position or the orientation of the viewpoint in the background image having the change in the position or the orientation of the viewpoint.

(27) The image processing device of any of (24) through (26) and (28) through (42), wherein the object placement unit moves the object, to bring the object having the set orientation and the set size into contact with the floor.

(28) The image processing device of any of (24) through (27) and (29) through (42), wherein the object placement unit measures the length of a designated area in the background image.

(29) The image processing device of any of (24) through (28) and (30) through (42), wherein the object placement unit simulates lighting in the background image based on light source parameters and the depth data, and causes the background image to reflect the simulated lighting, the light source parameters being parameters related to a light source.

(30) The image processing device of any of (24) through (29) and (31) through (42), wherein the object placement unit identifies a portion that satisfies line-of-flow conditions in the background image having the object placed therein, and emphasizes the identified portion in the background image having the object placed therein.

(31) The image processing device of any of (24) through (30) and (32) through (42), wherein the object placement unit sets the orientation and the size of a person in a position in which an image of the person is to be placed in a background having the object placed therein, and places the image of the person having the set orientation and the set size in the designated position in the background image having the object placed therein, the orientation and the size of the person being set based on the depth data, the base-line length information, and the three-dimensional modeling data of the image of the person.

(32) The image processing device of any of (24) through (31) and (33) through (42), wherein the object placement unit sets the orientation and the size of the object selected from candidates for the object in the position in which the object selected from the candidates for the object is to be placed in the background image, and places the object selected from the candidates for the object having the set orientation and the set size in the designated position in the background image, the orientation and the size of the selected object being set based on the depth data, the base-line length information, and the three-dimensional modeling data of the object selected from the candidates for the object.

(33) The image processing device of any of (24) through (32) and (34) through (42), wherein the object placement unit identifies objects that can be placed in the background image, and selects the object to be placed in the background image from

the identified objects, the objects being identified based on the depth data, the base-line length information, and the three-dimensional modeling data.

(34) The image processing device of any of (24) through (33) and (35) through (42), further including:

an imaging unit that captures an image of the subject, and obtains the captured image as the background image; and

a depth data generation unit that generates the depth data of the captured image obtained by the imaging unit.

(35) The image processing device of any of (24) through (34) and (36) through (42), wherein

the captured image is a multiview image formed with images having different viewpoints from one another,

the depth data generation unit generates the depth data of the multiview image, and

the image processing device further includes a virtual captured image generation unit that generates a virtual captured image as the background image based on the multiview image and the depth data, the virtual captured image being obtained by imaging the subject of the multiview image.

(36) The image processing device of any of (24) through (35) and (37) through (42), wherein the object is an image of furniture.

(37) The image processing device of any of (24) through (36) and (38) through (42), further including:

a purchase processing unit that performs a purchase process to purchase the furniture that is placed in the background image by the object placement unit.

(38) The image processing device of any of (24) through (37) and (39) through (42), further including

a transmission unit that transmits multiview image data as the data of a multiview image and the depth data of the multiview image, the multiview image being formed with images having different viewpoints from one another and used for generating the background image.

(39) The image processing device of any of (24) through (38) and (40) through (42), further including:

a combined image data generation unit that generates the image data of the background image having the object placed therein by the object placement unit,

wherein the transmission unit further transmits the combined image data generated by the combined image data generation unit.

(40) The image processing device of any of (24) through (39), (41), and (42), further including:

an application parameter generation unit that generates application parameters that are

parameters related to combining of the background image and the object,
wherein the transmission unit further transmits the application parameters generated by the application parameter generation unit.
(41) The image processing device of any of (24) through (40) and (42), further including:
a metadata generation unit that generates metadata about the multiview image,
wherein the transmission unit further transmits the metadata generated by the metadata generation unit.
(42) The image processing device of any of (24) through (41), wherein the metadata includes the base-line length information.
(43) An image processing method including:
setting the orientation and the size of an object in a position in which the object is to be placed in a background image, the orientation and the size being set based on depth data, base-line length information, and the three-dimensional modeling data of the object, the depth data indicating the distance to a subject in the background image, the base-line length information being information indicating a reference length in the background image; and
placing the object having the set orientation and the set size in the designated position in the background image.

Reference Signs List

[0346] 100 Multiview-image using service platform
200 Multiview-image using service providing system
201 Terminal device
202 Server
221 CPU
236 Imaging unit
251 CPU
281 Imaging control unit
282 Metadata generation unit
283 Encoding unit
284 Transmission control unit
291 User management unit
292 Acquisition control unit
293 Depth detection unit
294 File generation unit
295 Data management unit
321 Multiview image file

331 Multiview image encoded data
332 Depth data
333 Metadata
401 Terminal device
402 Application providing server
411 CPU
441 Application purchase processing unit
451 User management unit
452 Application sales processing unit
453 Data management unit
461 Application provision processing unit
511 User instruction reception processing unit
512 Display control unit
513 Transmission control unit
521 User management unit
522 Application selection processing unit
523 Image selection processing unit
524 Lens selection processing unit
525 User designated parameter setting unit
526 Virtual lens processing unit
527 Data management unit
601 Furniture sales server
651 User instruction reception processing unit
652 Display control unit
653 Imaging control unit
654 Metadata generation unit
655 Depth detection unit
656 Virtual captured image generation unit
657 Furniture image placement processing unit
658 Purchase processing unit
659 File generation unit
660 Combined image data generation unit
661 Application parameter generation unit
662 Transmission control unit
671 User management unit
672 Application selection unit
673 Furniture data selection unit
674 Purchase processing unit

675 Acquisition control unit
676 Data management unit
681 Furniture data provision unit
682 Purchase processing unit

Claims

[Claim 1] An image processing apparatus, comprising:
circuitry configured to initiate a setting of an object for display within a background image in accordance with a modeling condition associated with a position at which the object is set, based on depth data and base-line length information associated with the background image and modeling data of the object.

[Claim 2] The image processing apparatus according to claim 1,wherein the circuitry is further configured to initiate a changing of a condition of the object to a condition corresponding to a second position, based on a change of position at which the object is set from a first position to the second position.

[Claim 3] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate a changing of a condition of the object from a condition associated with a first viewpoint to a condition associated with a second view point, based on a changing of a viewpoint of the background image from the first viewpoint to the second viewpoint.

[Claim 4] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate a changing of a condition of the object from a condition associated with a first viewing direction to a condition associated with a second viewing direction, based on a changing of a direction of a viewpoint of the background image from the first viewing direction to the second viewing direction.

[Claim 5] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate a moving of the object, and repositioning of the object to have a condition of making contact with a plane of the background image.

[Claim 6] The image processing apparatus according to claim 5, wherein the condition of making contact with the plane is determined based on a distance between the object and the plane.

[Claim 7] The image processing apparatus according to claim 1, wherein a condition of the object is a condition associated with a position and an orientation of the object.

[Claim 8] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate a simulation of a lighting in the background image based on light source parameters and the depth data,

the light source parameters being parameters related to a light source.

[Claim 9] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate an identification of a portion that satisfies line-of-flow conditions in the background image having the object placed therein, and initiates an emphasizing of the identified portion.

[Claim 10] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate a setting of an image of a person within the background image, in accordance with a modeling condition associated with a position at which the image of the person is set within the background image having the object placed therein, and based on the depth data, the base-line length information, and modeling data of the image of the person.

[Claim 11] The image processing apparatus according to claim 1, wherein the object is selected from among one or more candidate objects, in accordance with a modeling condition of the selected object associated with a position at which the selected object is set in the background image, and based on the depth data, the base-line length information, and the modeling data of the selected object.

[Claim 12] The image processing apparatus according to claim 11, wherein the one or more candidate objects are objects that can be placed within the background image.

[Claim 13] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate a control of a capturing of an image of a subject, initiate an obtaining of the captured image as the background image, and initiate a generation of depth data of the captured image.

[Claim 14] The image processing apparatus according to claim 13, wherein
the captured image is a multiview image formed with a plurality of images having different viewpoints from one another, and
the circuitry is further configured to initiate a generation of depth data of the multiview image, and to initiate a generation of a virtual captured image as the background image based on the multiview image and the depth data, the virtual captured image being obtained by imaging a subject of the multiview image.

[Claim 15] The image processing apparatus according to claim 1, wherein the object is an image of furniture.

[Claim 16] The image processing apparatus according to claim 15, wherein the

circuitry is further configured to initiate a performing of a purchase process to purchase the furniture that is placed within the background image.

[Claim 17] The image processing apparatus according to claim 1, wherein the circuitry is further configured to initiate a transmission of multiview image data as data of a multiview image and depth data of the multiview image, the multiview image being formed with a plurality of images having different viewpoints from one another and used for generating the background image.

[Claim 18] The image processing apparatus according to claim 17, wherein the circuitry is further configured to initiate a generation of image data of the background image having the object set therein, and initiate a transmission of the generated image data.

[Claim 19] The image processing apparatus according to claim 17, wherein the circuitry is further configured to initiate a generation of an application parameter that is a parameter related to a combining of the background image and the object, and initiate a transmission of the generated application parameter.

[Claim 20] The image processing apparatus according to claim 17, wherein the circuitry is further configured to initiate a generation of metadata about the multiview image, and initiate a transmission of the generated metadata.

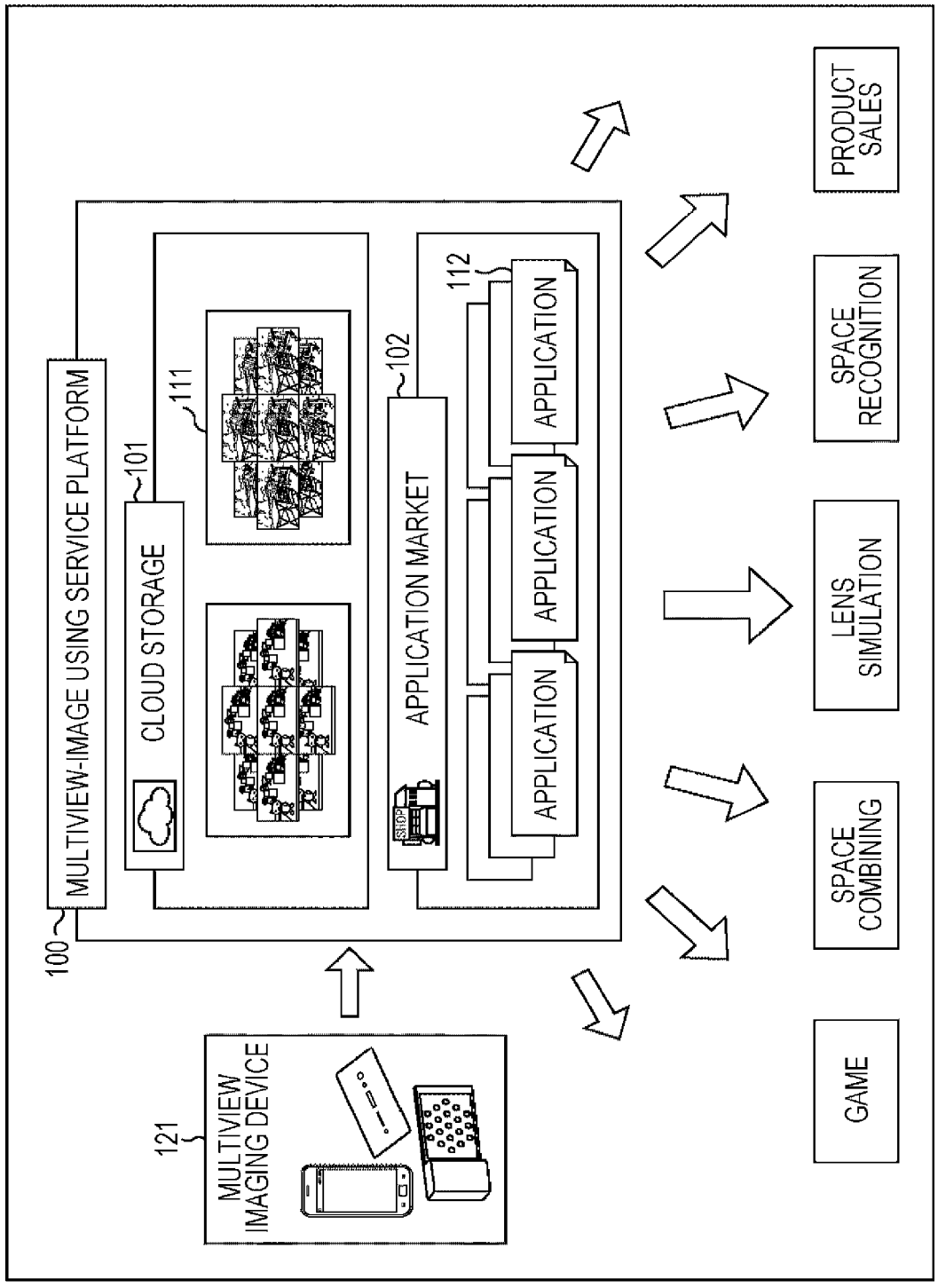
[Claim 21] The image processing apparatus according to claim 19, wherein the metadata includes the base-line length information.

[Claim 22] The image processing apparatus according to claim 1, wherein the depth data indicates a distance of depth direction in the background image, and the base-line length information indicates a reference length associated with the background image.

[Claim 23] An image processing method comprising:
setting an object for display within a background image in accordance with a modeling condition associated with a position at which the object is set, based on depth data and base-line length information associated with the background image and modeling data of the object; and
placing the set object to be displayed at the position within the background image.

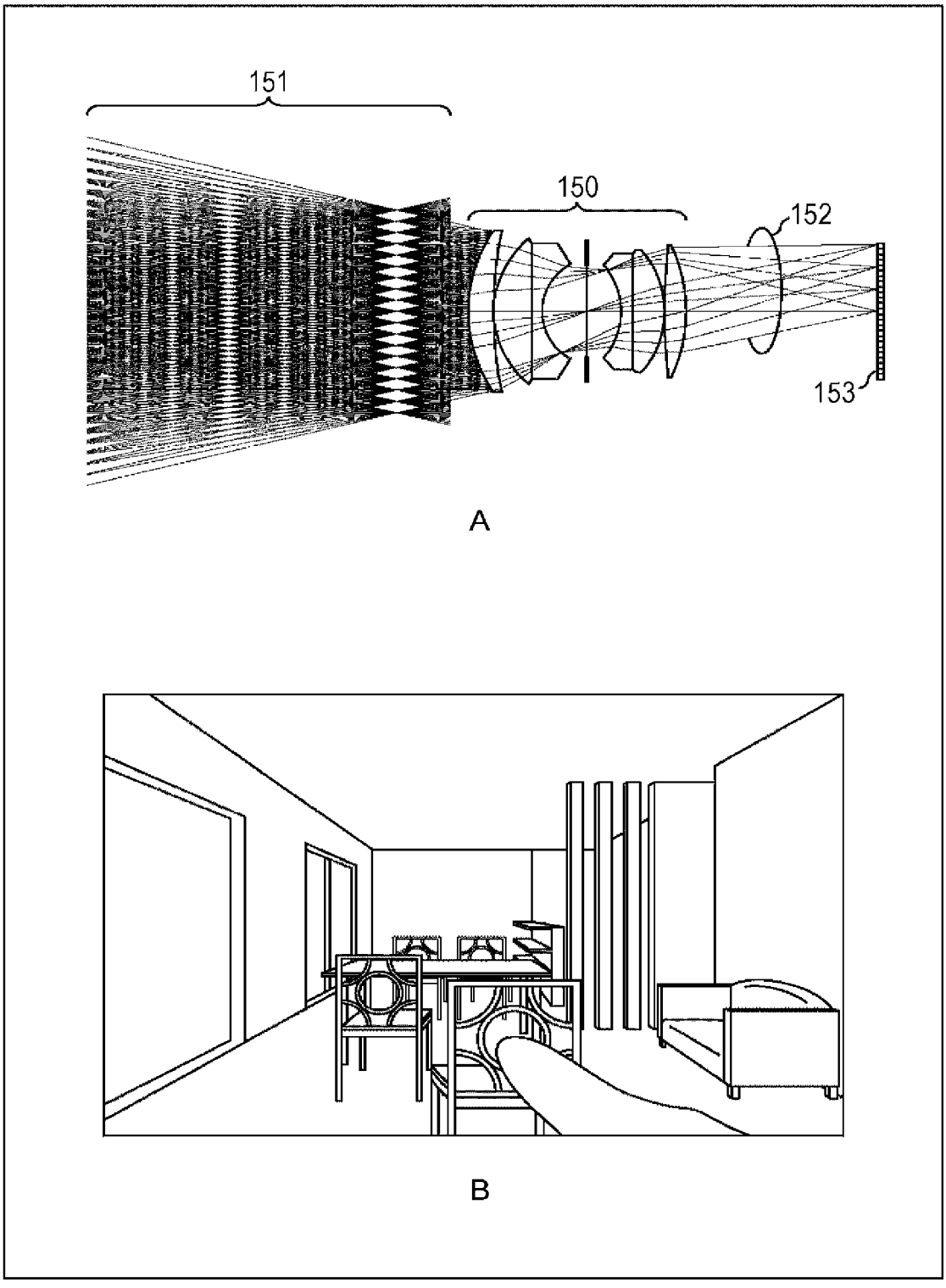
[Fig. 1]

FIG. 1


MULTIVIEW-IMAGE USING SERVICE PLATFORM
100
CLOUD STORAGE
101
111
APPLICATION MARKET
102
112
APPLICATION
APPLICATION
APPLICATION
SHOP
MULTIVIEW IMAGING DEVICE
121
GAME
SPACE COMBINING
LENS SIMULATION
SPACE RECOGNITION
PRODUCT SALES

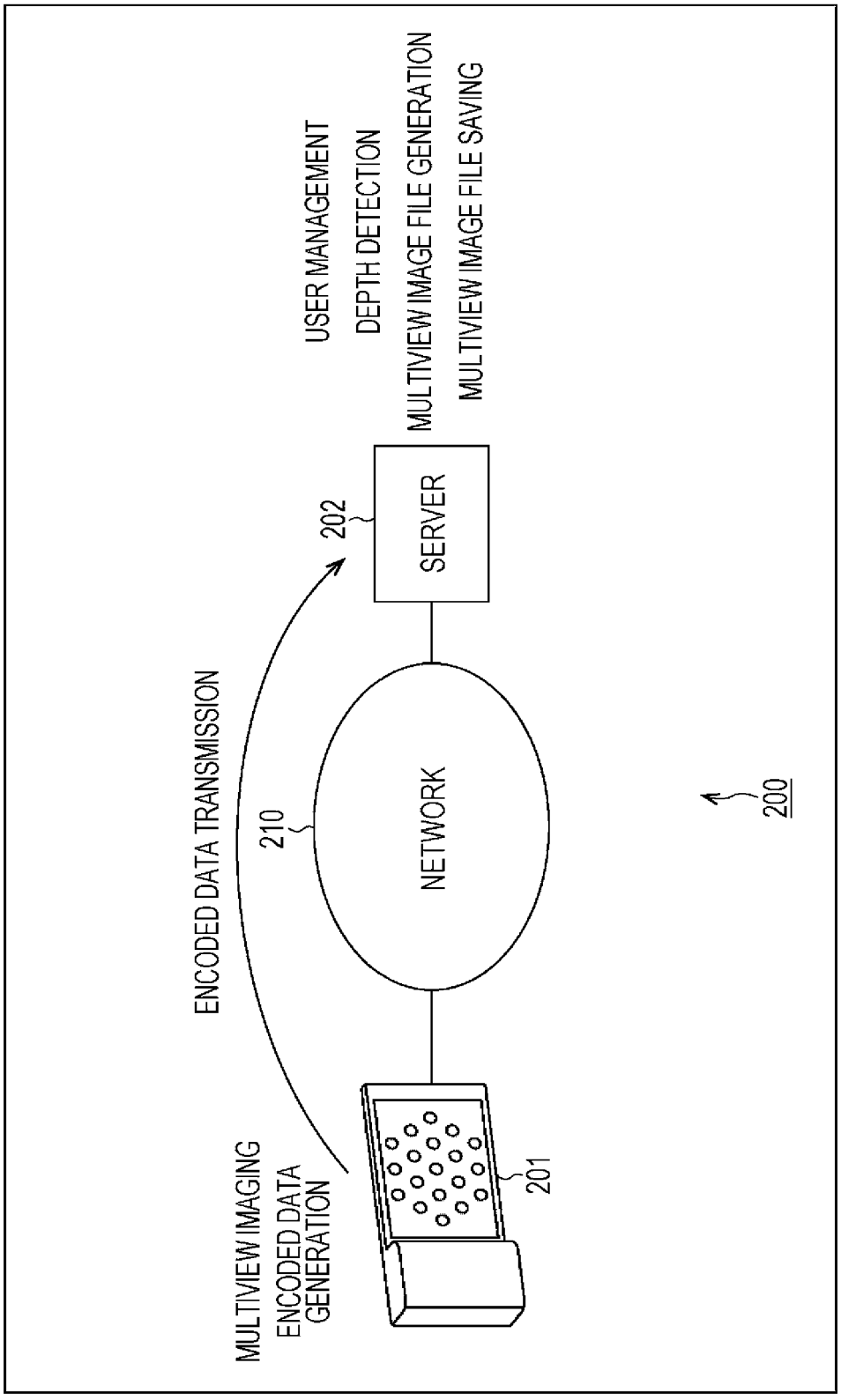
[Fig. 2]

FIG. 2



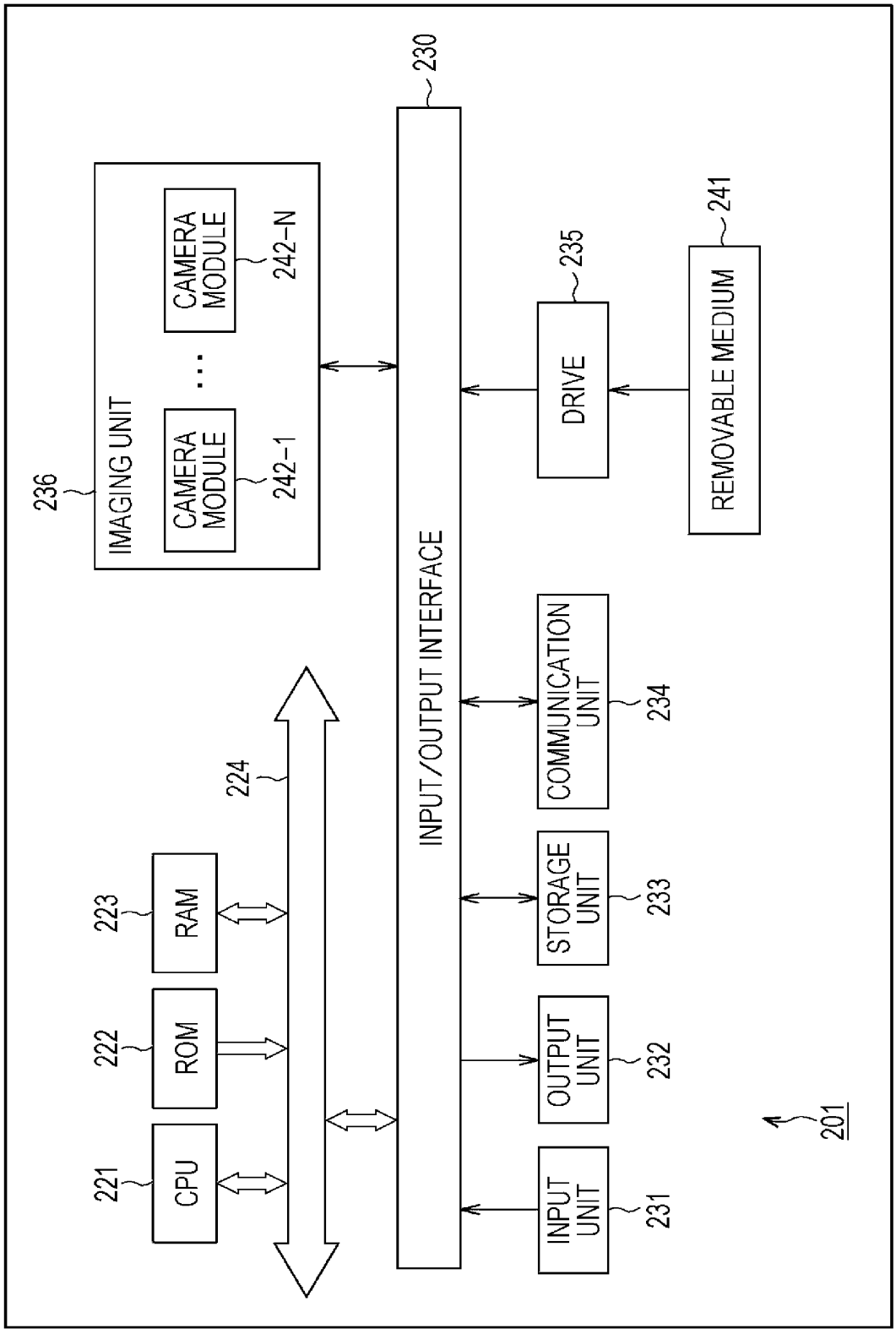
[Fig. 3]

FIG. 3


MULTIVIEW IMAGING
ENCODED DATA GENERATION
ENCODED DATA TRANSMISSION
USER MANAGEMENT
DEPTH DETECTION
MULTIVIEW IMAGE FILE GENERATION
MULTIVIEW IMAGE FILE SAVING
NETWORK
SERVER
201
202
210
200

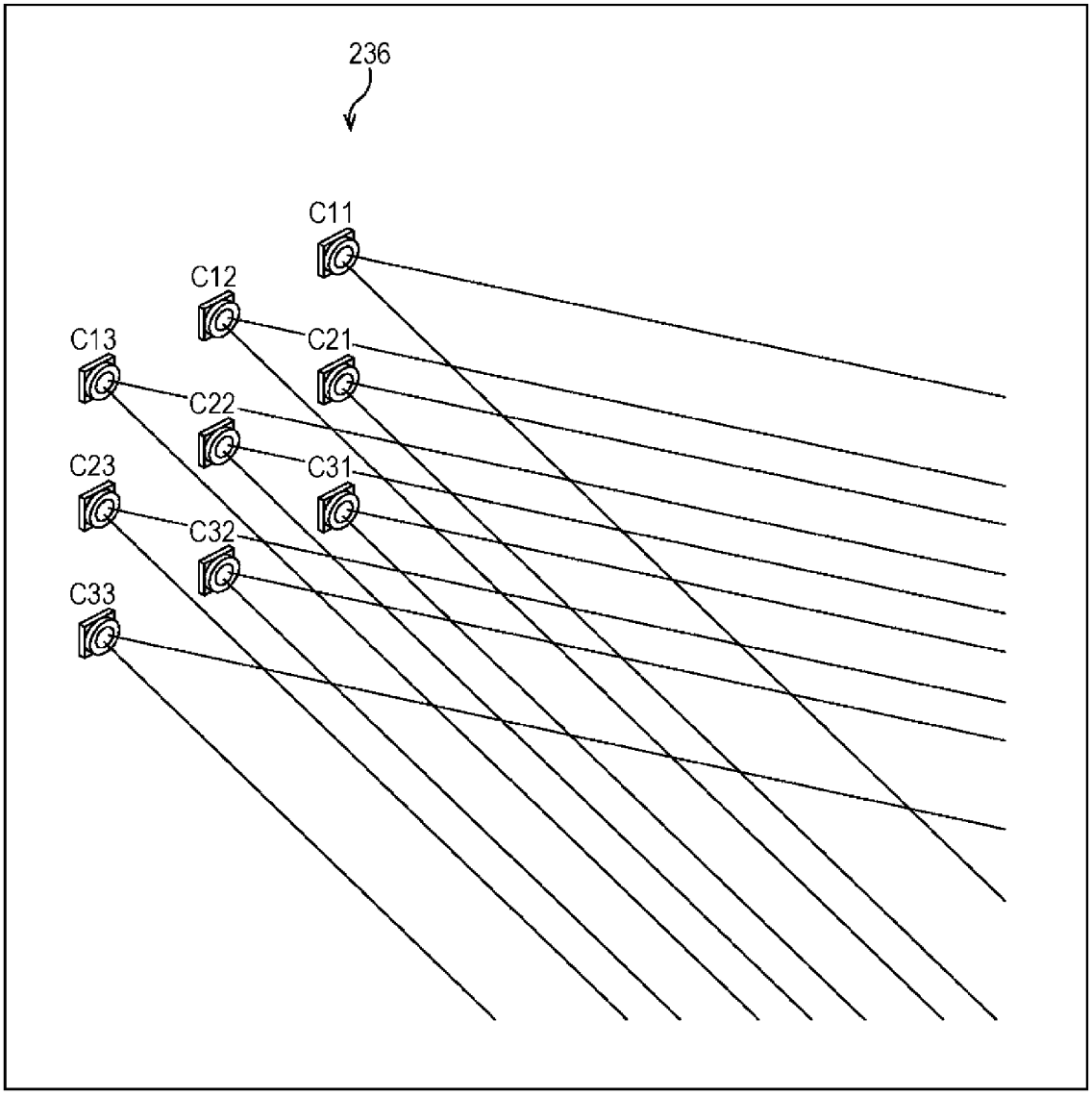
[Fig. 4]

FIG. 4


201
CPU
221
ROM
222
RAM
223
224
INPUT UNIT
231
OUTPUT UNIT
232
STORAGE UNIT
233
COMMUNICATION UNIT
234
INPUT/OUTPUT INTERFACE
230
DRIVE
235
REMOVABLE MEDIUM
241
IMAGING UNIT
236
CAMERA MODULE
242-1
CAMERA MODULE
242-N

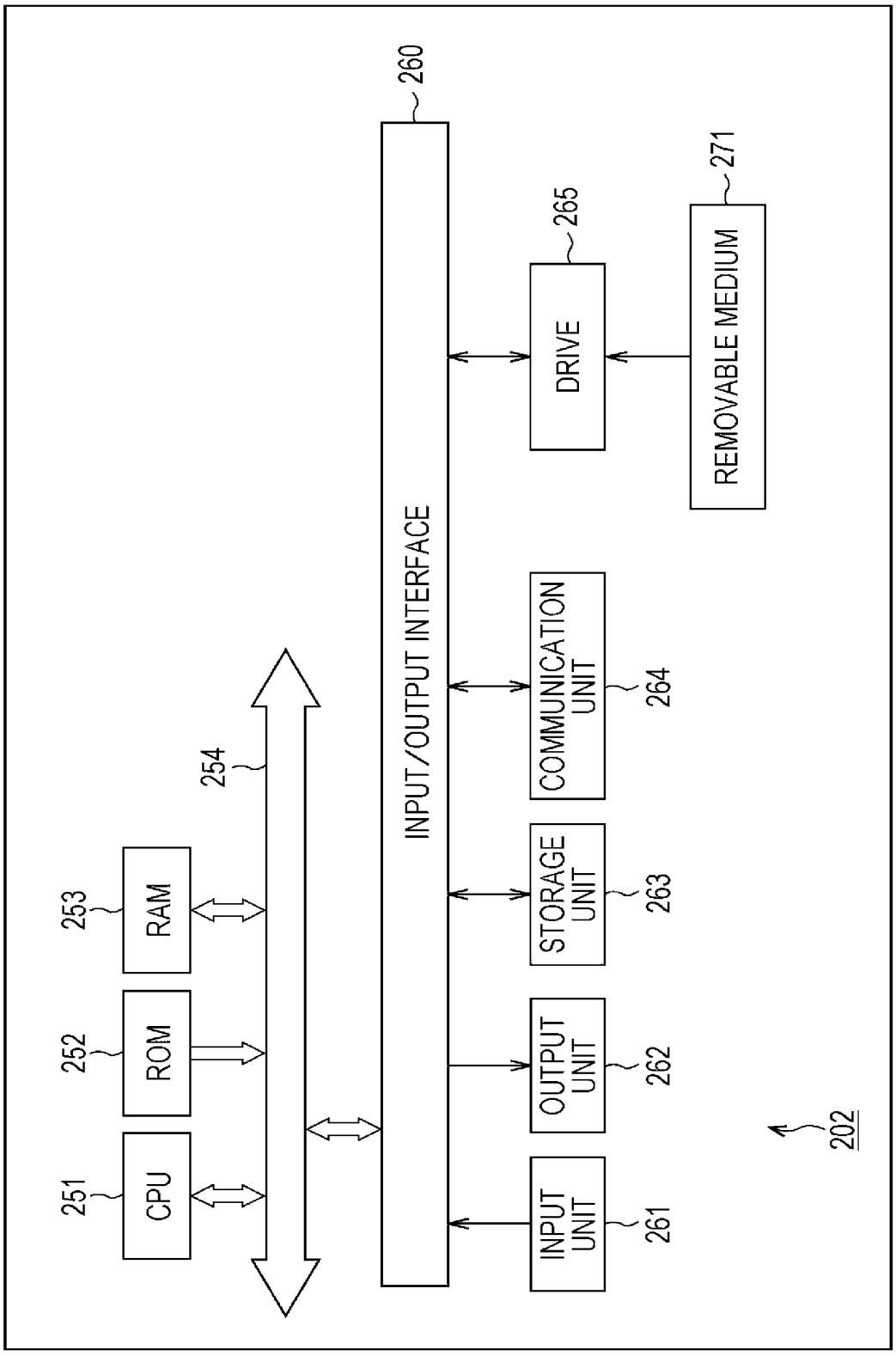
[Fig. 5]

FIG. 5



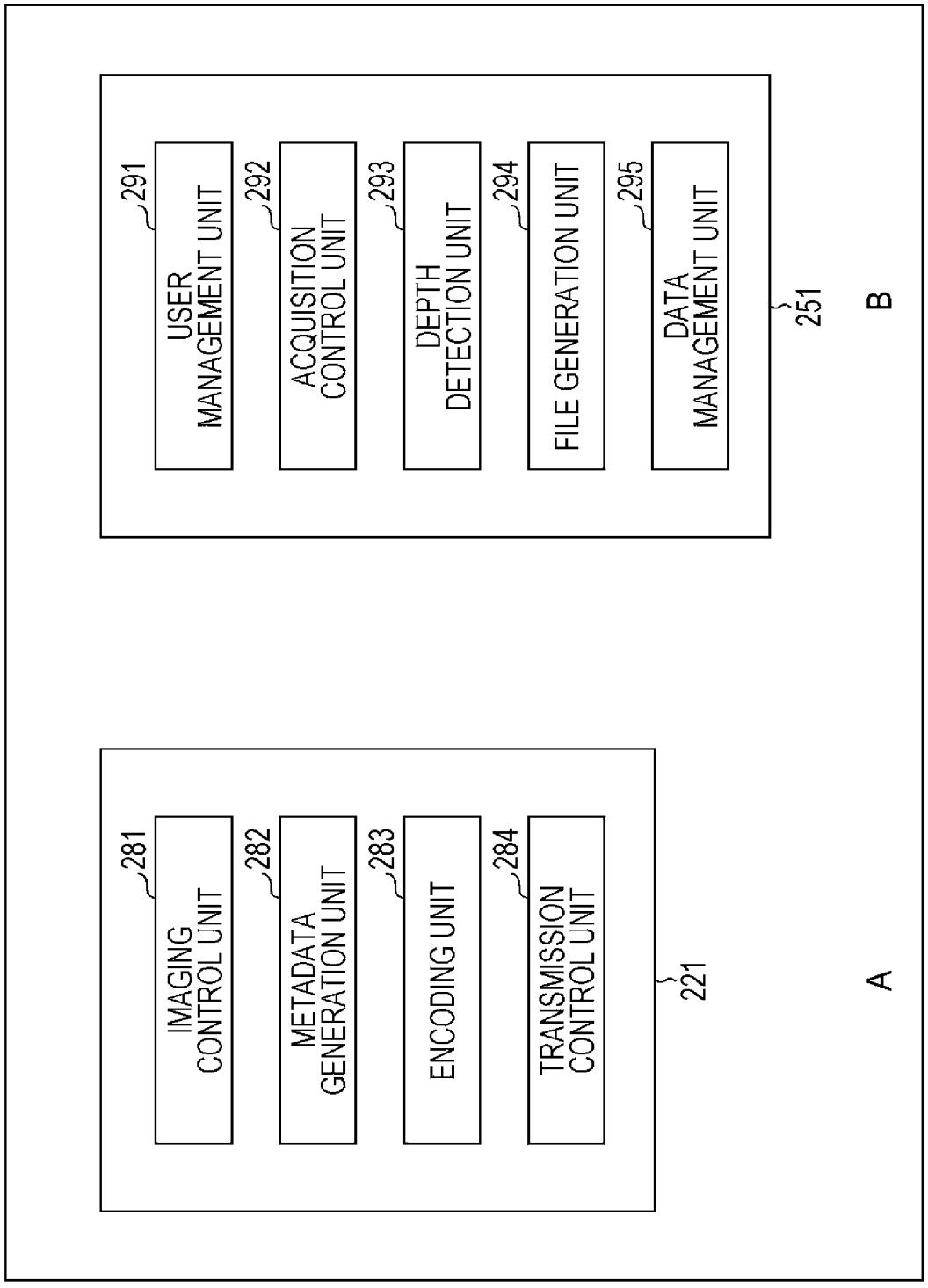
[Fig. 6]

FIG. 6


CPU
ROM
RAM
251
252
253
254
INPUT/OUTPUT INTERFACE
260
INPUT UNIT
OUTPUT UNIT
STORAGE UNIT
COMMUNICATION UNIT
DRIVE
261
262
263
264
265
REMOVABLE MEDIUM
271
202

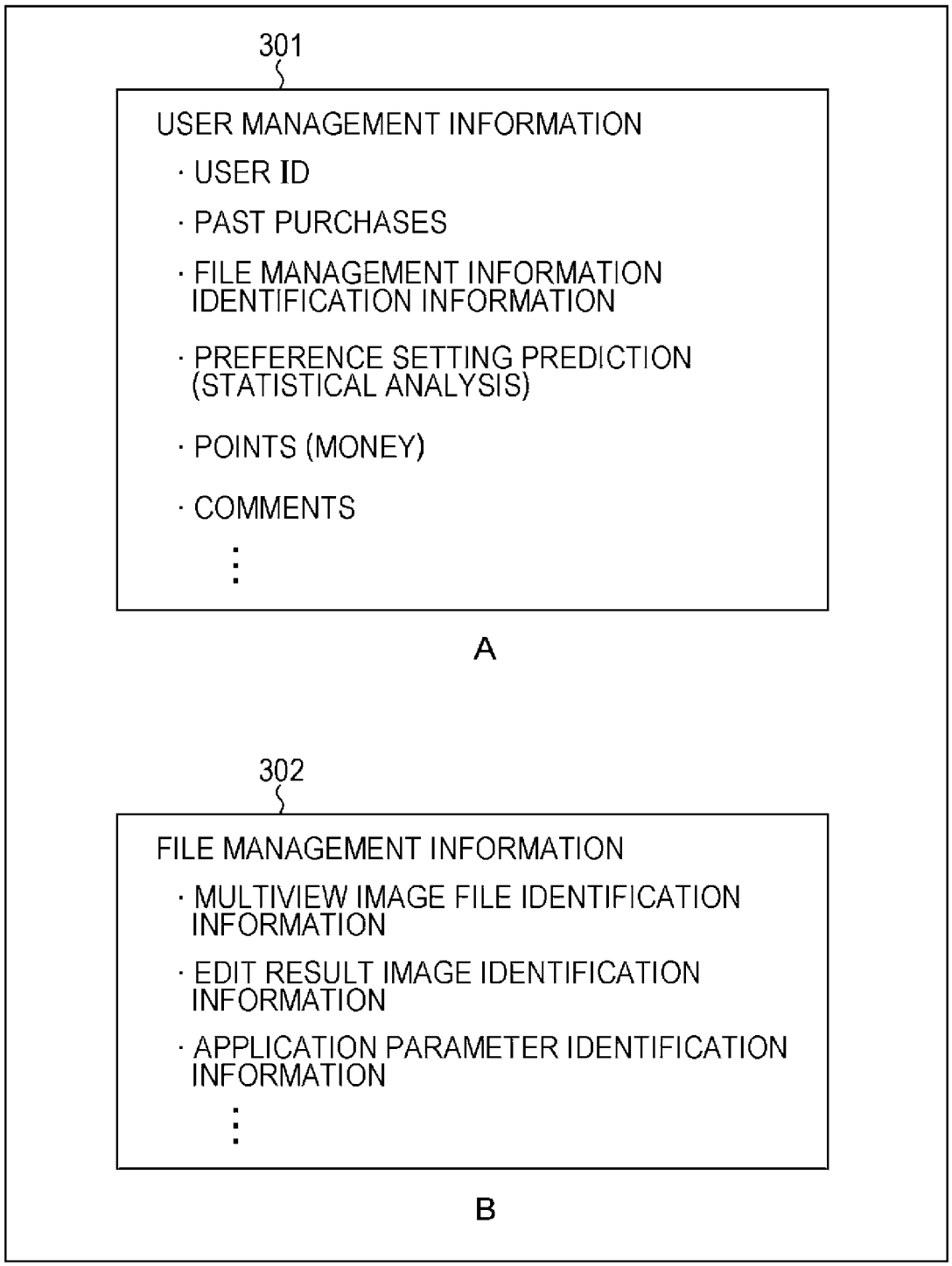
[Fig. 7]

FIG. 7


A
B
221
251
281
IMAGING CONTROL UNIT
282
METADATA GENERATION UNIT
283
ENCODING UNIT
284
TRANSMISSION CONTROL UNIT
291
USER MANAGEMENT UNIT
292
ACQUISITION CONTROL UNIT
293
DEPTH DETECTION UNIT
294
FILE GENERATION UNIT
295
DATA MANAGEMENT UNIT

[Fig. 8]

FIG. 8


301
USER MANAGEMENT INFORMATION
· USER ID
· PAST PURCHASES
· FILE MANAGEMENT INFORMATION IDENTIFICATION INFORMATION
· PREFERENCE SETTING PREDICTION (STATISTICAL ANALYSIS)
· POINTS (MONEY)
· COMMENTS
A
302
FILE MANAGEMENT INFORMATION
· MULTIVIEW IMAGE FILE IDENTIFICATION INFORMATION
· EDIT RESULT IMAGE IDENTIFICATION INFORMATION
· APPLICATION PARAMETER IDENTIFICATION INFORMATION
B

[Fig. 9]

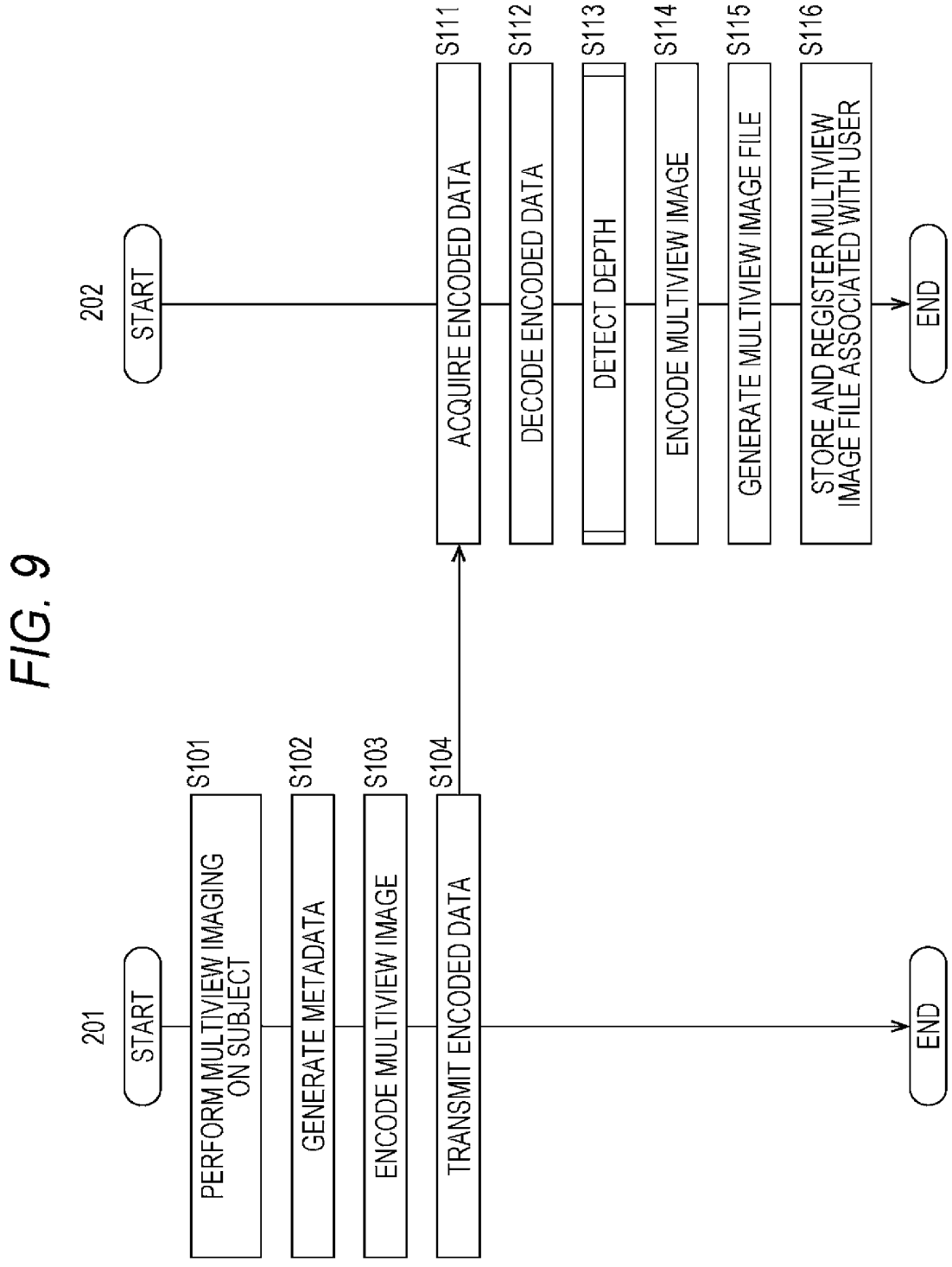
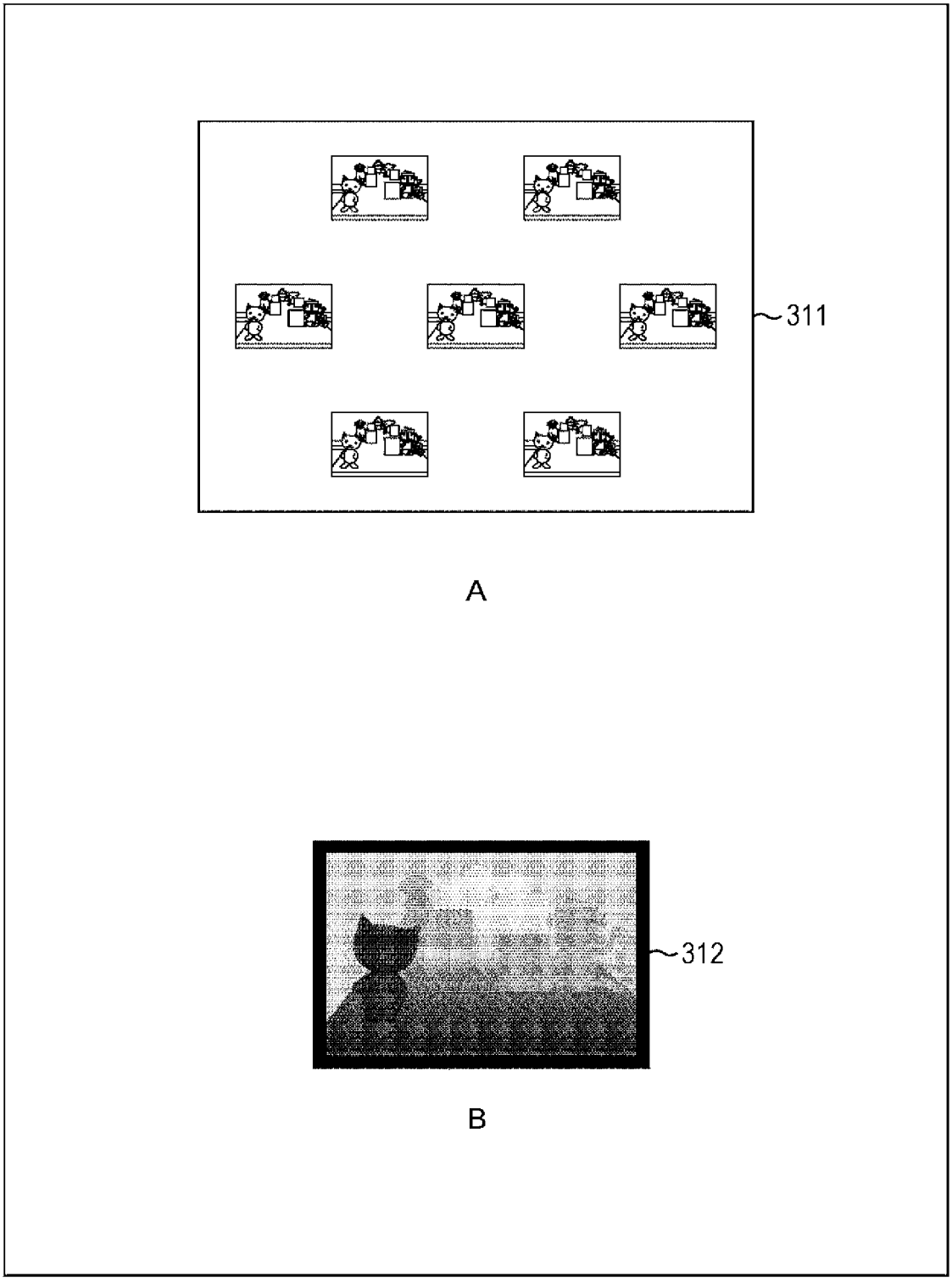

201
START
S101
PERFORM MULTIVIEW IMAGING ON SUBJECT
S102
GENERATE METADATA
S103
ENCODE MULTIVIEW IMAGE
S104
TRANSMIT ENCODED DATA
END
202
START
S111
ACQUIRE ENCODED DATA
S112
DECODE ENCODED DATA
S113
DETECT DEPTH
S114
ENCODE MULTIVIEW IMAGE
S115
GENERATE MULTIVIEW IMAGE FILE
S116
STORE AND REGISTER MULTIVIEW IMAGE FILE ASSOCIATED WITH USER
END

FIG. 9

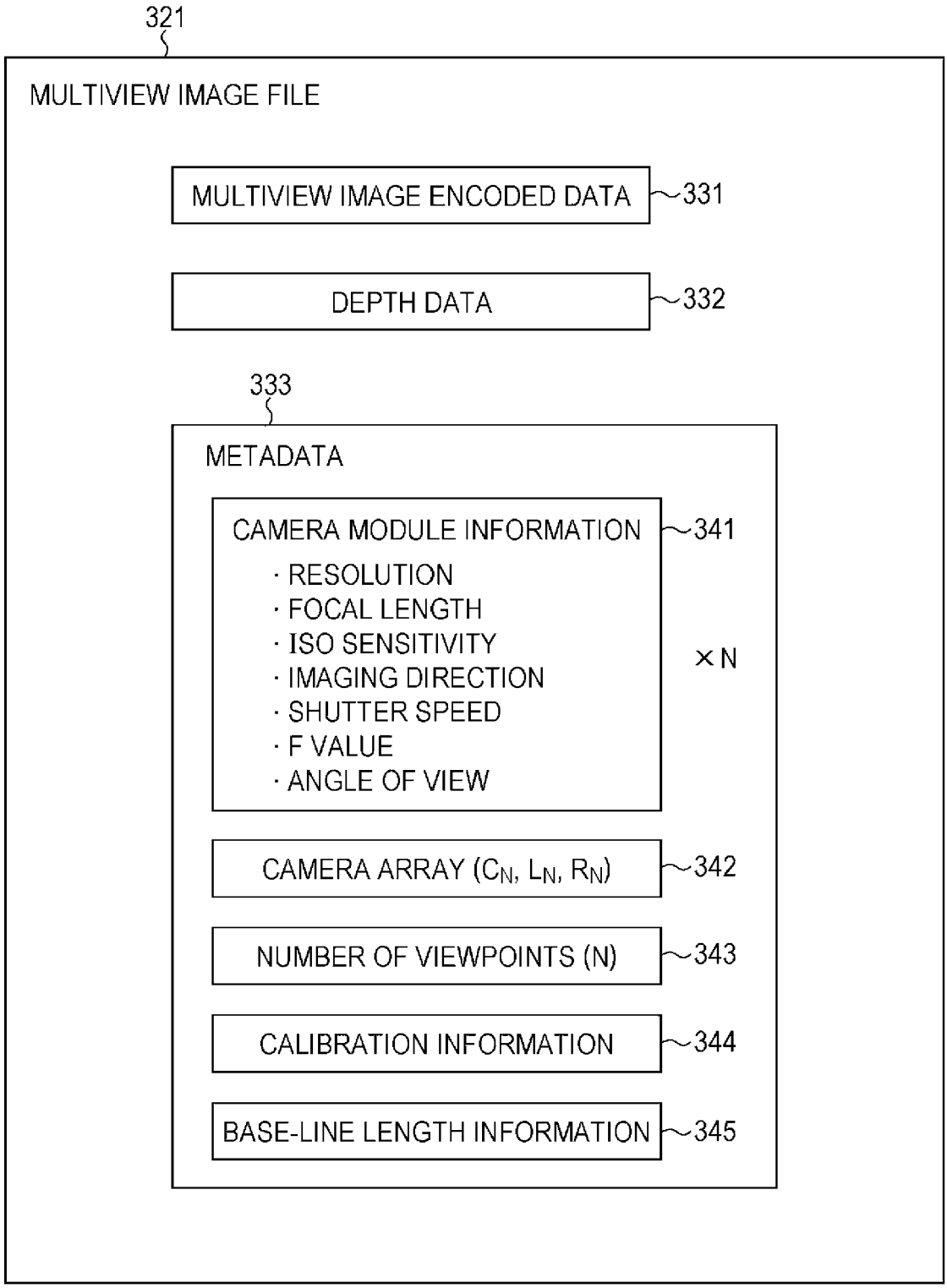
[Fig. 10]

FIG. 10



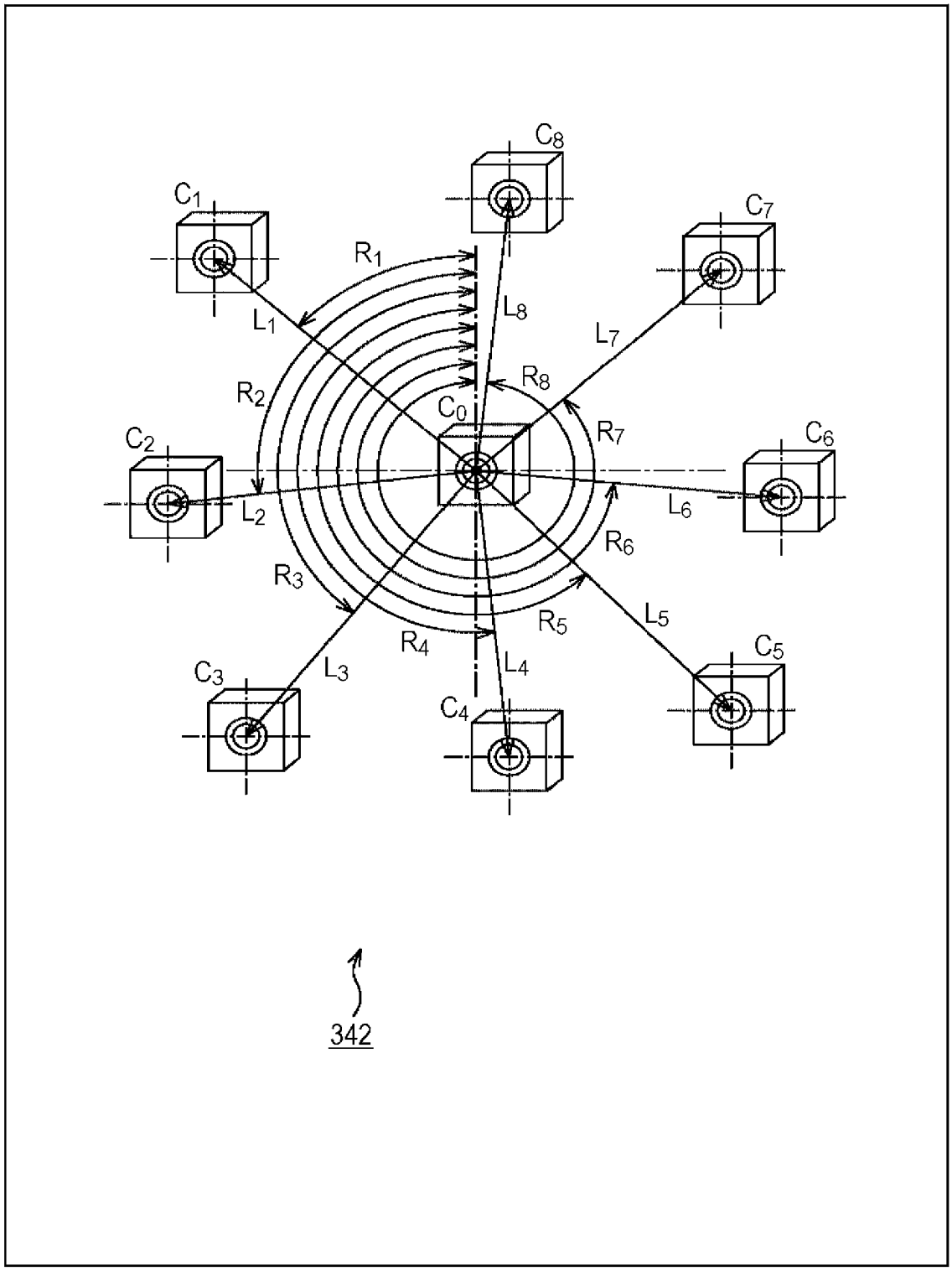
[Fig. 11]

FIG. 11


321
MULTIVIEW IMAGE FILE
MULTIVIEW IMAGE ENCODED DATA
331
DEPTH DATA
332
333
METADATA
CAMERA MODULE INFORMATION
341
· RESOLUTION
· FOCAL LENGTH
· ISO SENSITIVITY
· IMAGING DIRECTION
· SHUTTER SPEED
· F VALUE
· ANGLE OF VIEW
× N
CAMERA ARRAY (CN, LN, RN)
342
NUMBER OF VIEWPOINTS (N)
343
CALIBRATION INFORMATION
344
BASE-LINE LENGTH INFORMATION
345

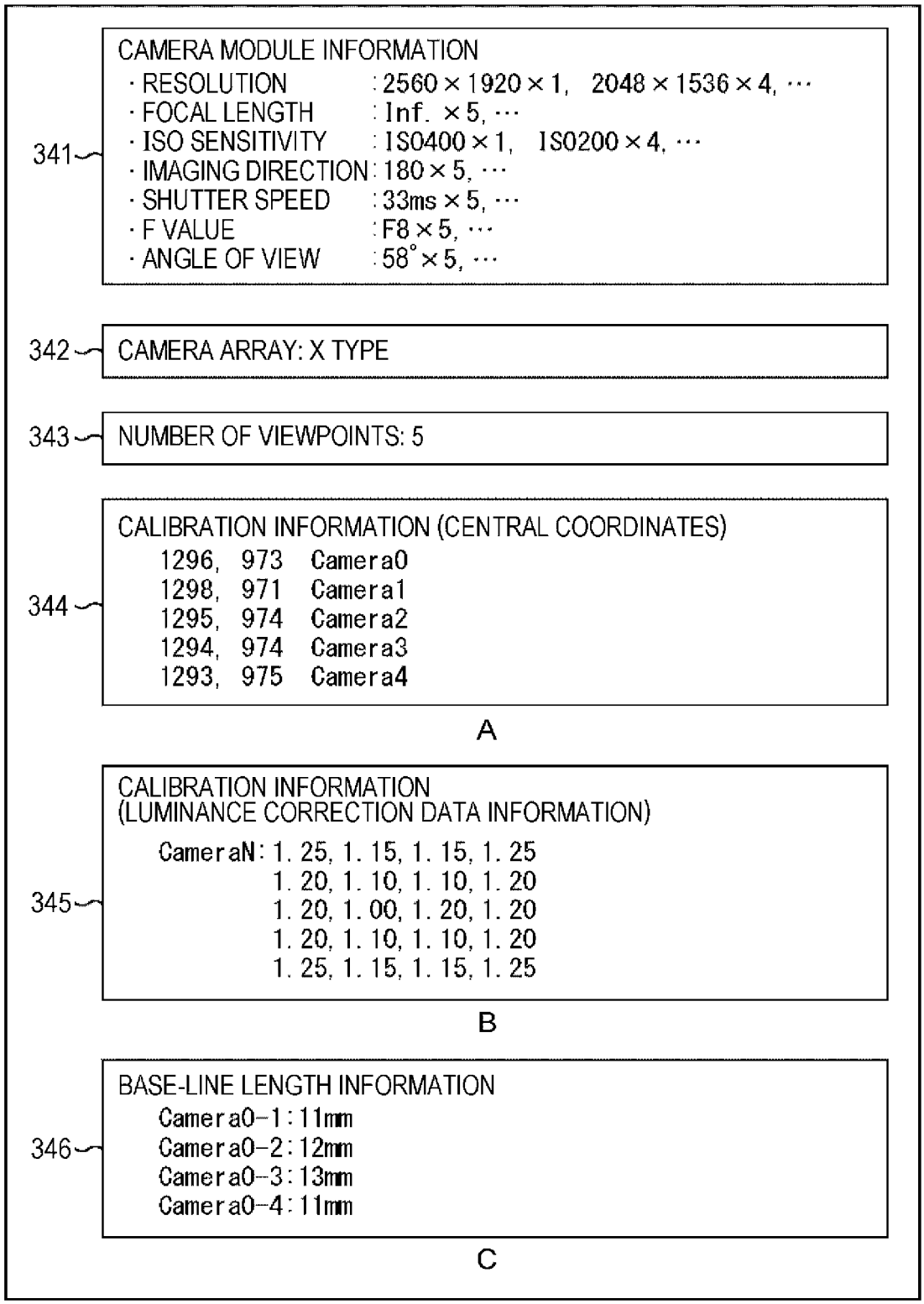
[Fig. 12]

FIG. 12


C1
C2
C3
C4
C5
C6
C7
C8
C0
L1
L2
L3
L4
L5
L6
L7
L8
R1
R2
R3
R4
R5
R6
R7
R8
342

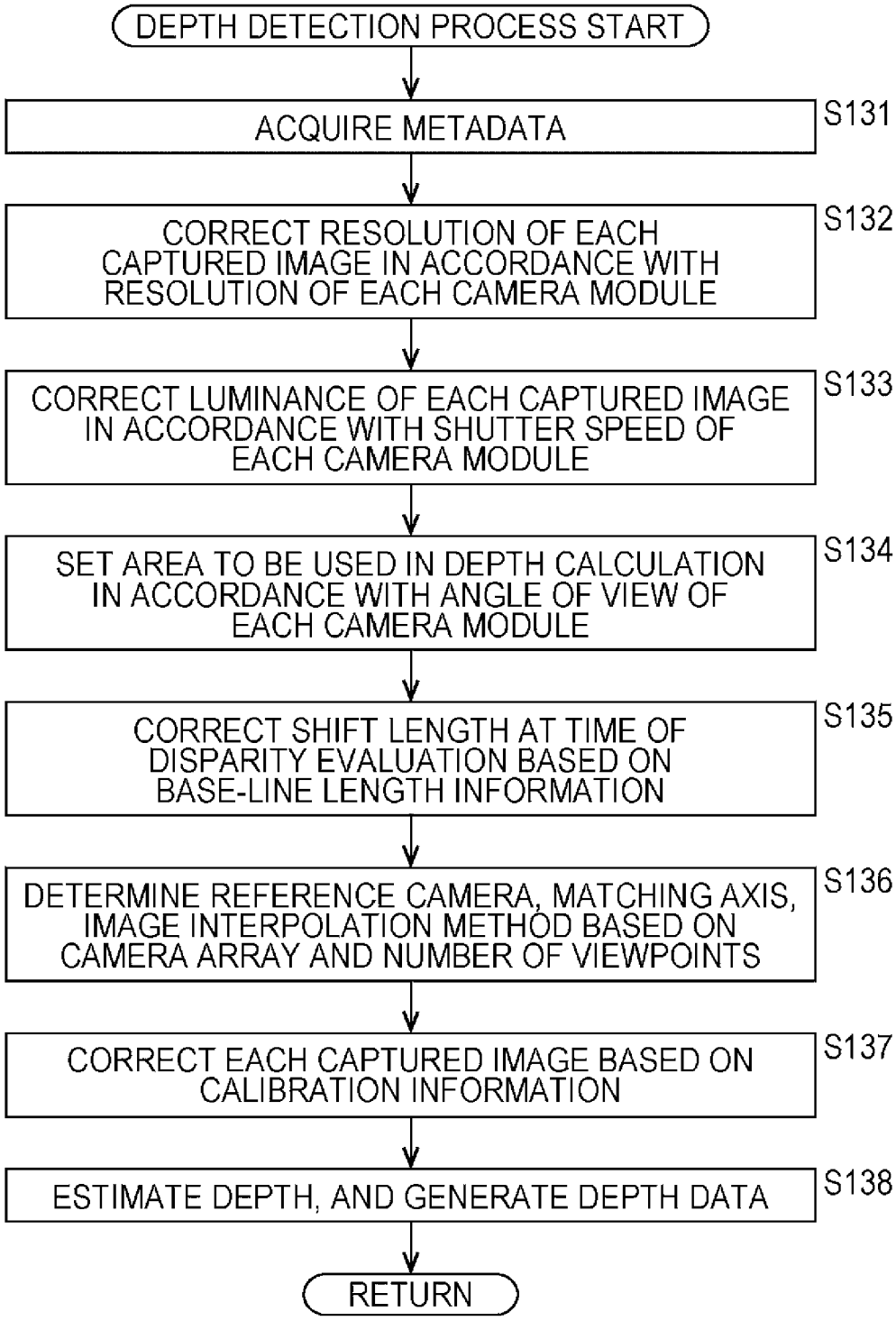
[Fig. 13]

FIG. 13


CAMERA MODULE INFORMATION
· RESOLUTION : 2560 × 1920 × 1, 2048 × 1536 × 4, ···
· FOCAL LENGTH : Inf. × 5, ···
· ISO SENSITIVITY : ISO400 × 1, ISO200 × 4, ···
· IMAGING DIRECTION : 180 × 5, ···
· SHUTTER SPEED : 33ms × 5, ···
· F VALUE : F8 × 5, ···
· ANGLE OF VIEW : 58° × 5, ···
341
CAMERA ARRAY: X TYPE
342
NUMBER OF VIEWPOINTS: 5
343
CALIBRATION INFORMATION (CENTRAL COORDINATES)
1296, 973 Camera0
1298, 971 Camera1
1295, 974 Camera2
1294, 974 Camera3
1293, 975 Camera4
344
A
CALIBRATION INFORMATION
(LUMINANCE CORRECTION DATA INFORMATION)
CameraN: 1.25, 1.15, 1.15, 1.25
1.20, 1.10, 1.10, 1.20
1.20, 1.00, 1.20, 1.20
1.20, 1.10, 1.10, 1.20
1.25, 1.15, 1.15, 1.25
345
B
BASE-LINE LENGTH INFORMATION
Camera0-1 : 11mm
Camera0-2 : 12mm
Camera0-3 : 13mm
Camera0-4 : 11mm
346
C

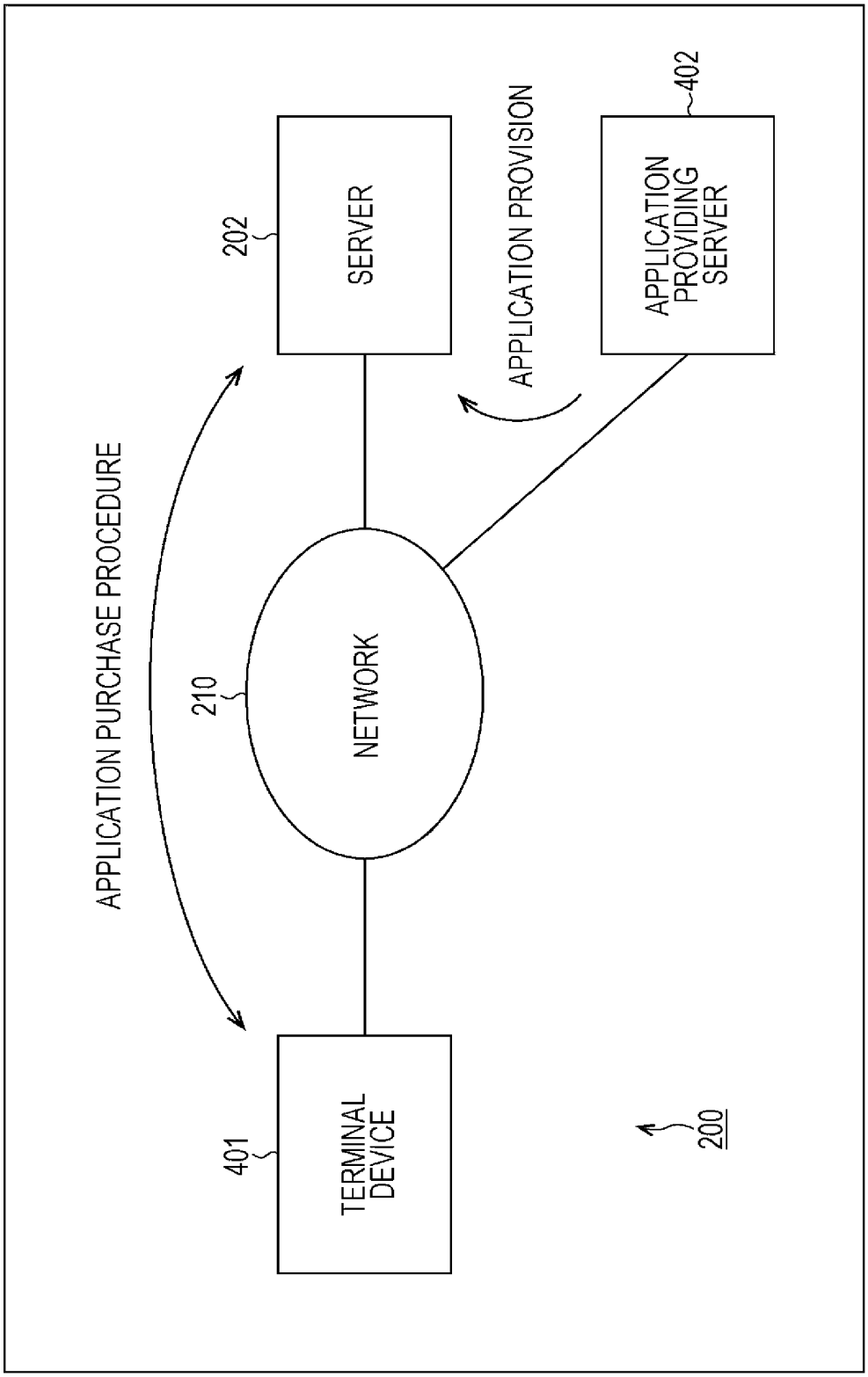
[Fig. 14]

FIG. 14


DEPTH DETECTION PROCESS START
ACQUIRE METADATA
S131
CORRECT RESOLUTION OF EACH CAPTURED IMAGE IN ACCORDANCE WITH RESOLUTION OF EACH CAMERA MODULE
S132
CORRECT LUMINANCE OF EACH CAPTURED IMAGE IN ACCORDANCE WITH SHUTTER SPEED OF EACH CAMERA MODULE
S133
SET AREA TO BE USED IN DEPTH CALCULATION IN ACCORDANCE WITH ANGLE OF VIEW OF EACH CAMERA MODULE
S134
CORRECT SHIFT LENGTH AT TIME OF DISPARITY EVALUATION BASED ON BASE-LINE LENGTH INFORMATION
S135
DETERMINE REFERENCE CAMERA, MATCHING AXIS, IMAGE INTERPOLATION METHOD BASED ON CAMERA ARRAY AND NUMBER OF VIEWPOINTS
S136
CORRECT EACH CAPTURED IMAGE BASED ON CALIBRATION INFORMATION
S137
ESTIMATE DEPTH, AND GENERATE DEPTH DATA
S138
RETURN

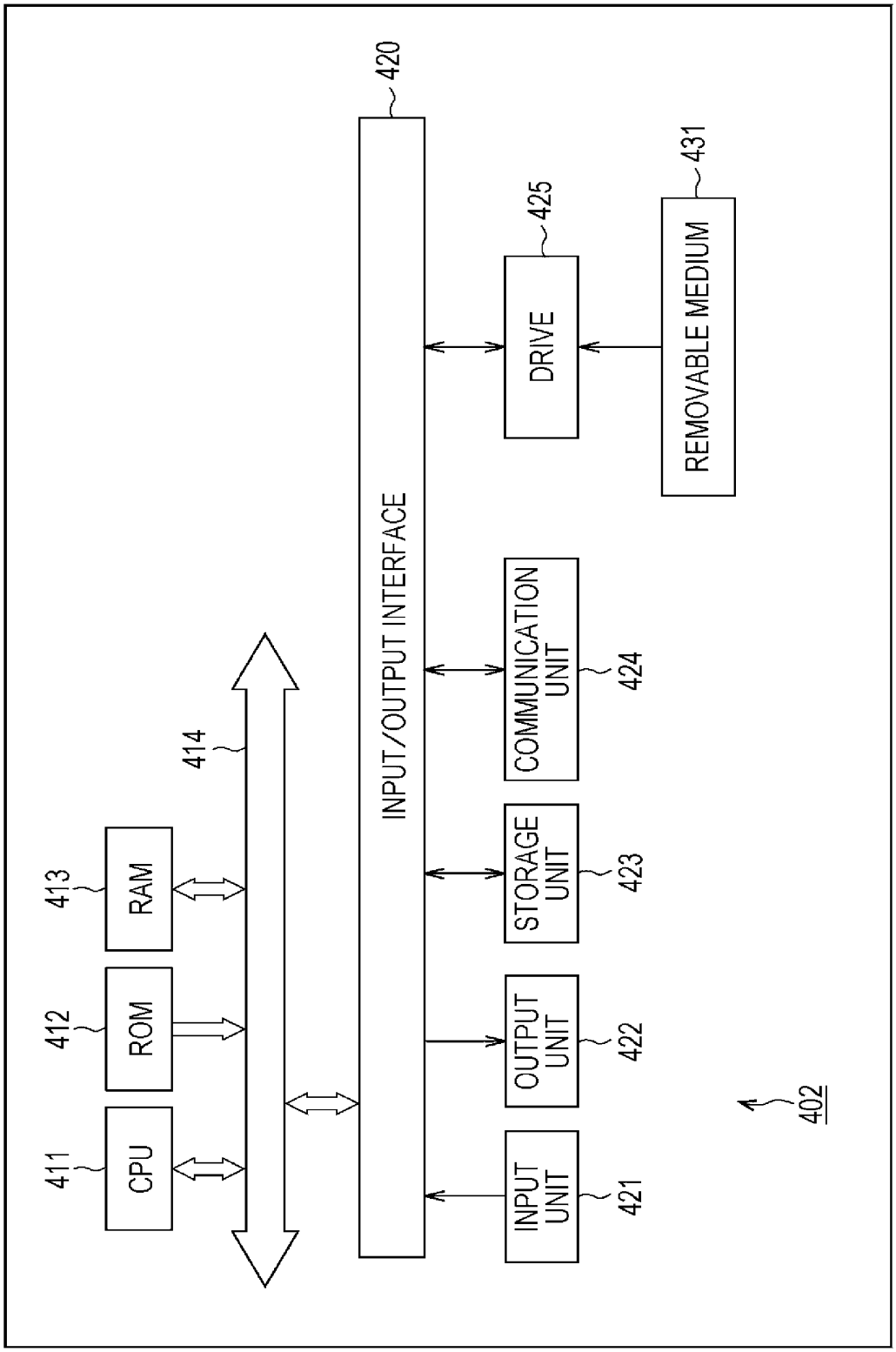
[Fig. 15]

FIG. 15


APPLICATION PURCHASE PROCEDURE
APPLICATION PROVISION
SERVER
202
APPLICATION PROVIDING SERVER
402
NETWORK
210
TERMINAL DEVICE
401
200

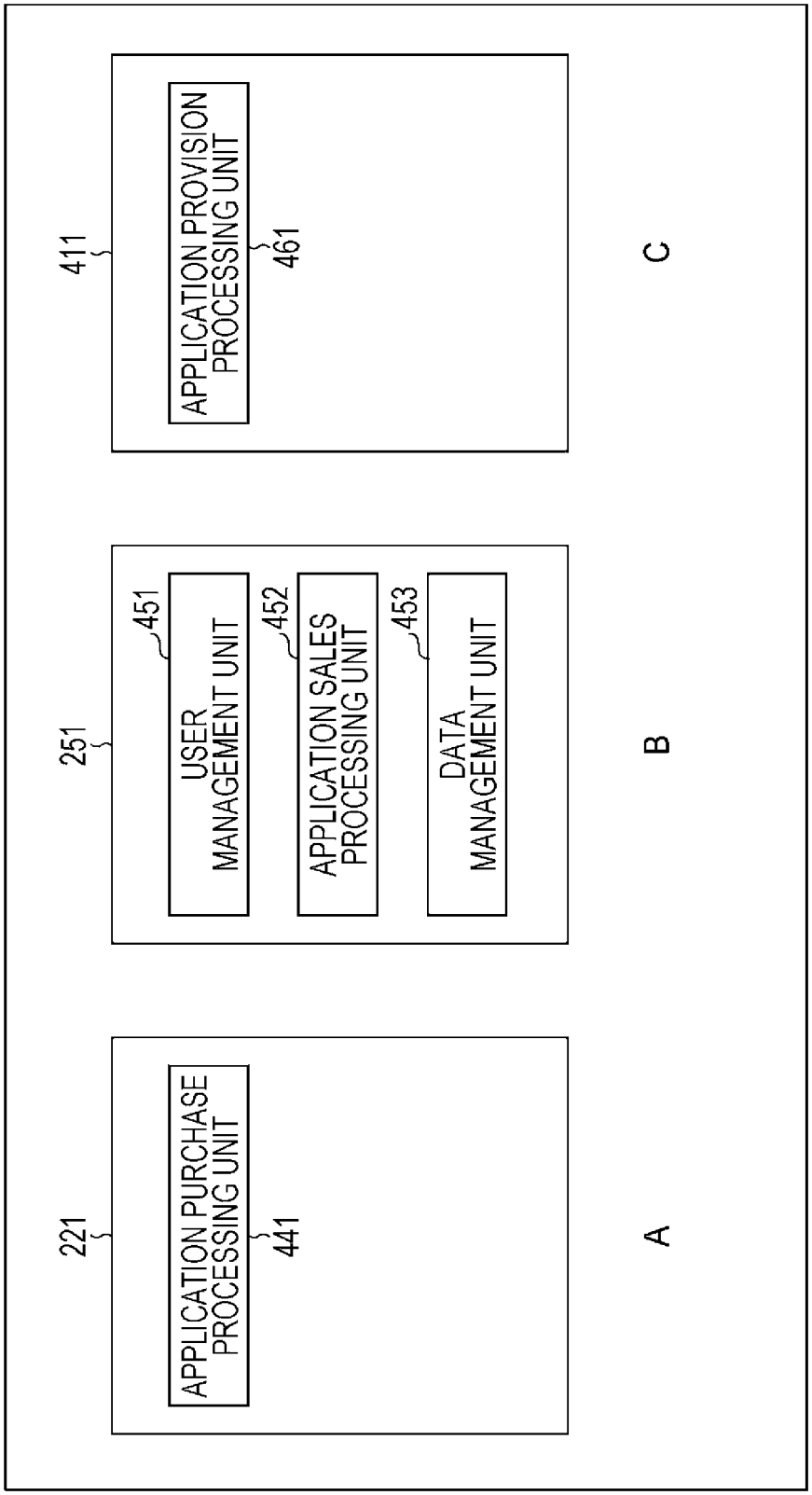
[Fig. 16]

FIG. 16


CPU
411
ROM
412
RAM
413
414
INPUT/OUTPUT INTERFACE
420
INPUT UNIT
421
OUTPUT UNIT
422
STORAGE UNIT
423
COMMUNICATION UNIT
424
DRIVE
425
REMOVABLE MEDIUM
431
402

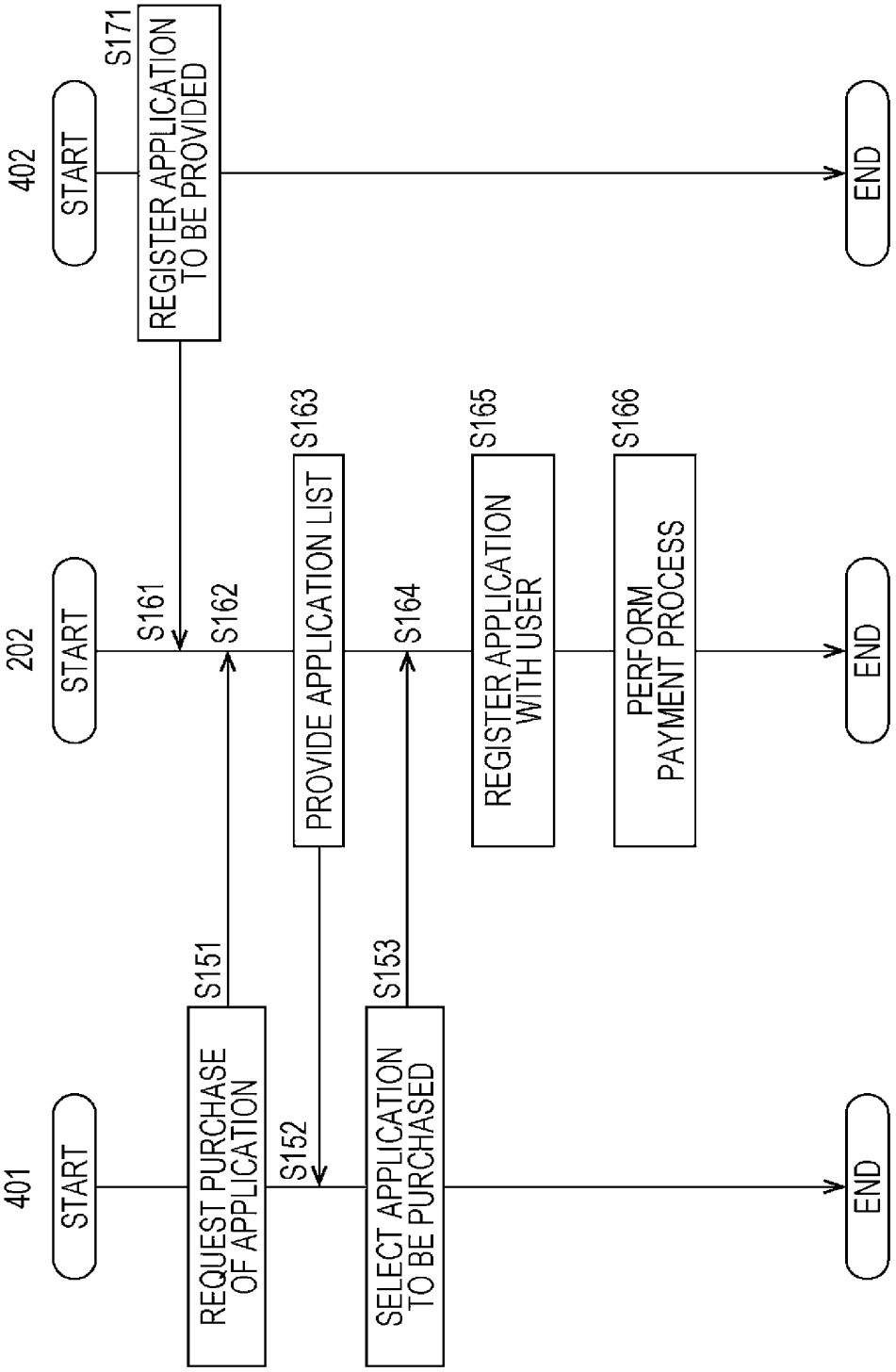
[Fig. 17]

FIG. 17


A
B
C
221
APPLICATION PURCHASE PROCESSING UNIT
441
251
USER MANAGEMENT UNIT
451
APPLICATION SALES PROCESSING UNIT
452
DATA MANAGEMENT UNIT
453
411
APPLICATION PROVISION PROCESSING UNIT
461

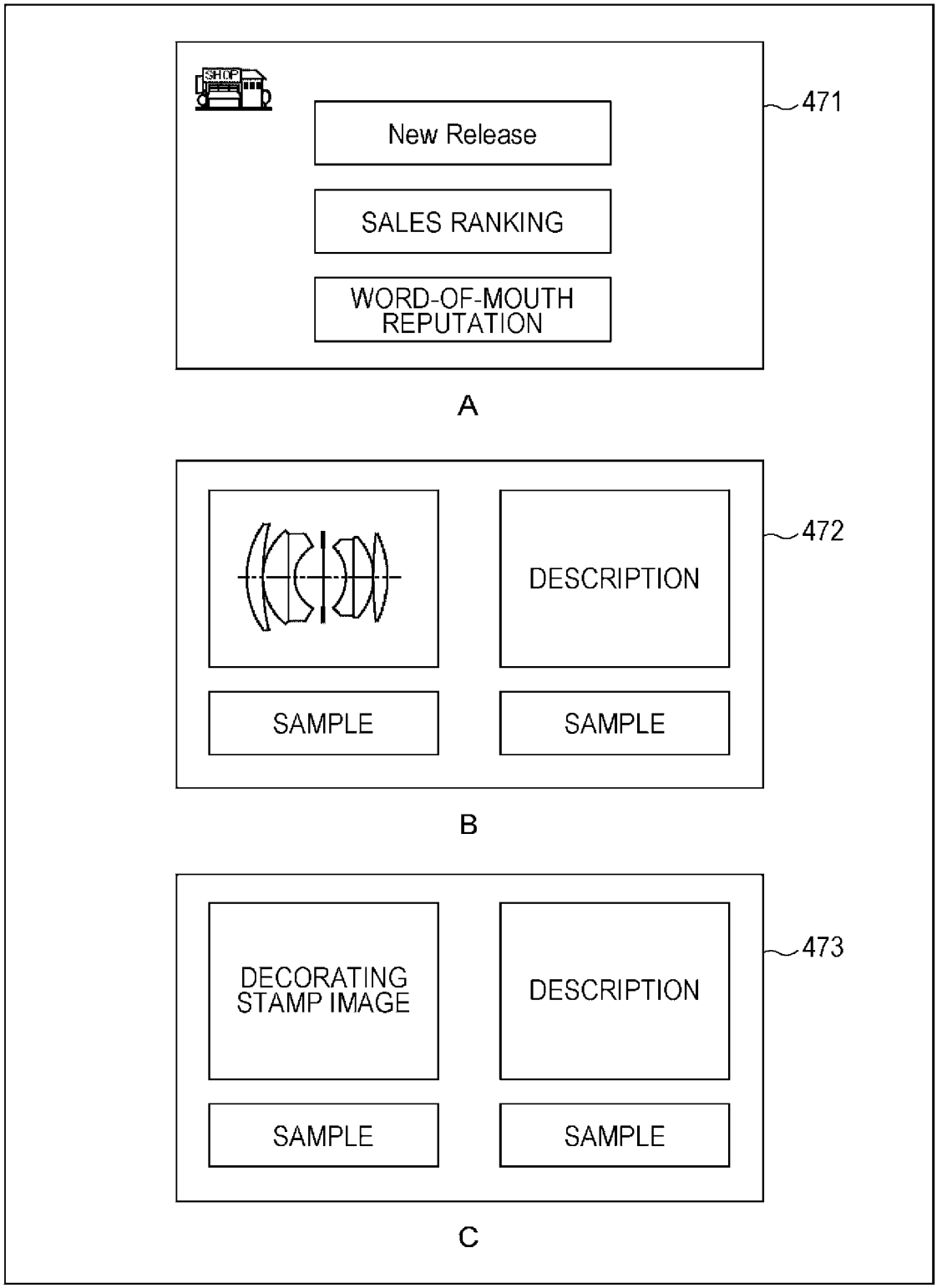
[Fig. 18]

FIG. 18


401
START
REQUEST PURCHASE OF APPLICATION
S151
S152
SELECT APPLICATION TO BE PURCHASED
S153
END
202
START
S161
S162
PROVIDE APPLICATION LIST
S163
S164
REGISTER APPLICATION WITH USER
S165
PERFORM PAYMENT PROCESS
S166
END
402
START
S171
REGISTER APPLICATION TO BE PROVIDED
END

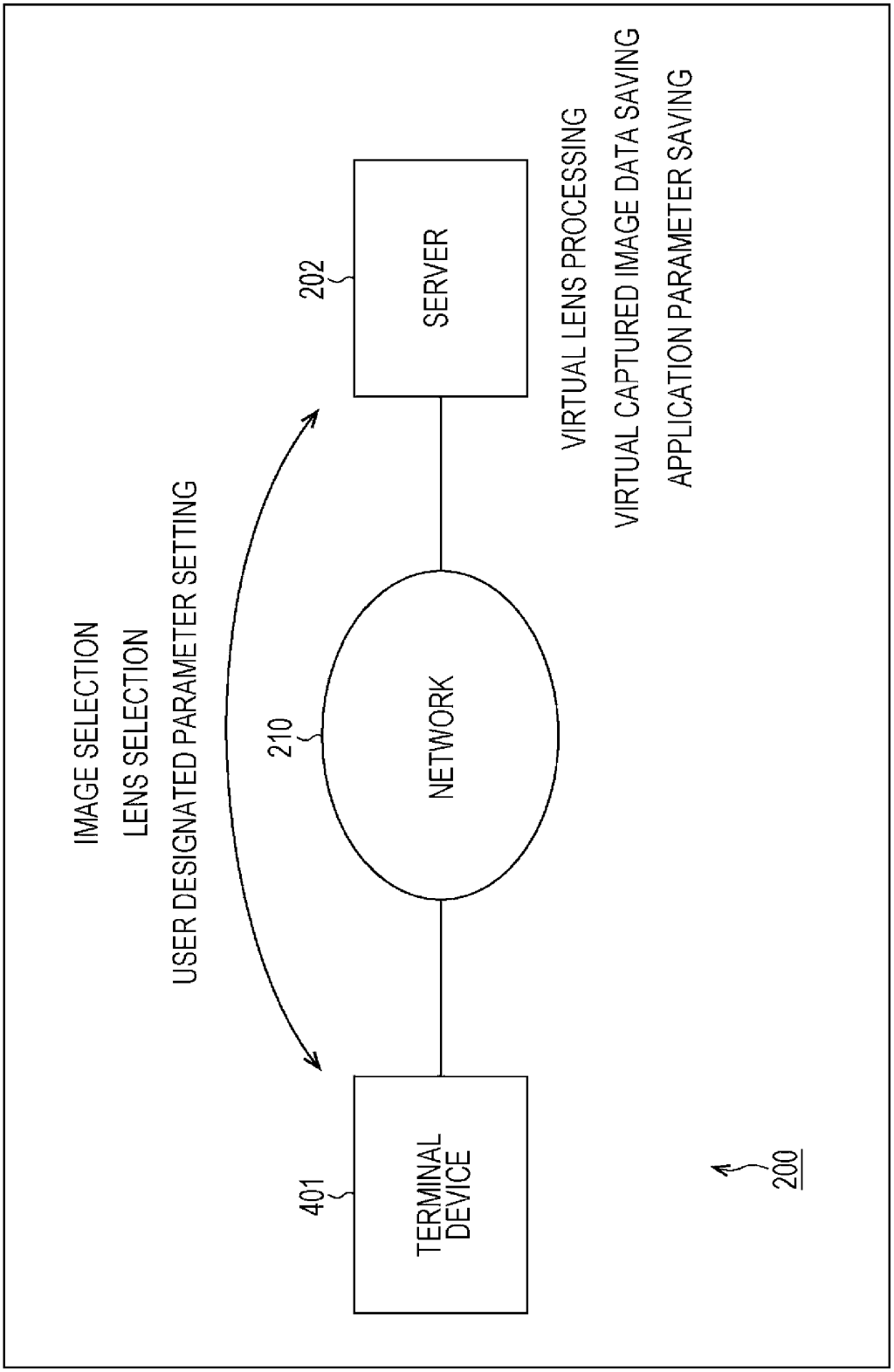
[Fig. 19]

FIG. 19


SHOP
New Release
SALES RANKING
WORD-OF-MOUTH REPUTATION
471
A
DESCRIPTION
SAMPLE
SAMPLE
472
B
DECORATING STAMP IMAGE
DESCRIPTION
SAMPLE
SAMPLE
473
C

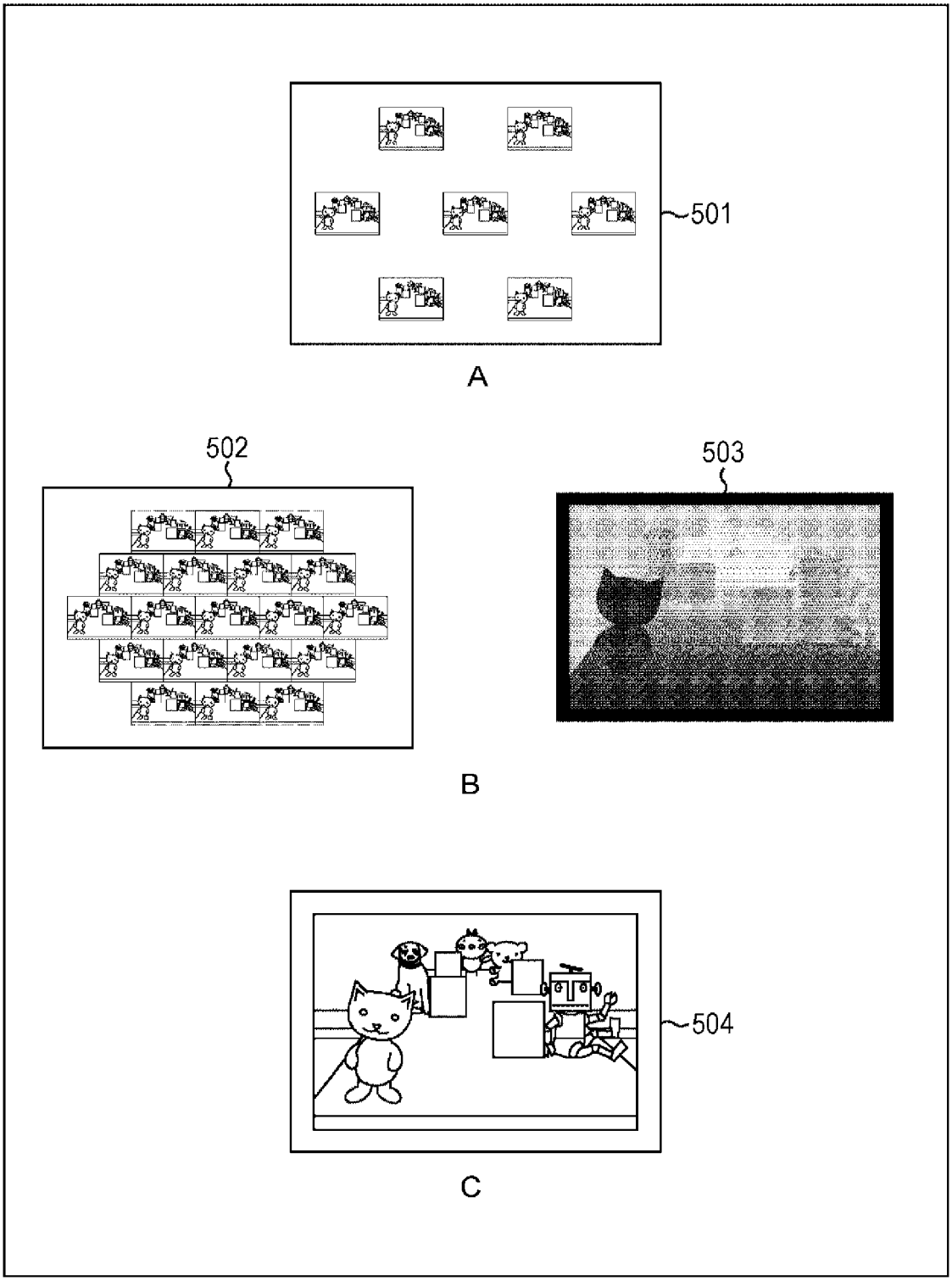
[Fig. 20]

FIG. 20


IMAGE SELECTION
LENS SELECTION
USER DESIGNATED PARAMETER SETTING
VIRTUAL LENS PROCESSING
VIRTUAL CAPTURED IMAGE DATA SAVING
APPLICATION PARAMETER SAVING
SERVER
202
NETWORK
210
TERMINAL DEVICE
401
200

[Fig. 21]

FIG. 21



[Fig. 22]

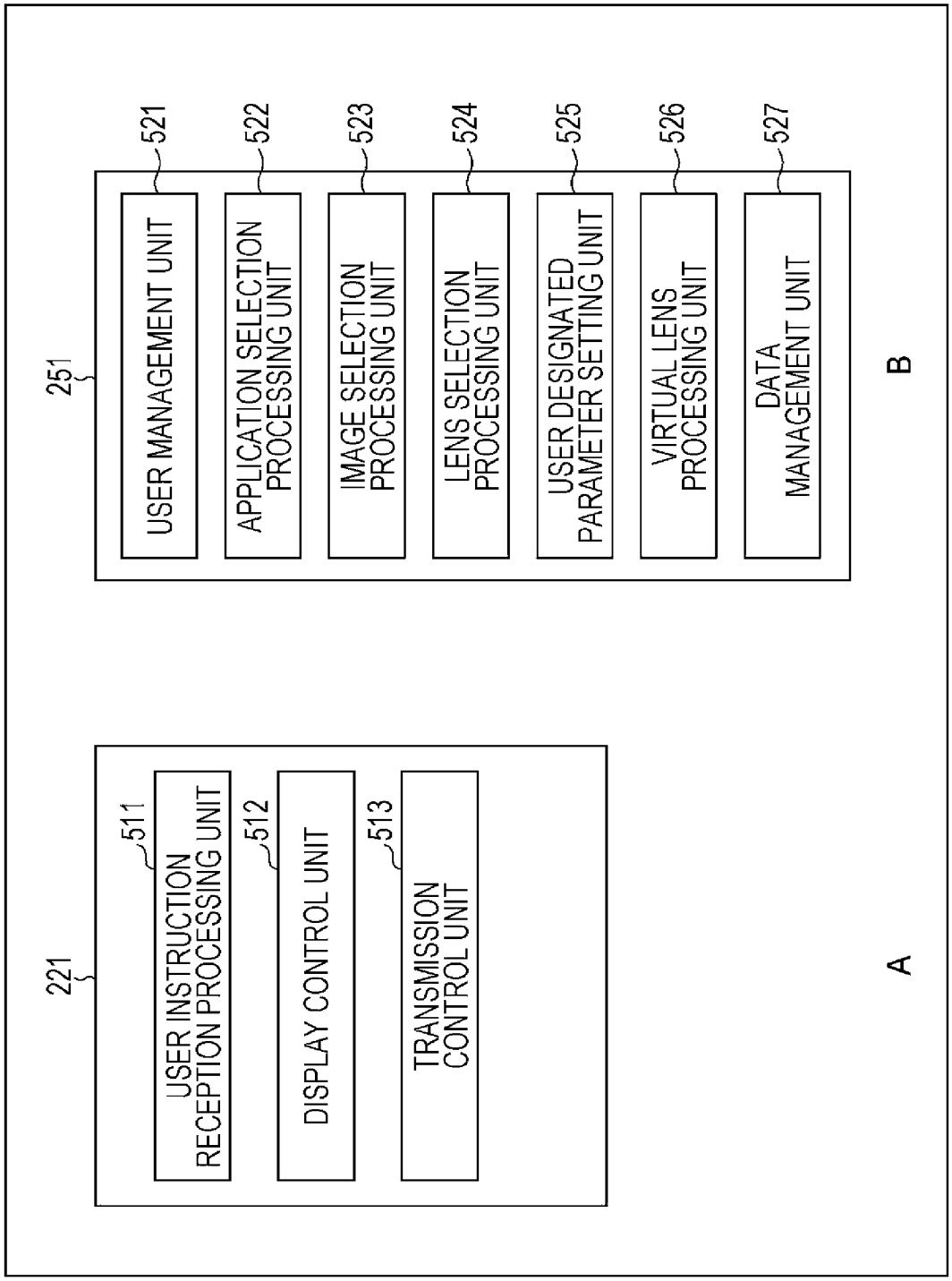
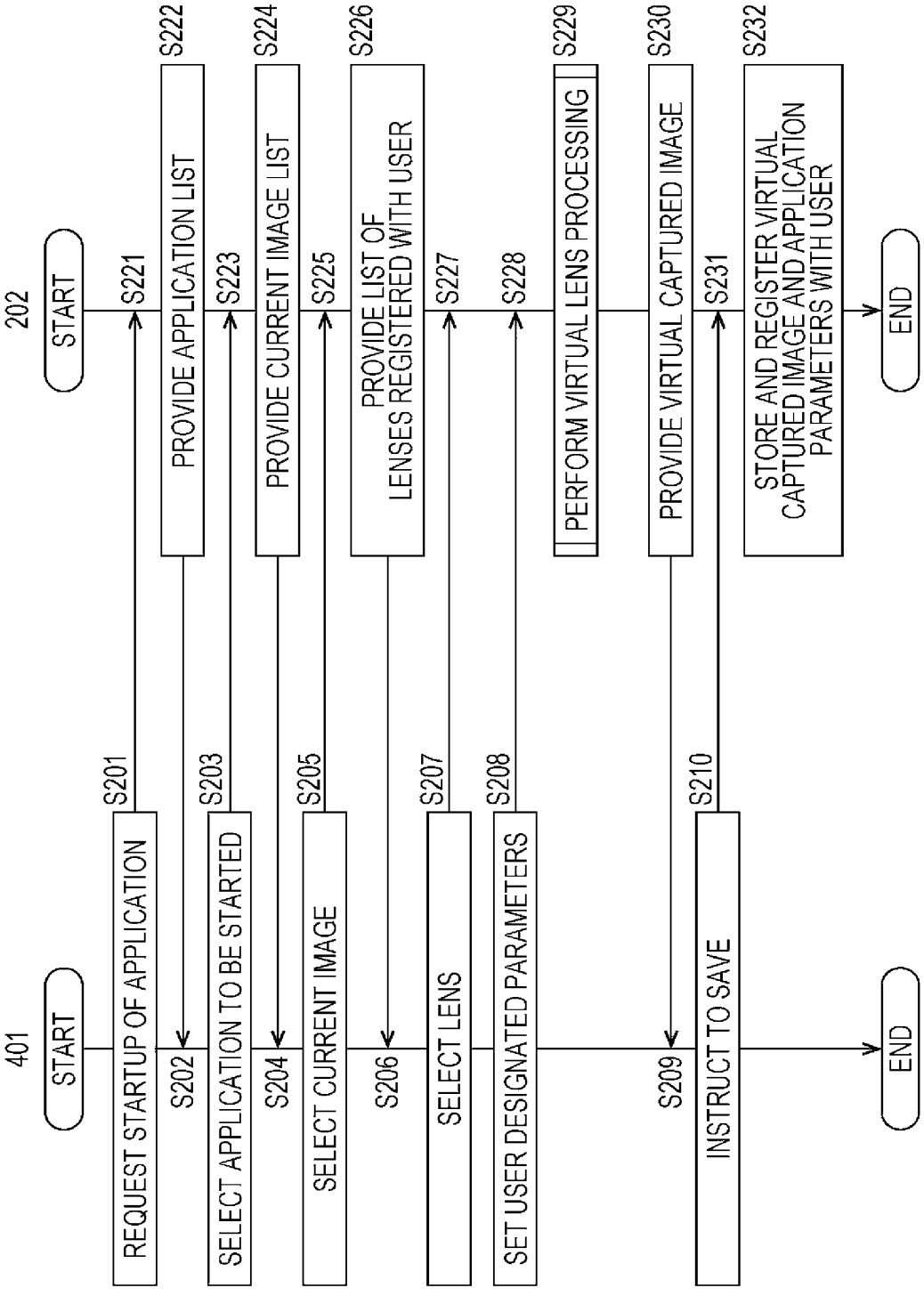

A
221
511
USER INSTRUCTION RECEPTION PROCESSING UNIT
512
DISPLAY CONTROL UNIT
513
TRANSMISSION CONTROL UNIT
B
251
521
USER MANAGEMENT UNIT
522
APPLICATION SELECTION PROCESSING UNIT
523
IMAGE SELECTION PROCESSING UNIT
524
LENS SELECTION PROCESSING UNIT
525
USER DESIGNATED PARAMETER SETTING UNIT
526
VIRTUAL LENS PROCESSING UNIT
527
DATA MANAGEMENT UNIT

FIG. 22

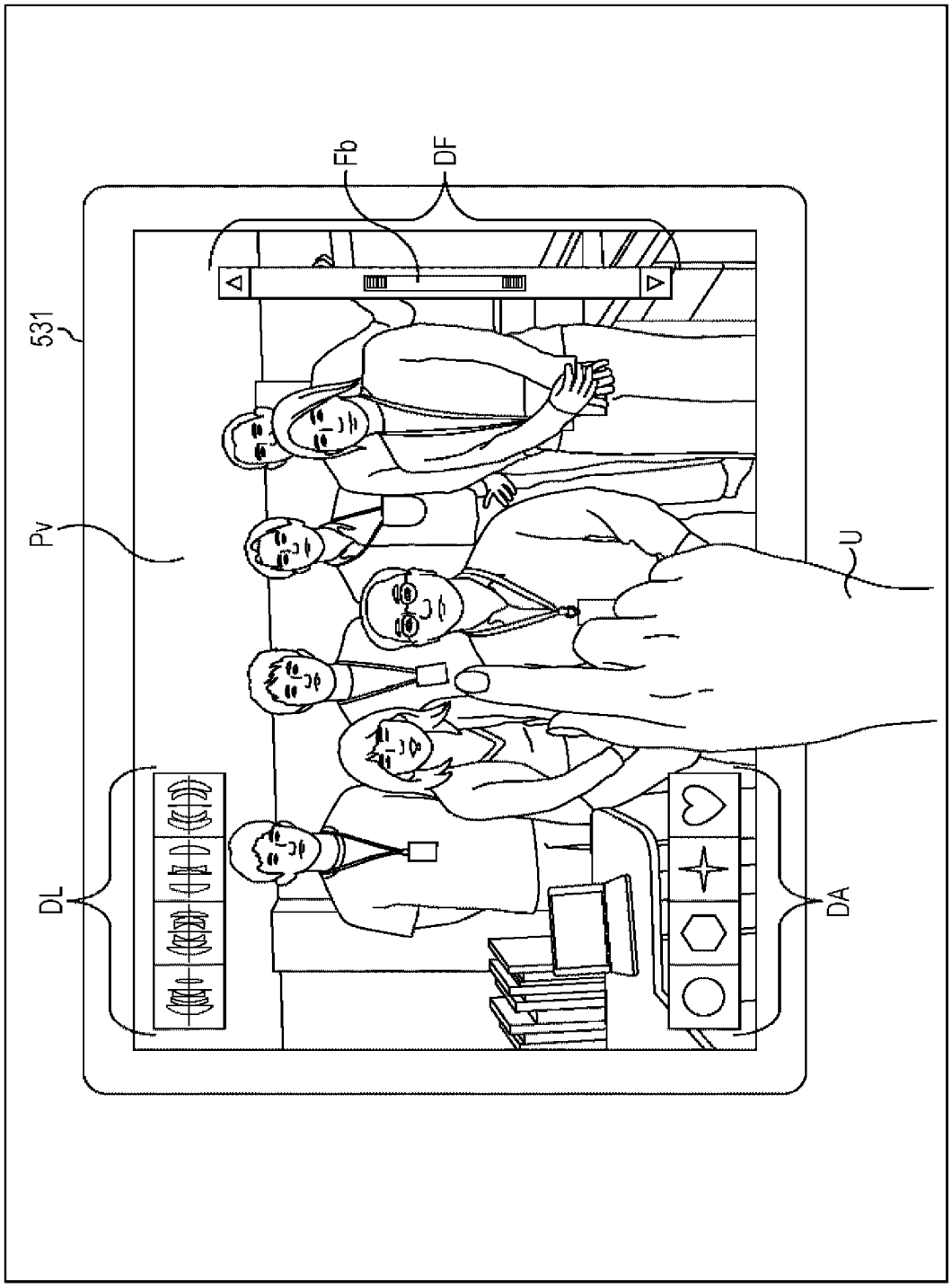
[Fig. 23]

FIG. 23


401
START
S201
REQUEST STARTUP OF APPLICATION
S202
S203
SELECT APPLICATION TO BE STARTED
S204
S205
SELECT CURRENT IMAGE
S206
S207
SELECT LENS
S208
SET USER DESIGNATED PARAMETERS
S209
S210
INSTRUCT TO SAVE
END
202
START
S221
PROVIDE APPLICATION LIST
S222
S223
PROVIDE CURRENT IMAGE LIST
S224
S225
PROVIDE LIST OF LENSES REGISTERED WITH USER
S226
S227
S228
PERFORM VIRTUAL LENS PROCESSING
S229
S230
PROVIDE VIRTUAL CAPTURED IMAGE
S231
S232
STORE AND REGISTER VIRTUAL CAPTURED IMAGE AND APPLICATION PARAMETERS WITH USER
END

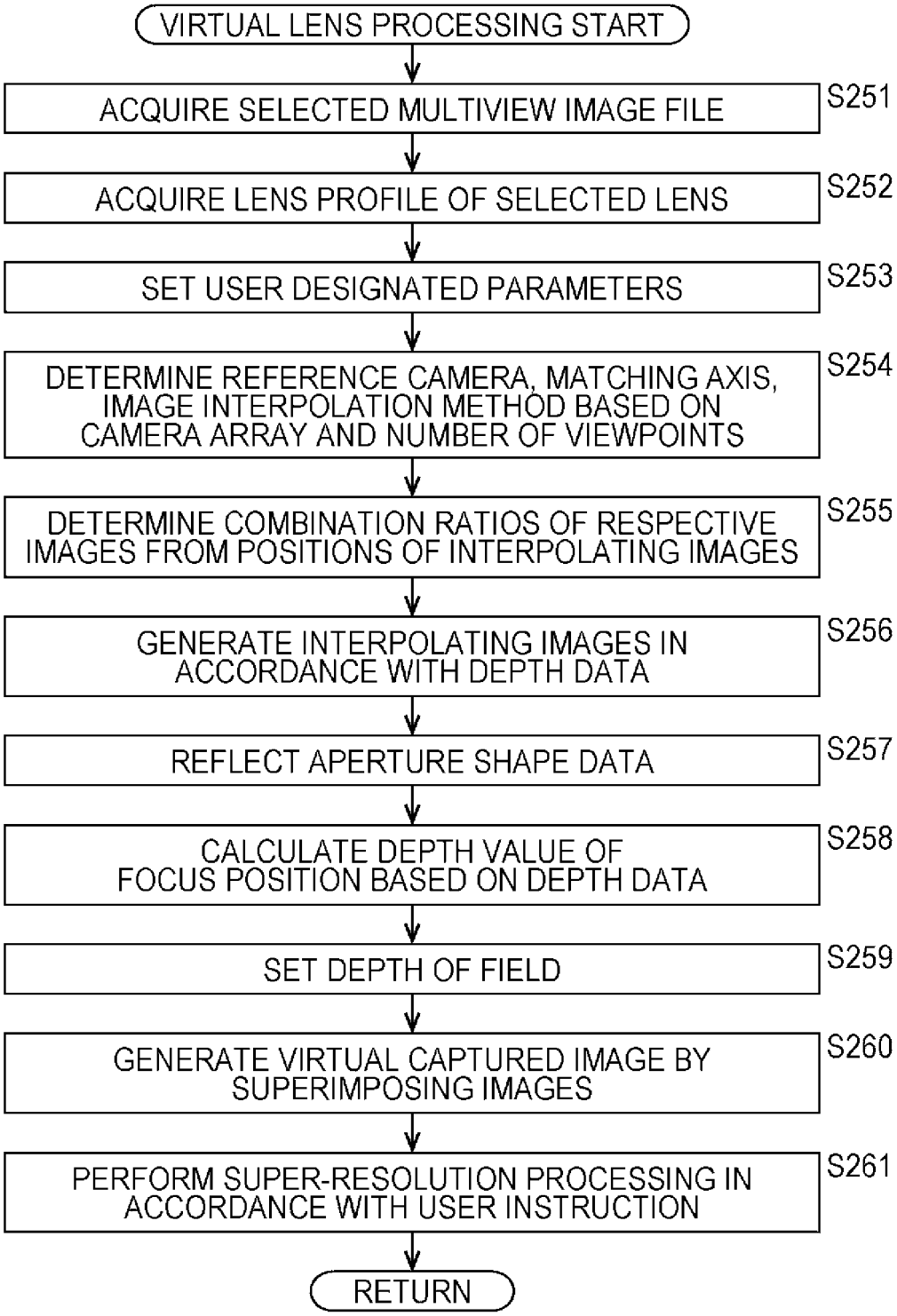
[Fig. 24]

FIG. 24



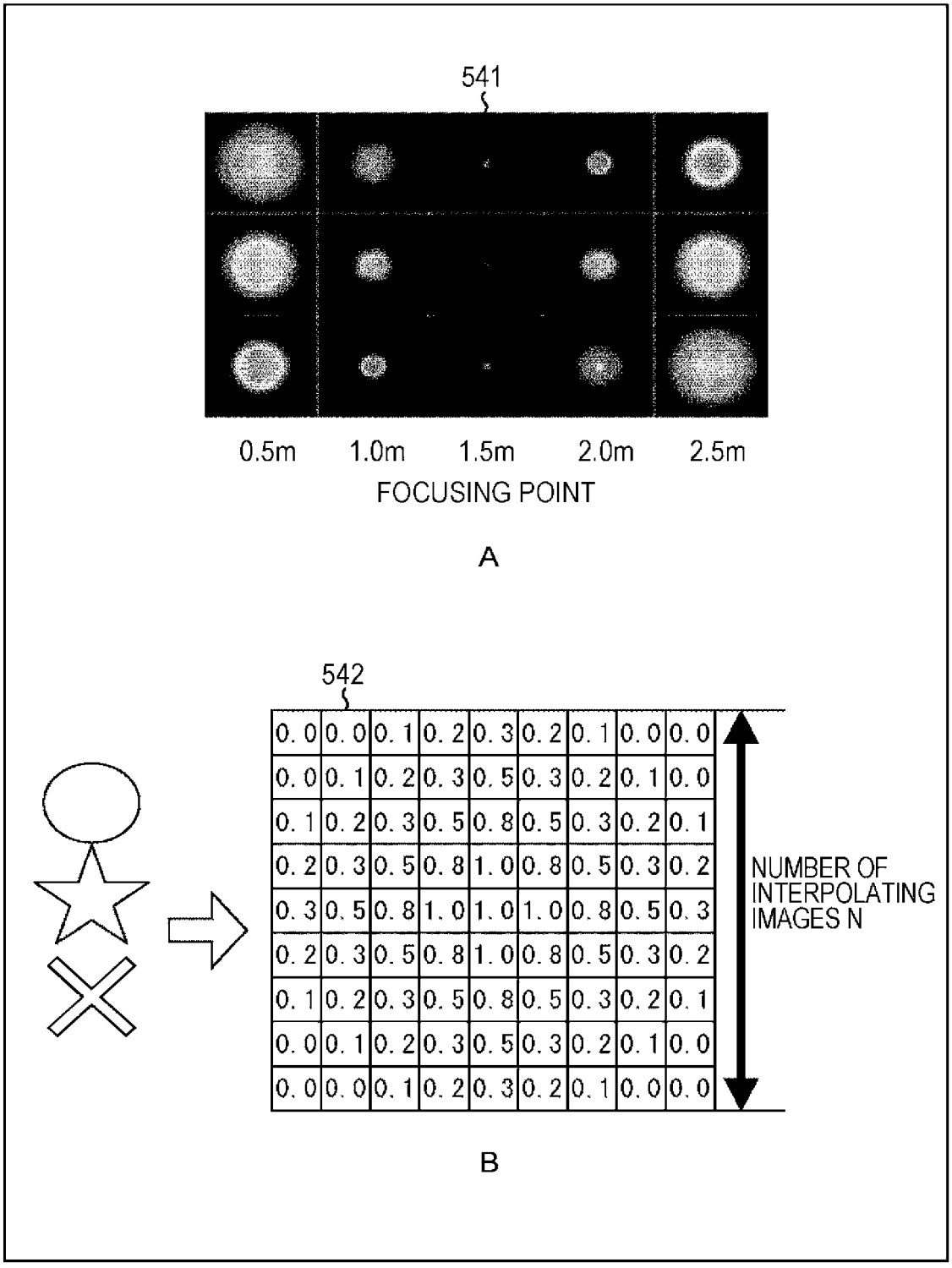
[Fig. 25]

FIG. 25


VIRTUAL LENS PROCESSING START
ACQUIRE SELECTED MULTIVIEW IMAGE FILE
S251
ACQUIRE LENS PROFILE OF SELECTED LENS
S252
SET USER DESIGNATED PARAMETERS
S253
DETERMINE REFERENCE CAMERA, MATCHING AXIS, IMAGE INTERPOLATION METHOD BASED ON CAMERA ARRAY AND NUMBER OF VIEWPOINTS
S254
DETERMINE COMBINATION RATIOS OF RESPECTIVE IMAGES FROM POSITIONS OF INTERPOLATING IMAGES
S255
GENERATE INTERPOLATING IMAGES IN ACCORDANCE WITH DEPTH DATA
S256
REFLECT APERTURE SHAPE DATA
S257
CALCULATE DEPTH VALUE OF FOCUS POSITION BASED ON DEPTH DATA
S258
SET DEPTH OF FIELD
S259
GENERATE VIRTUAL CAPTURED IMAGE BY SUPERIMPOSING IMAGES
S260
PERFORM SUPER-RESOLUTION PROCESSING IN ACCORDANCE WITH USER INSTRUCTION
S261
RETURN

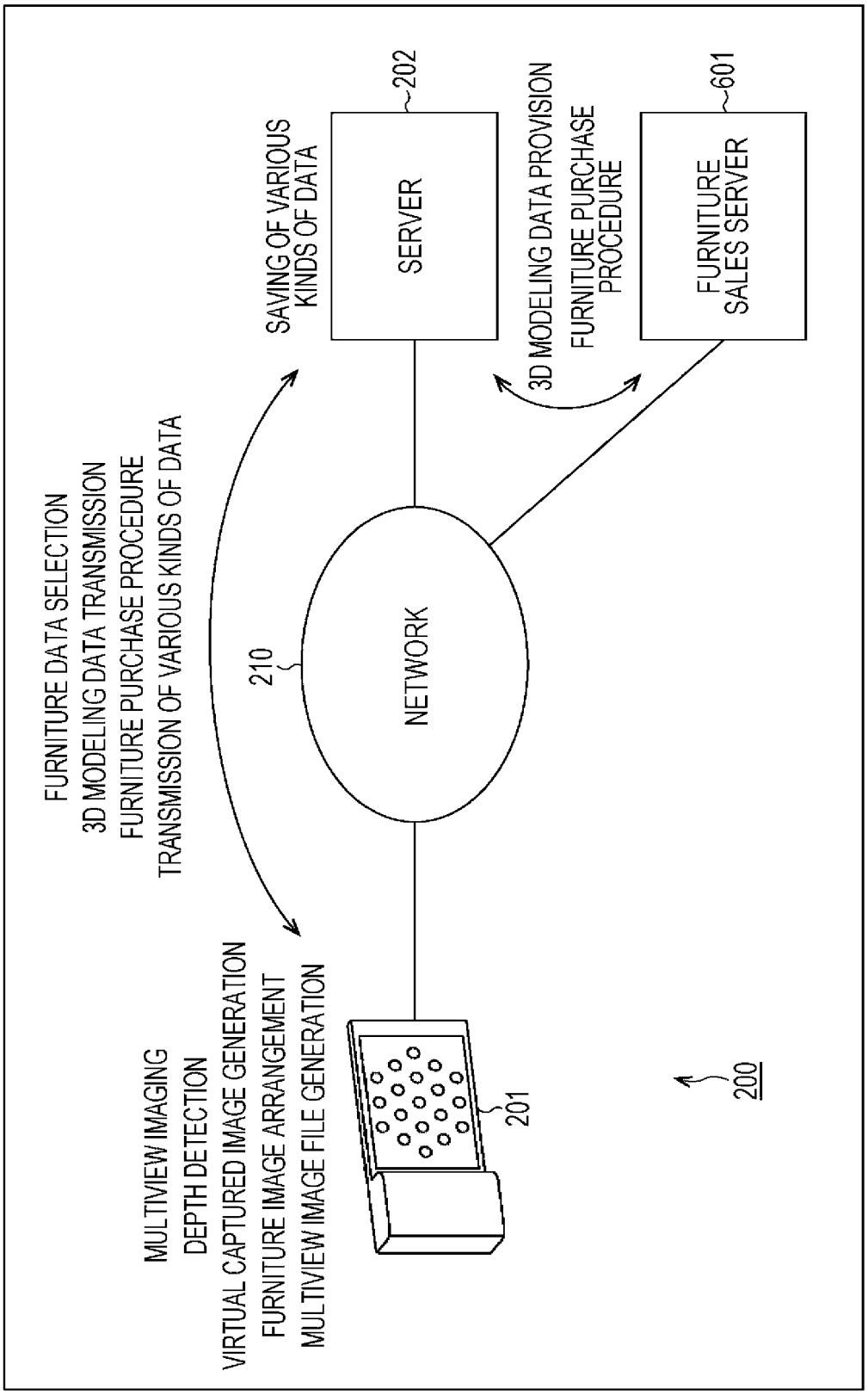
[Fig. 26]

FIG. 26


541
0.5m
1.0m
1.5m
2.0m
2.5m
FOCUSING POINT
A
542
0.0 0.0 0.1 0.2 0.3 0.2 0.1 0.0 0.0
0.0 0.1 0.2 0.3 0.5 0.3 0.2 0.1 0.0
0.1 0.2 0.3 0.5 0.8 0.5 0.3 0.2 0.1
0.2 0.3 0.5 0.8 1.0 0.8 0.5 0.3 0.2
0.3 0.5 0.8 1.0 1.0 1.0 0.8 0.5 0.3
0.2 0.3 0.5 0.8 1.0 0.8 0.5 0.3 0.2
0.1 0.2 0.3 0.5 0.8 0.5 0.3 0.2 0.1
0.0 0.1 0.2 0.3 0.5 0.3 0.2 0.1 0.0
0.0 0.0 0.1 0.2 0.3 0.2 0.1 0.0 0.0
NUMBER OF INTERPOLATING IMAGES N
B

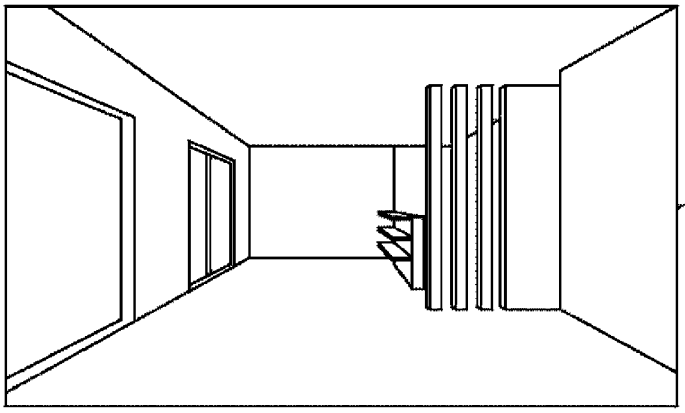
[Fig. 27]

FIG. 27

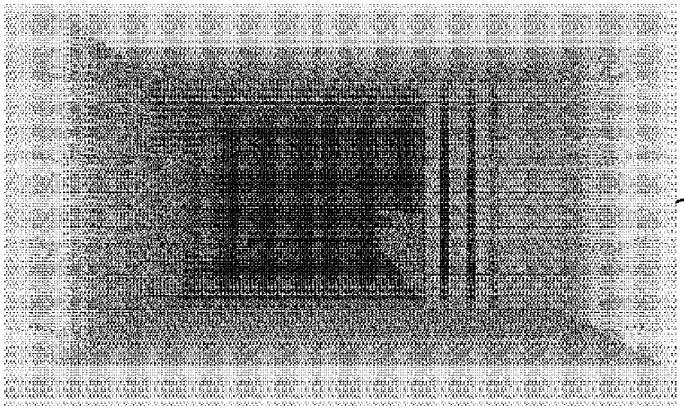

FURNITURE DATA SELECTION
3D MODELING DATA TRANSMISSION
FURNITURE PURCHASE PROCEDURE
TRANSMISSION OF VARIOUS KINDS OF DATA
MULTIVIEW IMAGING
DEPTH DETECTION
VIRTUAL CAPTURED IMAGE GENERATION
FURNITURE IMAGE ARRANGEMENT
MULTIVIEW IMAGE FILE GENERATION
SAVING OF VARIOUS KINDS OF DATA
3D MODELING DATA PROVISION
FURNITURE PURCHASE PROCEDURE
210
NETWORK
SERVER
202
FURNITURE SALES SERVER
601
201
200

[Fig. 28]

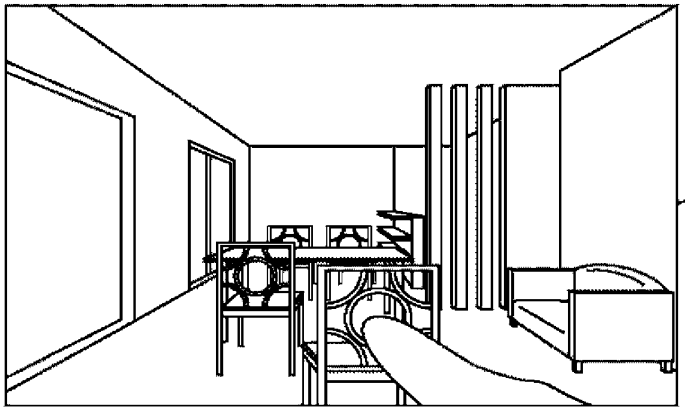
FIG. 28



A



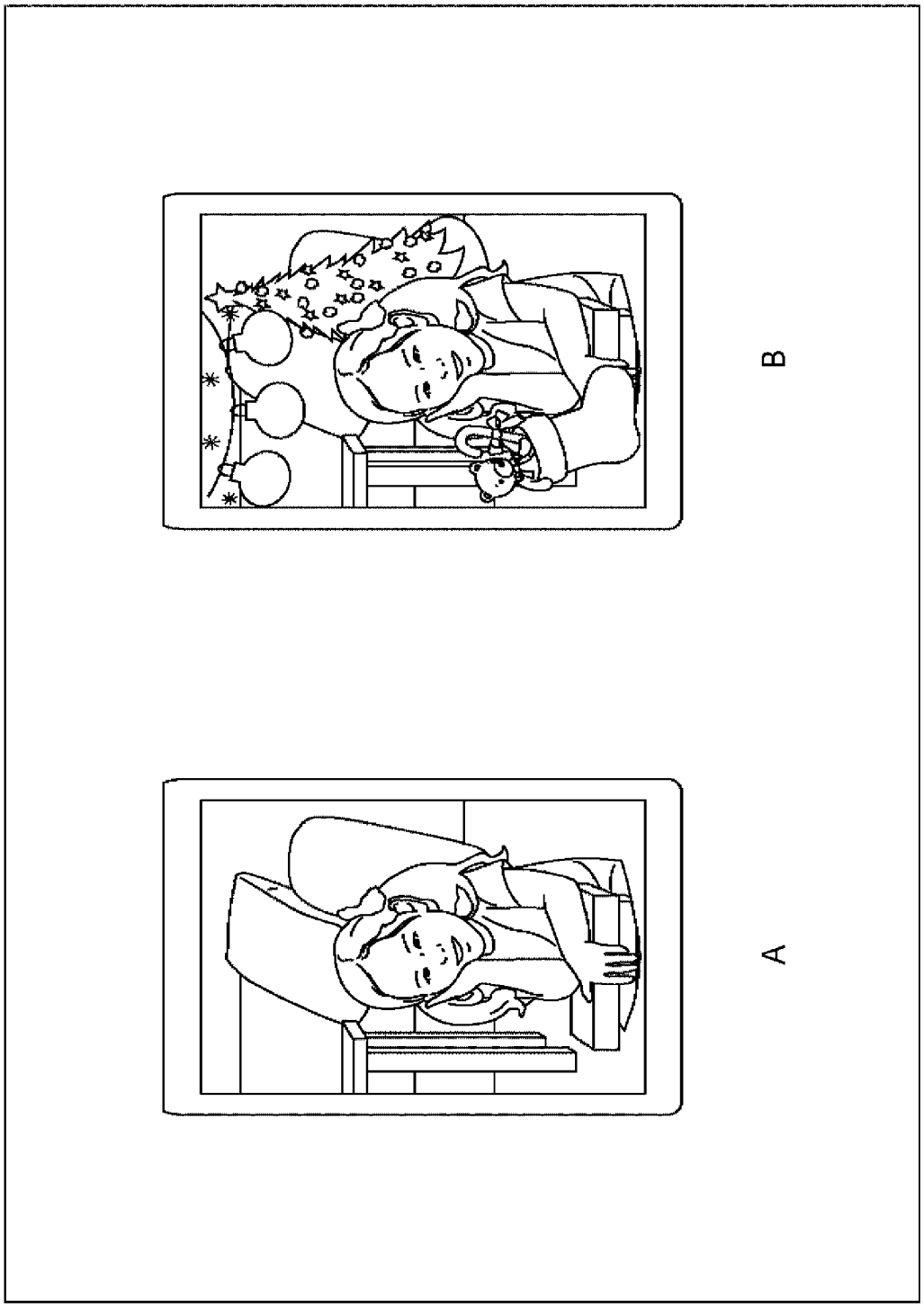
B



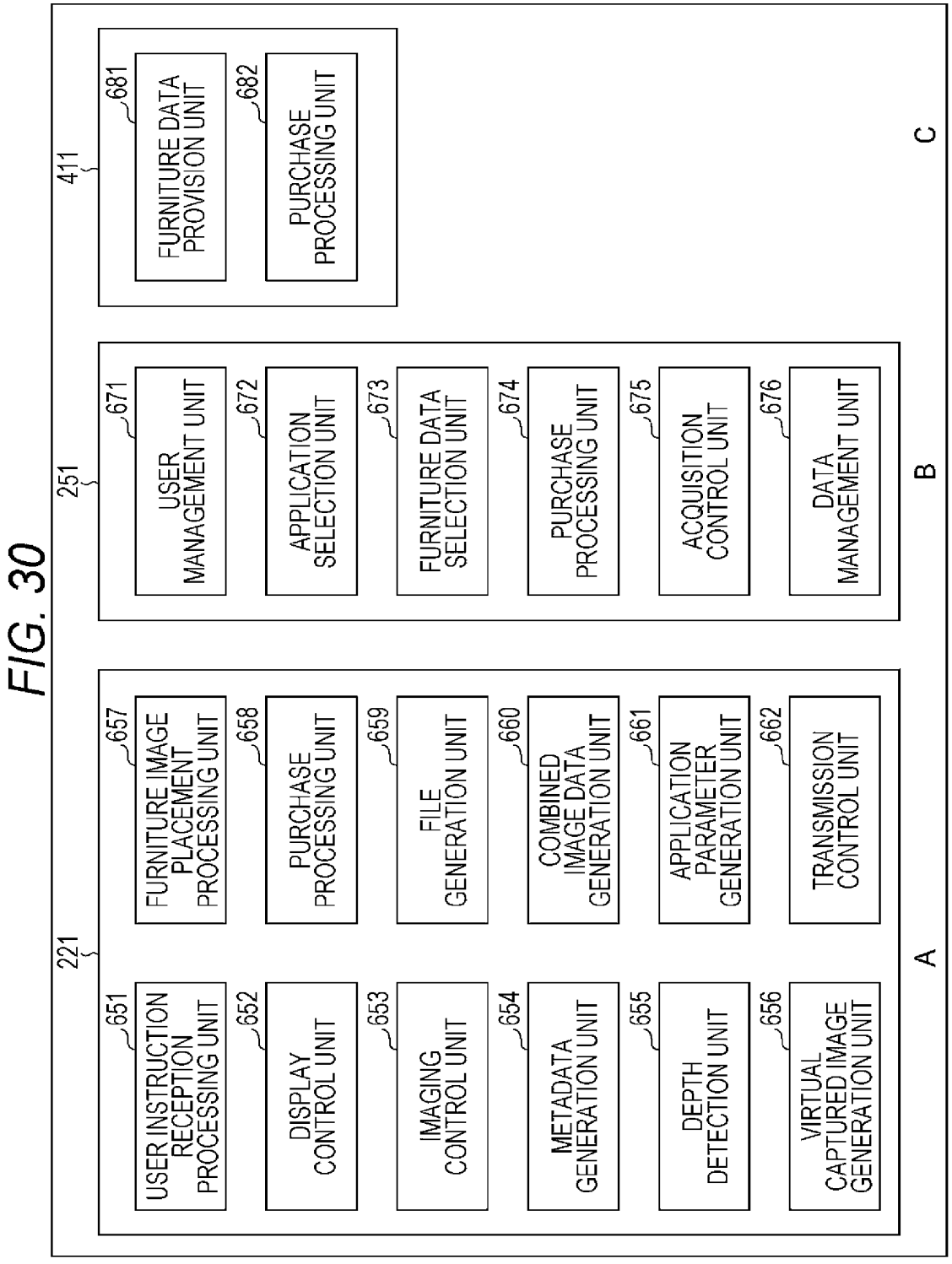
C

[Fig. 29]

FIG. 29

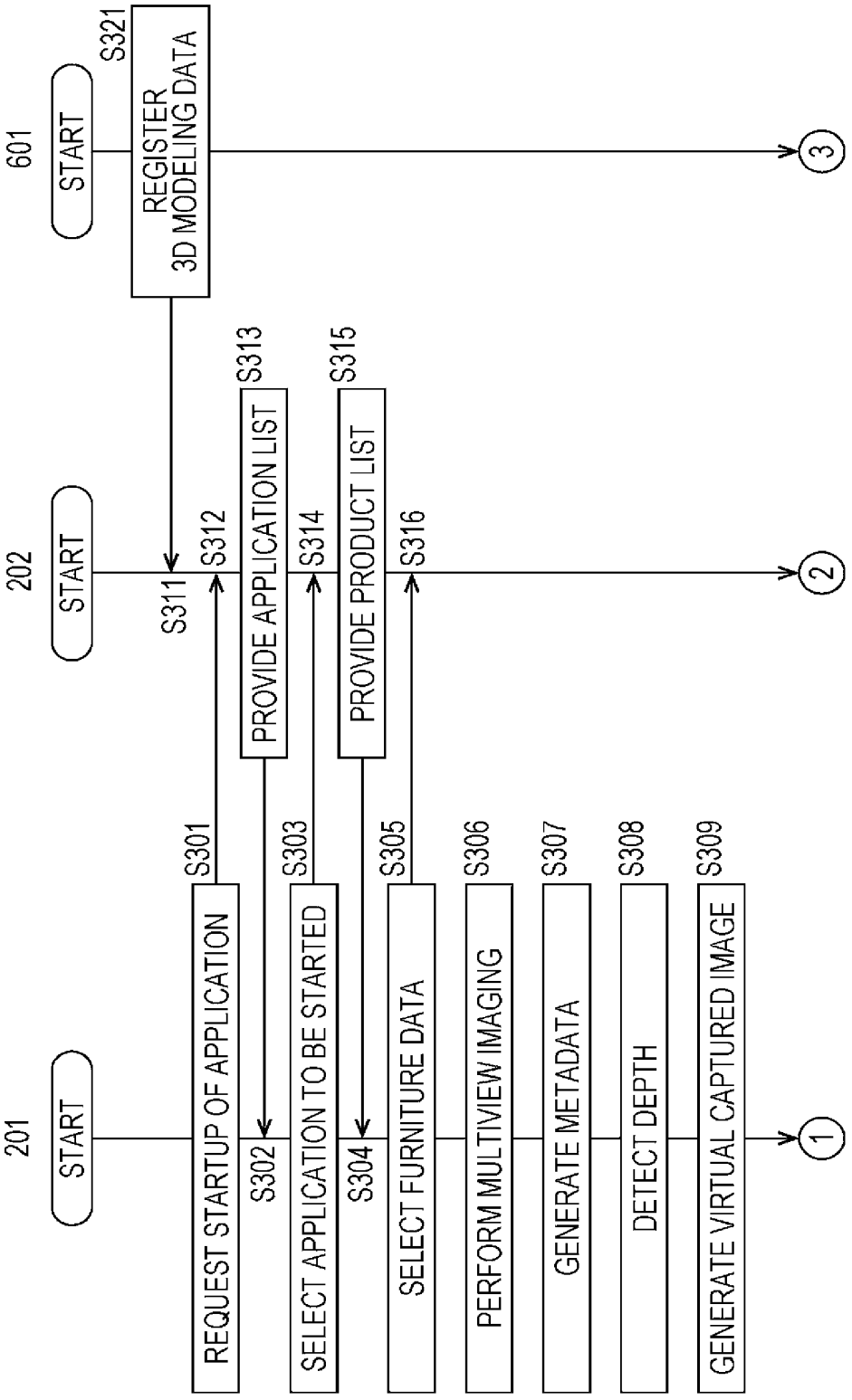


[Fig. 30]


FIG. 30
A
221
651 USER INSTRUCTION RECEPTION PROCESSING UNIT
652 DISPLAY CONTROL UNIT
653 IMAGING CONTROL UNIT
654 METADATA GENERATION UNIT
655 DEPTH DETECTION UNIT
656 VIRTUAL CAPTURED IMAGE GENERATION UNIT
657 FURNITURE IMAGE PLACEMENT PROCESSING UNIT
658 PURCHASE PROCESSING UNIT
659 FILE GENERATION UNIT
660 COMBINED IMAGE DATA GENERATION UNIT
661 APPLICATION PARAMETER GENERATION UNIT
662 TRANSMISSION CONTROL UNIT
B
251
671 USER MANAGEMENT UNIT
672 APPLICATION SELECTION UNIT
673 FURNITURE DATA SELECTION UNIT
674 PURCHASE PROCESSING UNIT
675 ACQUISITION CONTROL UNIT
676 DATA MANAGEMENT UNIT
C
411
681 FURNITURE DATA PROVISION UNIT
682 PURCHASE PROCESSING UNIT

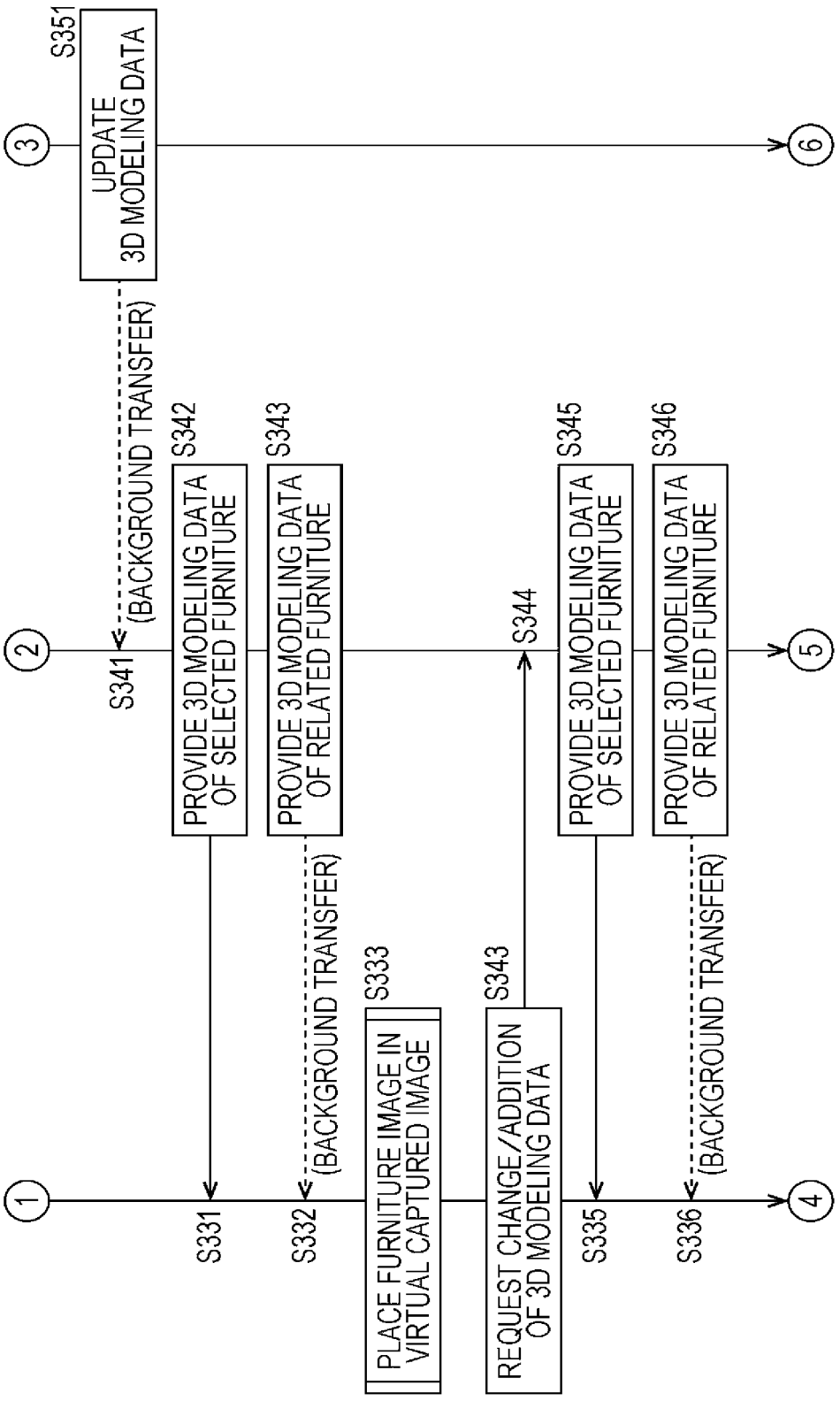
[Fig. 31]

FIG. 31


601
START
S321
REGISTER 3D MODELING DATA
3
202
START
S311
S312
PROVIDE APPLICATION LIST
S313
S314
PROVIDE PRODUCT LIST
S315
S316
2
201
START
S301
REQUEST STARTUP OF APPLICATION
S302
S303
SELECT APPLICATION TO BE STARTED
S304
S305
SELECT FURNITURE DATA
S306
PERFORM MULTIVIEW IMAGING
S307
GENERATE METADATA
S308
DETECT DEPTH
S309
GENERATE VIRTUAL CAPTURED IMAGE
1

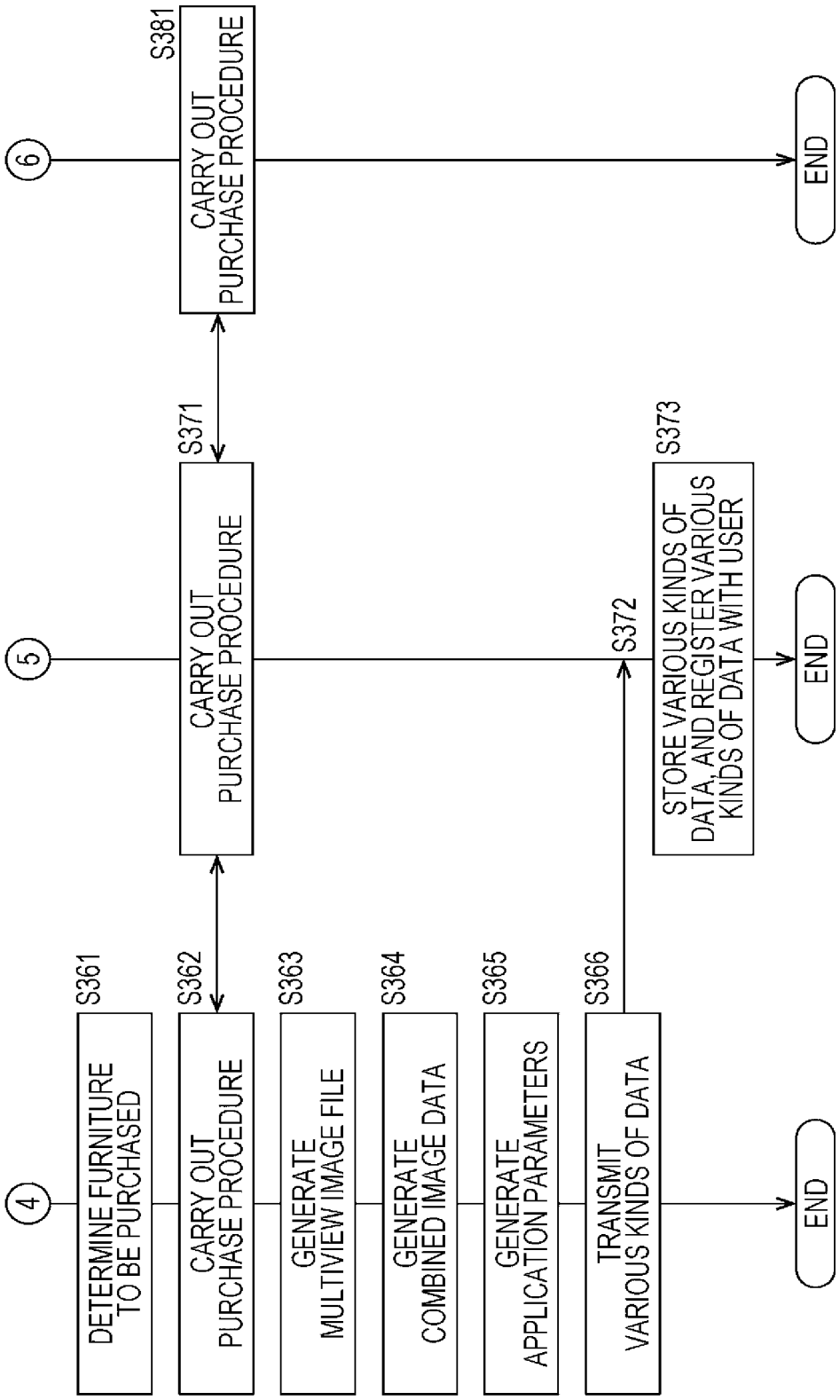
[Fig. 32]

FIG. 32


S351
UPDATE 3D MODELING DATA
3
6
(BACKGROUND TRANSFER)
S341
2
S342
PROVIDE 3D MODELING DATA OF SELECTED FURNITURE
S343
PROVIDE 3D MODELING DATA OF RELATED FURNITURE
S344
S345
PROVIDE 3D MODELING DATA OF SELECTED FURNITURE
S346
PROVIDE 3D MODELING DATA OF RELATED FURNITURE
5
1
S331
S332
(BACKGROUND TRANSFER)
S333
PLACE FURNITURE IMAGE IN VIRTUAL CAPTURED IMAGE
S343
REQUEST CHANGE/ADDITION OF 3D MODELING DATA
S335
S336
(BACKGROUND TRANSFER)
4

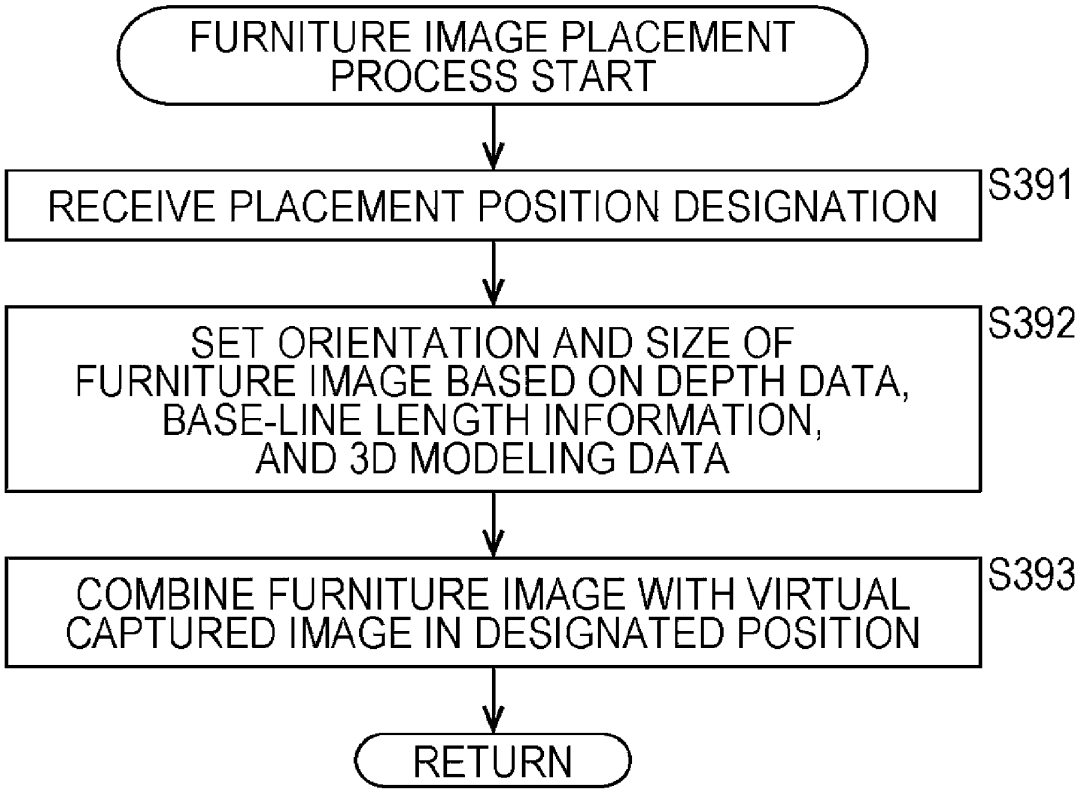
[Fig. 33]

FIG. 33


4
DETERMINE FURNITURE TO BE PURCHASED
S361
CARRY OUT PURCHASE PROCEDURE
S362
GENERATE MULTIVIEW IMAGE FILE
S363
GENERATE COMBINED IMAGE DATA
S364
GENERATE APPLICATION PARAMETERS
S365
TRANSMIT VARIOUS KINDS OF DATA
S366
END
5
CARRY OUT PURCHASE PROCEDURE
S371
S372
STORE VARIOUS KINDS OF DATA, AND REGISTER VARIOUS KINDS OF DATA WITH USER
S373
END
6
CARRY OUT PURCHASE PROCEDURE
S381
END

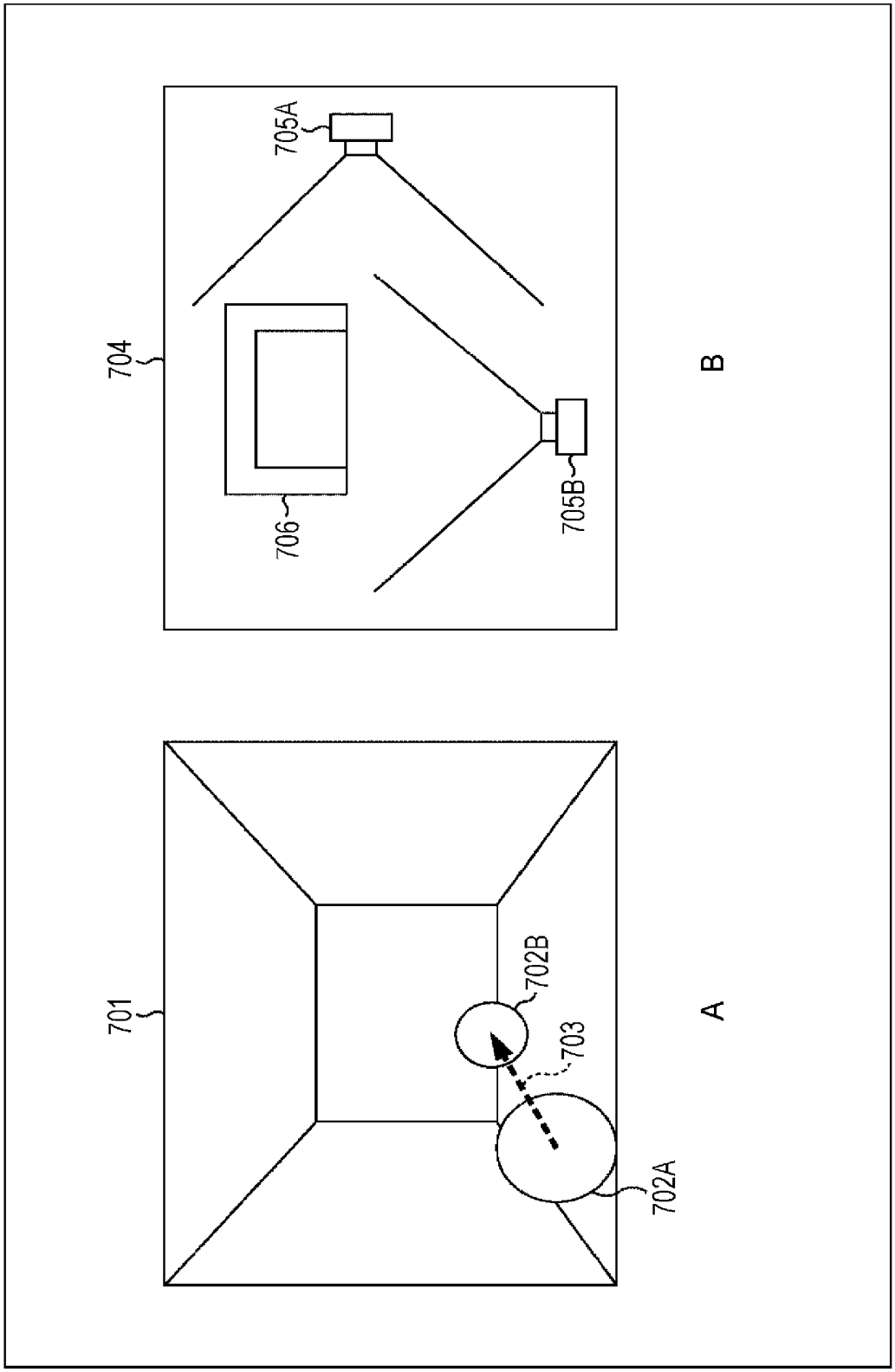
[Fig. 34]

FIG. 34


FURNITURE IMAGE PLACEMENT PROCESS START
RECEIVE PLACEMENT POSITION DESIGNATION
S391
SET ORIENTATION AND SIZE OF FURNITURE IMAGE BASED ON DEPTH DATA, BASE-LINE LENGTH INFORMATION, AND 3D MODELING DATA
S392
COMBINE FURNITURE IMAGE WITH VIRTUAL CAPTURED IMAGE IN DESIGNATED POSITION
S393
RETURN

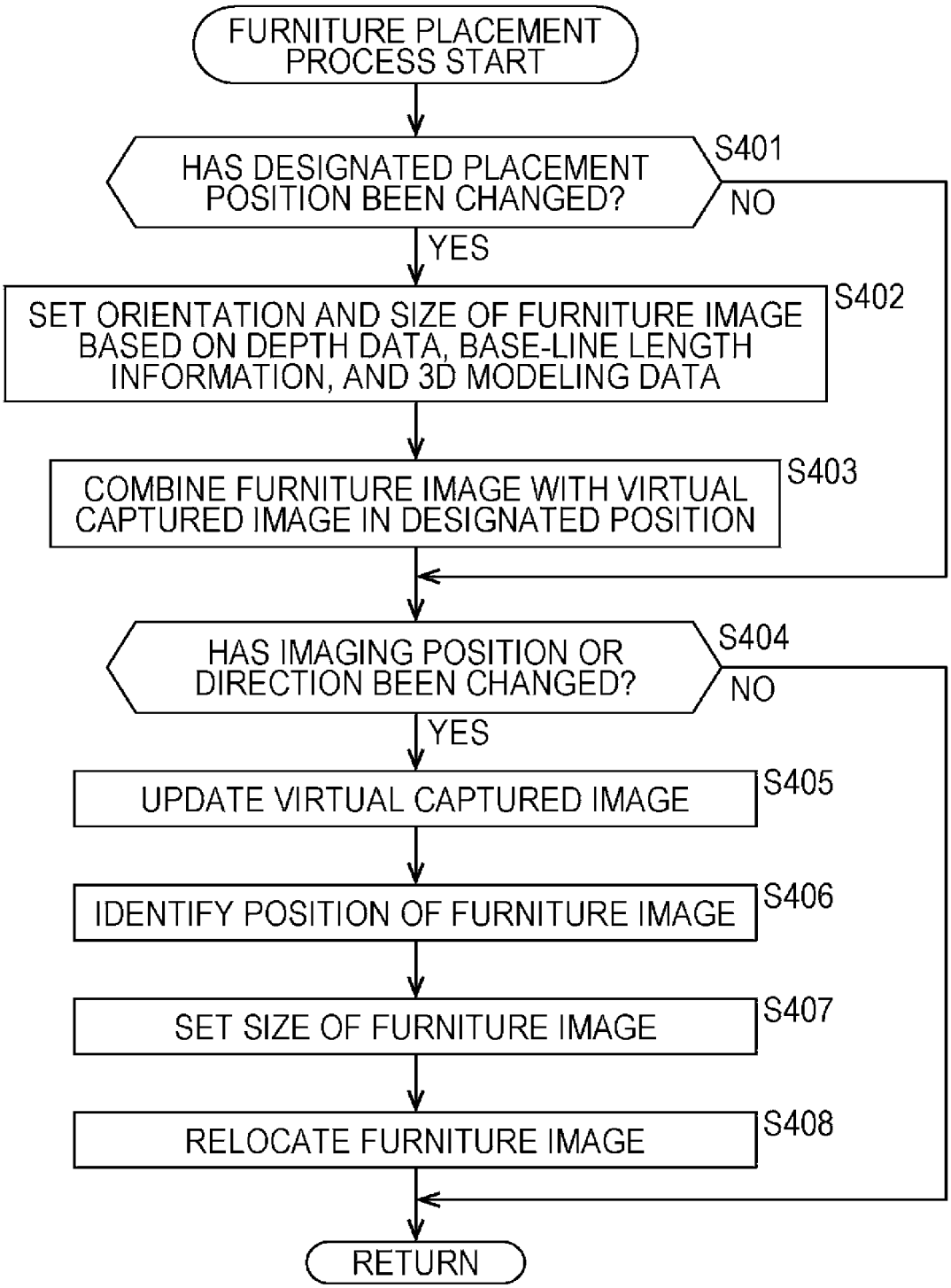
[Fig. 35]

FIG. 35



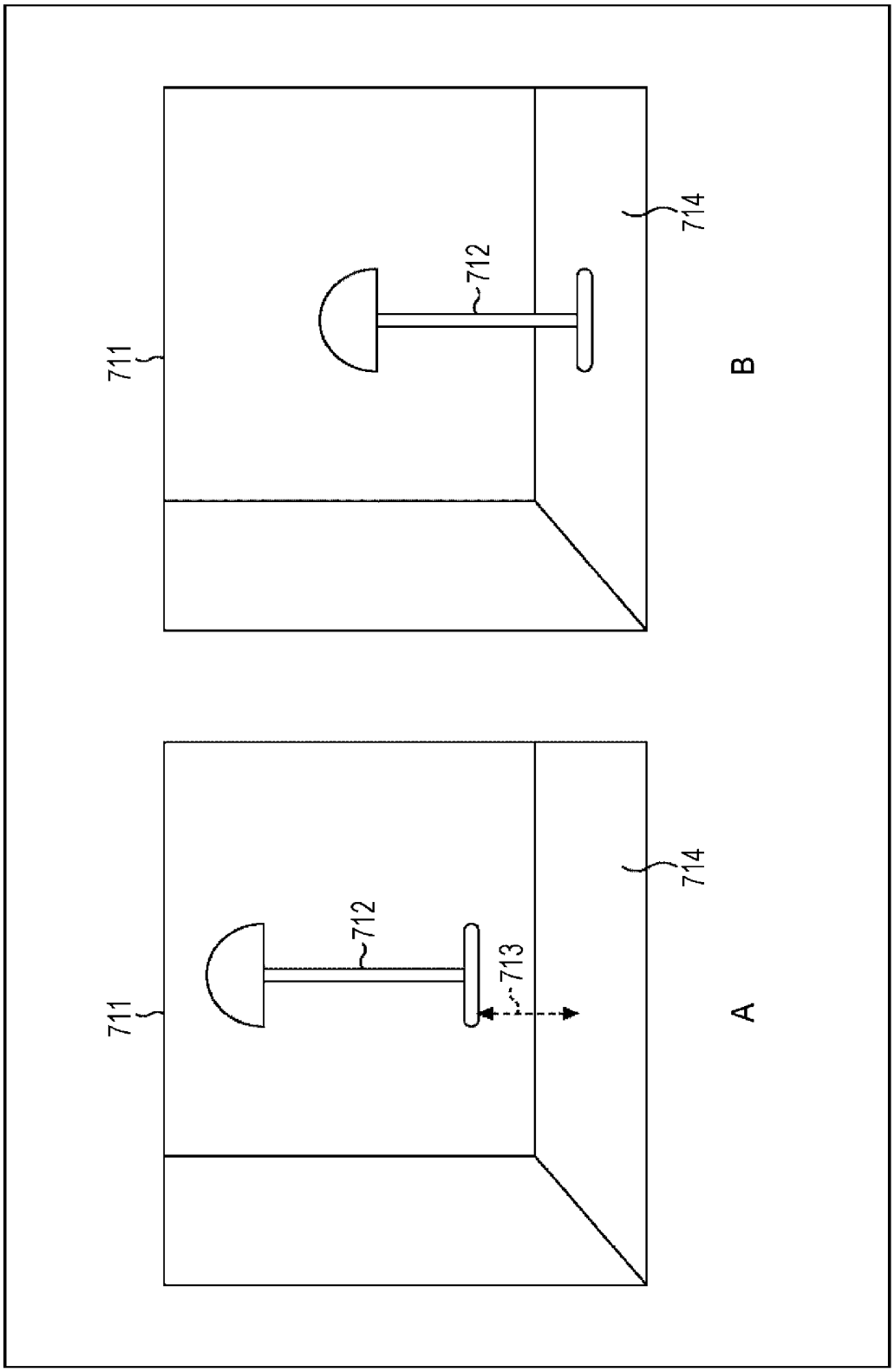
[Fig. 36]

FIG. 36


FURNITURE PLACEMENT PROCESS START
HAS DESIGNATED PLACEMENT POSITION BEEN CHANGED?
S401
NO
YES
SET ORIENTATION AND SIZE OF FURNITURE IMAGE BASED ON DEPTH DATA, BASE-LINE LENGTH INFORMATION, AND 3D MODELING DATA
S402
COMBINE FURNITURE IMAGE WITH VIRTUAL CAPTURED IMAGE IN DESIGNATED POSITION
S403
HAS IMAGING POSITION OR DIRECTION BEEN CHANGED?
S404
NO
YES
UPDATE VIRTUAL CAPTURED IMAGE
S405
IDENTIFY POSITION OF FURNITURE IMAGE
S406
SET SIZE OF FURNITURE IMAGE
S407
RELOCATE FURNITURE IMAGE
S408
RETURN

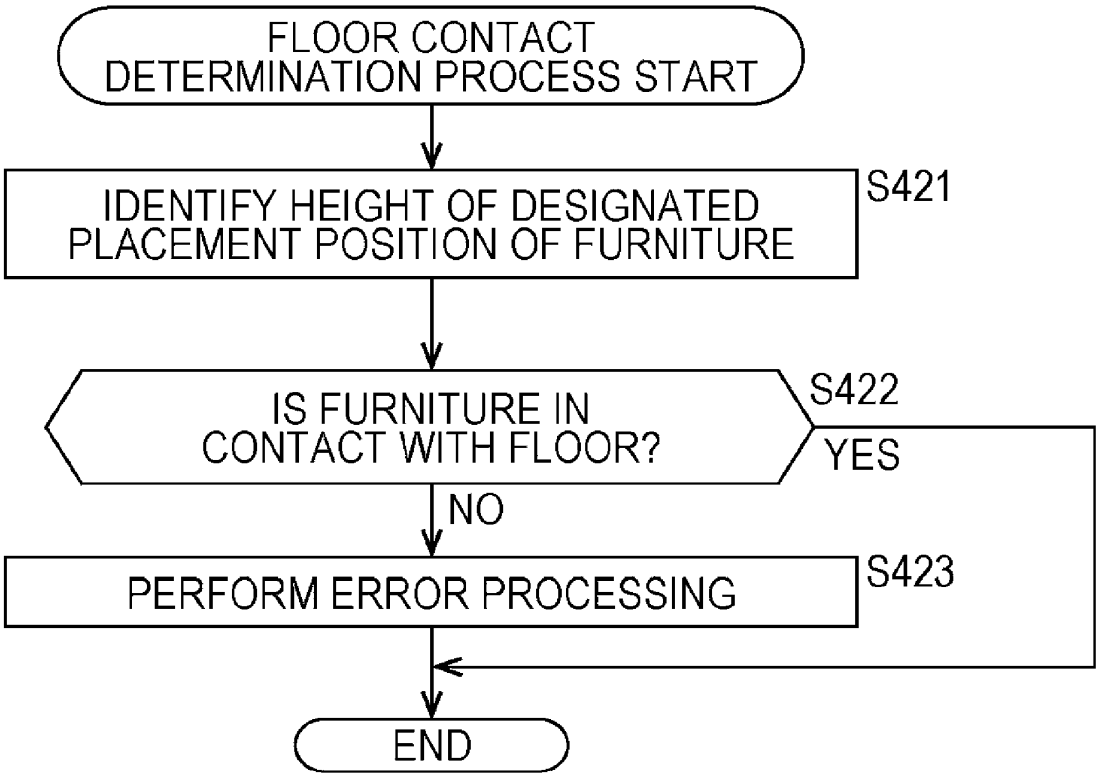
[Fig. 37]

FIG. 37



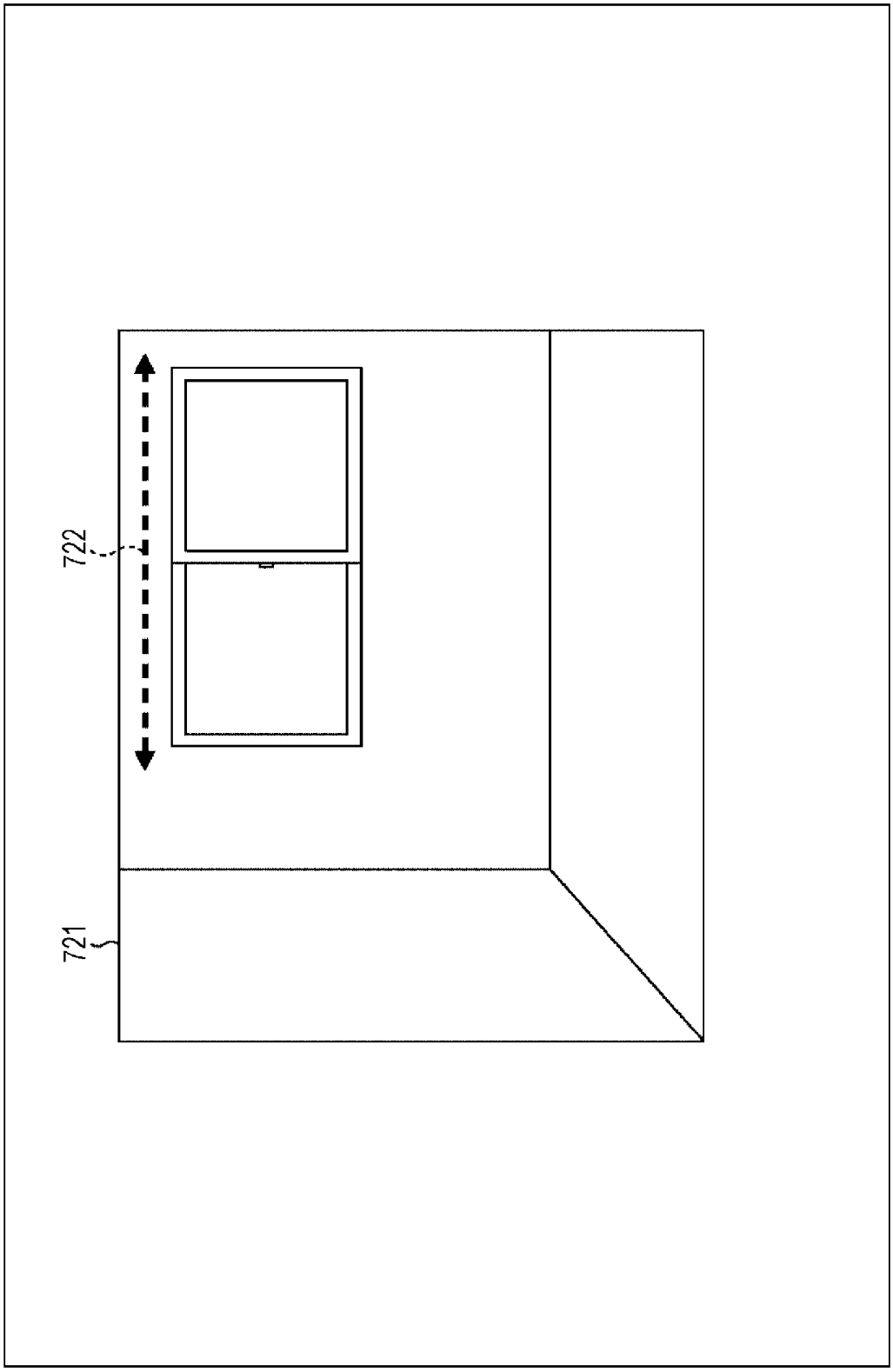
[Fig. 38]

FIG. 38


FLOOR CONTACT DETERMINATION PROCESS START
IDENTIFY HEIGHT OF DESIGNATED PLACEMENT POSITION OF FURNITURE
S421
IS FURNITURE IN CONTACT WITH FLOOR?
S422
YES
NO
PERFORM ERROR PROCESSING
S423
END

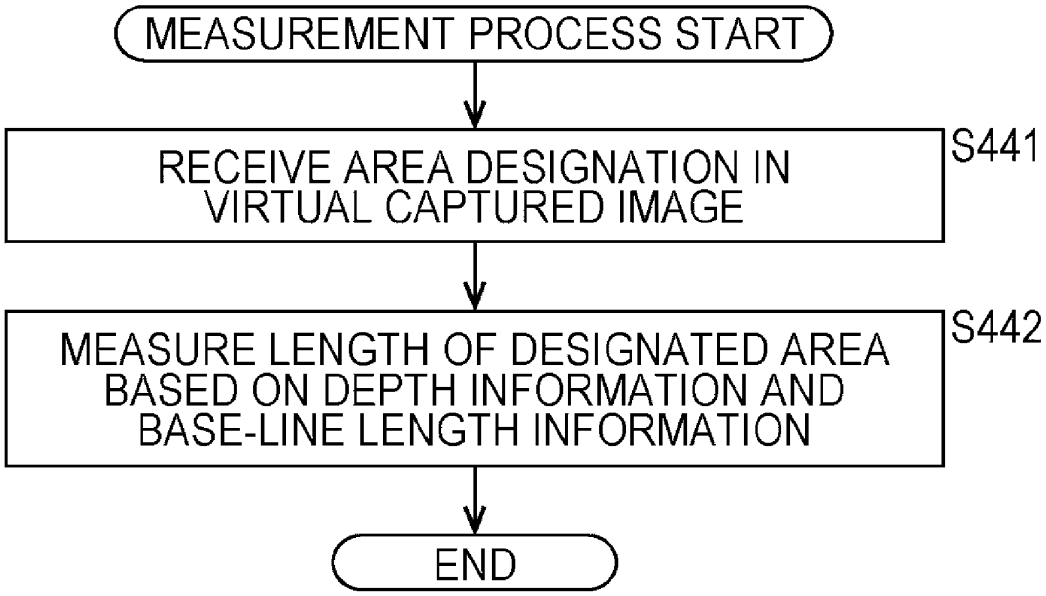
[Fig. 39]

FIG. 39



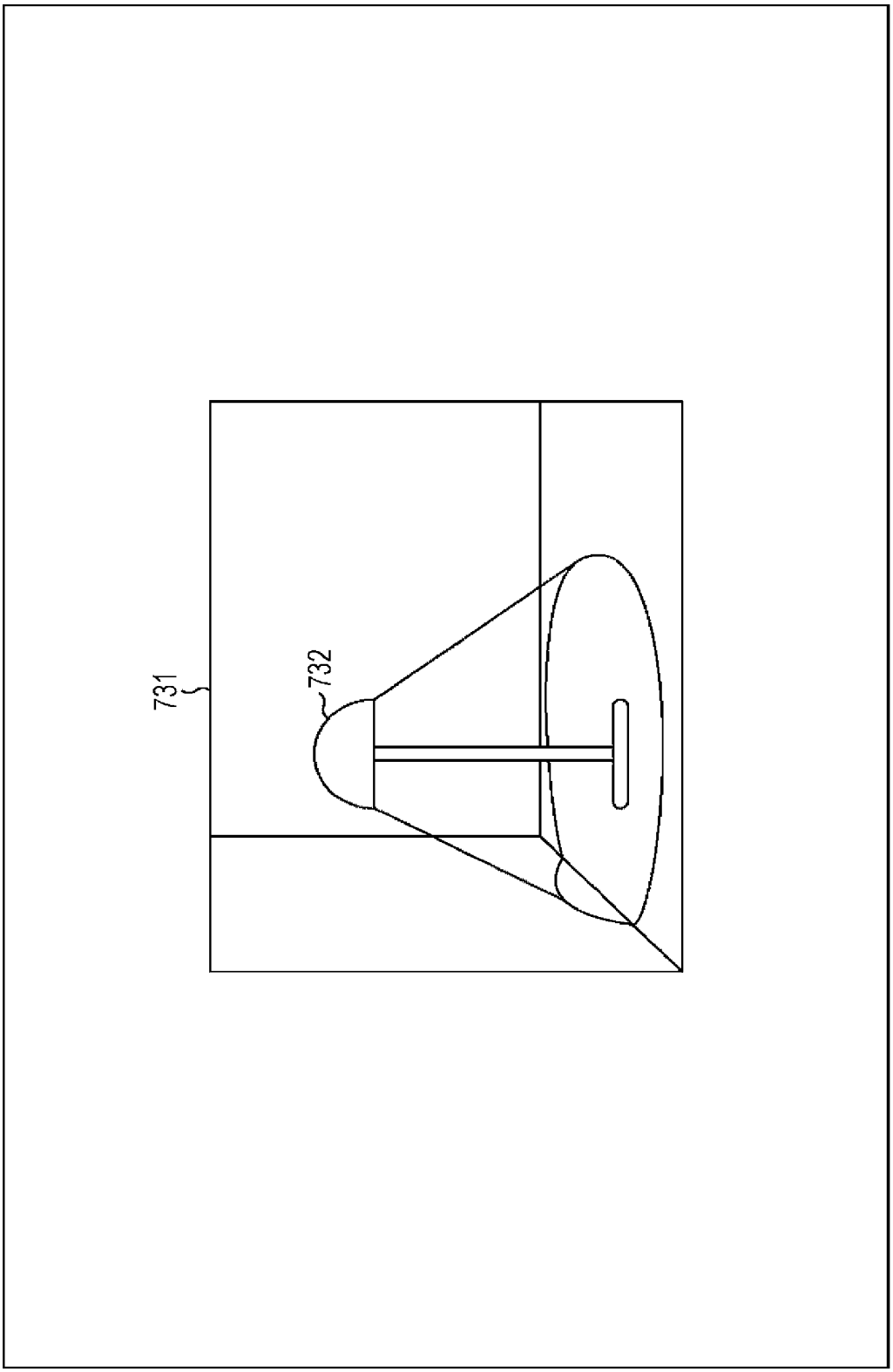
[Fig. 40]

FIG. 40


MEASUREMENT PROCESS START
RECEIVE AREA DESIGNATION IN VIRTUAL CAPTURED IMAGE
S441
MEASURE LENGTH OF DESIGNATED AREA BASED ON DEPTH INFORMATION AND BASE-LINE LENGTH INFORMATION
S442
END

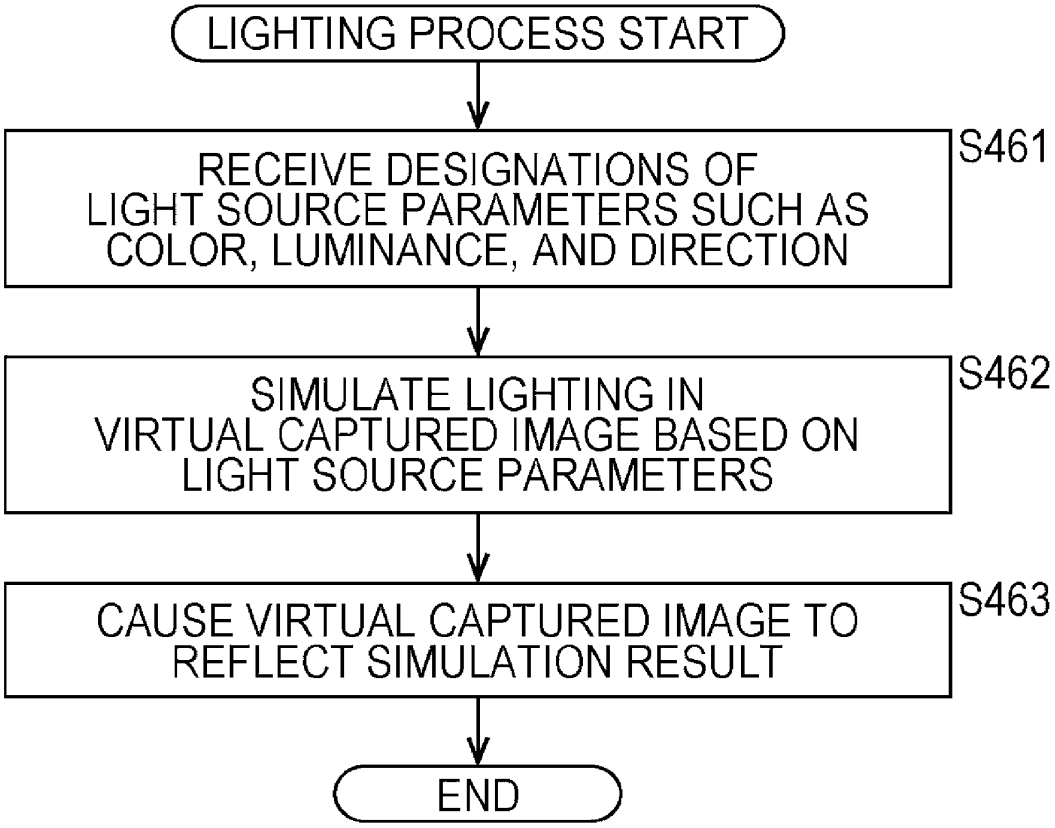
[Fig. 41]

FIG. 41



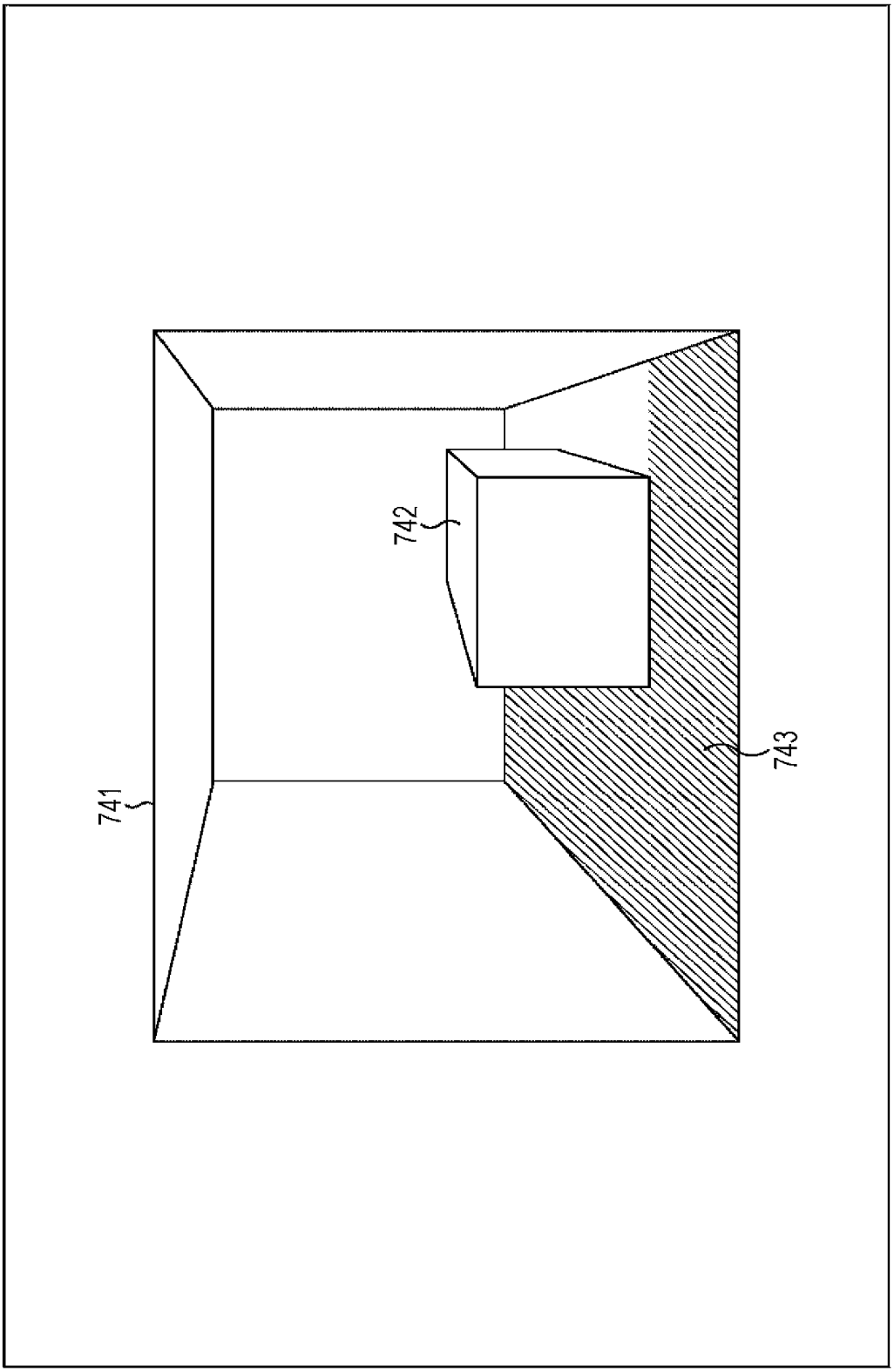
[Fig. 42]

FIG. 42


LIGHTING PROCESS START
RECEIVE DESIGNATIONS OF LIGHT SOURCE PARAMETERS SUCH AS COLOR, LUMINANCE, AND DIRECTION
S461
SIMULATE LIGHTING IN VIRTUAL CAPTURED IMAGE BASED ON LIGHT SOURCE PARAMETERS
S462
CAUSE VIRTUAL CAPTURED IMAGE TO REFLECT SIMULATION RESULT
S463
END

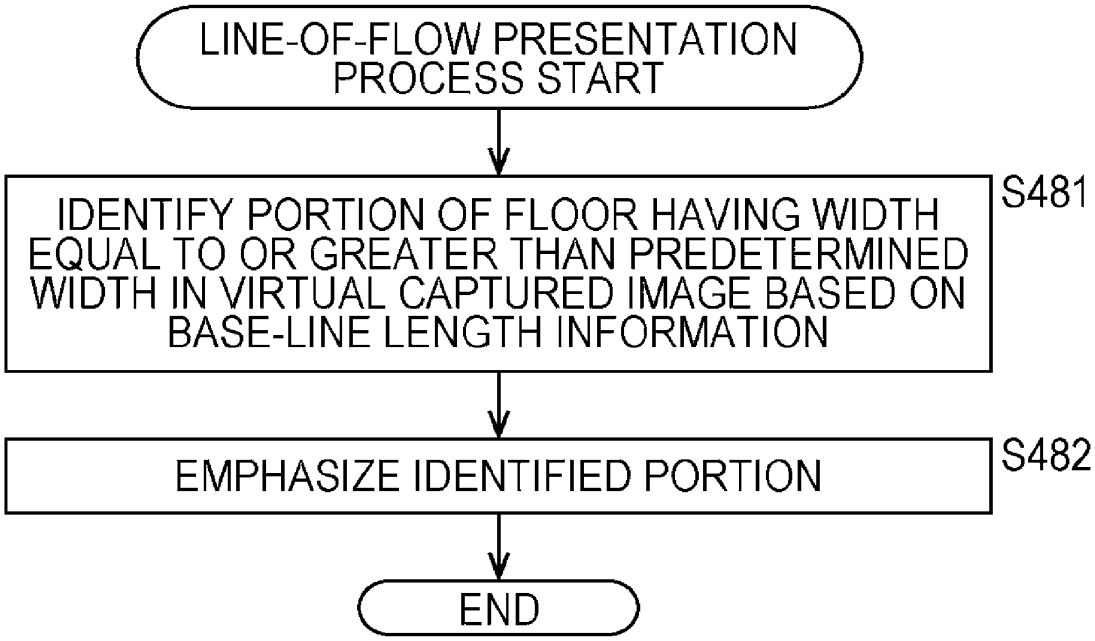
[Fig. 43]

FIG. 43



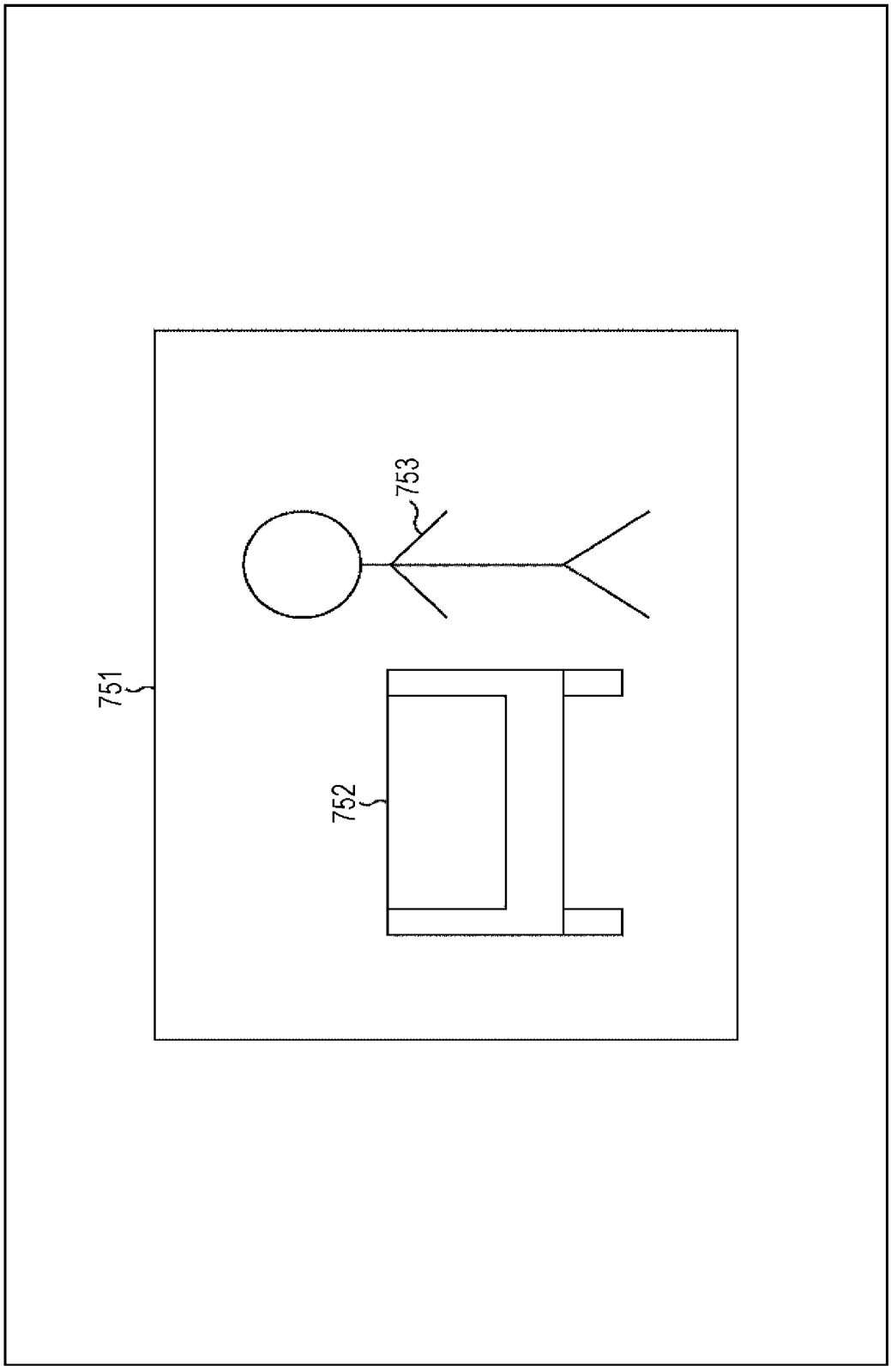
[Fig. 44]

FIG. 44


LINE-OF-FLOW PRESENTATION PROCESS START
IDENTIFY PORTION OF FLOOR HAVING WIDTH EQUAL TO OR GREATER THAN PREDETERMINED WIDTH IN VIRTUAL CAPTURED IMAGE BASED ON BASE-LINE LENGTH INFORMATION
S481
EMPHASIZE IDENTIFIED PORTION
S482
END

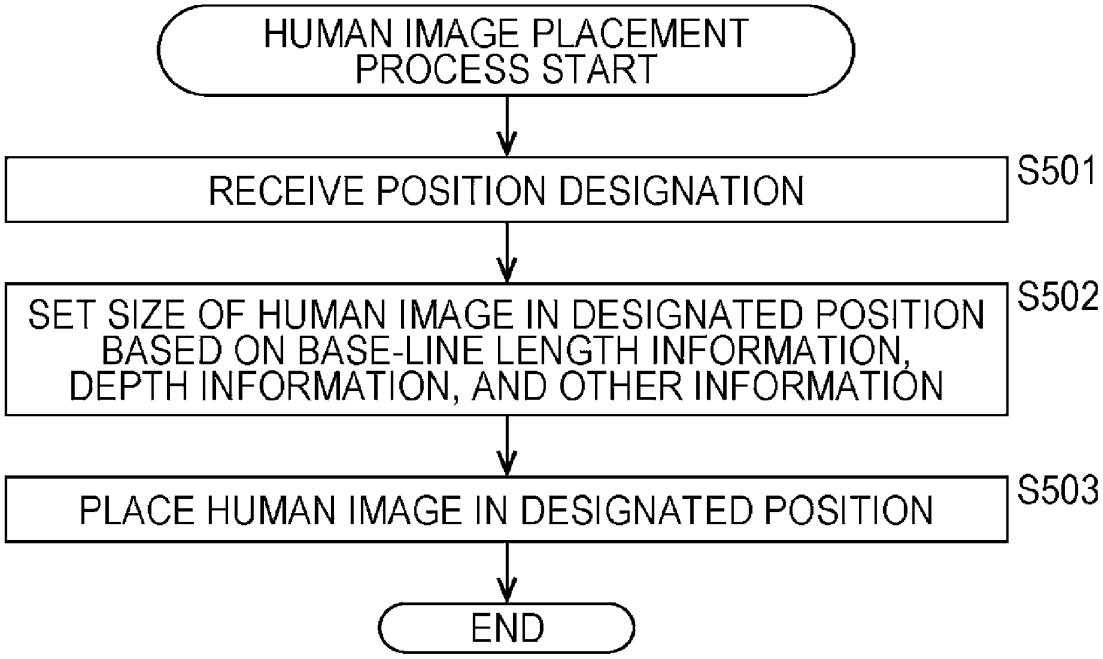
[Fig. 45]

FIG. 45



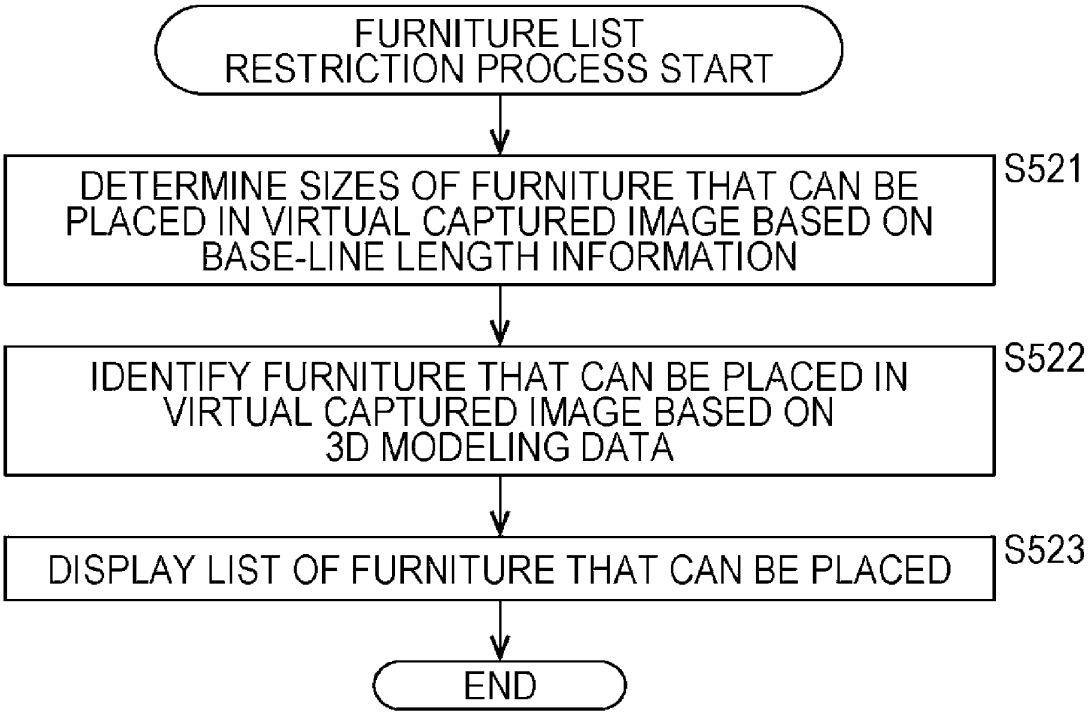
[Fig. 46]

FIG. 46


HUMAN IMAGE PLACEMENT PROCESS START
RECEIVE POSITION DESIGNATION
S501
SET SIZE OF HUMAN IMAGE IN DESIGNATED POSITION BASED ON BASE-LINE LENGTH INFORMATION, DEPTH INFORMATION, AND OTHER INFORMATION
S502
PLACE HUMAN IMAGE IN DESIGNATED POSITION
S503
END

[Fig. 47]

FIG. 47


FURNITURE LIST RESTRICTION PROCESS START
DETERMINE SIZES OF FURNITURE THAT CAN BE PLACED IN VIRTUAL CAPTURED IMAGE BASED ON BASE-LINE LENGTH INFORMATION
S521
IDENTIFY FURNITURE THAT CAN BE PLACED IN VIRTUAL CAPTURED IMAGE BASED ON 3D MODELING DATA
S522
DISPLAY LIST OF FURNITURE THAT CAN BE PLACED
S523
END

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2014/004507

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06T3/00 H04N5/45 H04N13/02 H04N13/00
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)
G06T 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, 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	WO 2013/029675 A1 (METAIO GMBH [DE]; BENHIMANE SELIM [DE]; LIEBERKNECHT SEBASTIAN [DE]; H) 7 March 2013 (2013-03-07) page 29, line 34 - page 30, line 27 page 33, line 25 - page 34, line 2 page 3, line 8 - line 10	1-23
A	WO 2011/102818 A1 (THOMSON LICENSING [FR]; BOYCE JILL MACDONALD [US]; RAMASWAMY KUMAR [US) 25 August 2011 (2011-08-25) claims 1,2	1-23
A	US 2007/156017 A1 (LAMPRECHT BEN [US] ET AL) 5 July 2007 (2007-07-05) claim 1; figure 6a	1-23

☐ 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
5 November 2014	13/11/2014

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	Thieme, Markus

1

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2014/004507

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2013029675 A1	07-03-2013	CN 103988226 A	13-08-2014
		EP 2751777 A1	09-07-2014
		US 2014293016 A1	02-10-2014
		WO 2013029675 A1	07-03-2013
WO 2011102818 A1	25-08-2011	CN 102860014 A	02-01-2013
		EP 2537346 A1	26-12-2012
		JP 2013520866 A	06-06-2013
		KR 20120131185 A	04-12-2012
		US 2012314029 A1	13-12-2012
		WO 2011102818 A1	25-08-2011
US 2007156017 A1	05-07-2007	US 2007156017 A1	05-07-2007
		US 2011050852 A1	03-03-2011

Form PCT/ISA/210 (patent family annex) (April 2005)

Electronic Acknowledgement Receipt	
EFS ID:	43227163
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	12-JUL-2021
Filing Date:	18-MAY-2021
Time Stamp:	17:33:51
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)	IDS-P001USC5.PDF	187235 829fdad0f71350d4a9732bea8ba83f34183c779d	no	2

Warnings:

Information:					
This is not an USPTO supplied IDS fillable form					
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Information:					
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Information:					
6	Foreign Reference	WO_2015037211_A1.pdf	5143009 e1aa7c37c62d1fcd3d8ea67ab7ade5264b6af9ce	no	117
Warnings:					
Information:					
		Total Files Size (in bytes):	52632408		

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

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

New International Application Filed with the USPTO as a Receiving Office

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PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	
	Attorney Docket Number	103033-1252977-P001USC5

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code [4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	103048046	CN		Apr 17, 2013	Zhejiang University		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
		17/317,809 , "U.S. Patent Application No.", Optical System for Collecting Distance Information Within a Field, May 11, 2021, 40 pages	

EXAMINER SIGNATURE

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	
	Attorney Docket Number	103033-1252977-P001USC5

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document.
[4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ William Shaffer /	Date (YYYY-MM-DD)	2021-07-09
Name/Print	William L. Shaffer	Registration Number	37,234

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Electronic Acknowledgement Receipt	
EFS ID:	43384226
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	29-JUL-2021
Filing Date:	18-MAY-2021
Time Stamp:	20:37:46
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	Foreign Reference	CN103048046-with-eng-abstract.pdf	556262 826e36e6adbf52baf73123515c5bd697f5176c02	no	10

Warnings:

Information:					
2	Non Patent Literature	P001USC4-APPLICATION.pdf	3408899 65e8f4aeba1e2ec774ab3c47909743c8f4e410dd	no	81
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Information:					
3	Information Disclosure Statement (IDS) Form (SB08)	IDS-P001USC5-1252977.pdf	184797 64d7806d1cf227966a1c3d08544c57ebe08732a1	no	2
Warnings:					
Information:					
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			Total Files Size (in bytes):	4149958	

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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.

Abstract of CN103048046 (A)

The invention discloses a double-beam spectrometer, which comprises a light source for emitting reference light and detection light and a spectrometer main unit. The double-beam spectrometer is also provided with a first optical fiber, a second optical fiber and a third optical fiber, wherein the first optical fiber is used for transmitting the reference light from the light source to the spectrometer main unit; the second optical fiber is used for transmitting the detection light from the light source to a sample; and the third optical fiber is used for transmitting the detection light with sample information from the sample to the spectrometer main unit. The spectrometer main unit comprises a slit piece, a collimating lens, a plane grating, an imaging lens, a cylindrical lens and an area array detector, which are sequentially arranged along a light path. The emergent light of the first and second optical fibers enters the slit piece. The reference light and the detection light are simultaneously displayed and received, and the influence of light source fluctuation, stray light and electrical noise is effectively eliminated.

Abstract of CN103048046 (A)

The invention discloses a double-beam spectrometer, which comprises a light source for emitting reference light and detection light and a spectrometer main unit. The double-beam spectrometer is also provided with a first optical fiber, a second optical fiber and a third optical fiber, wherein the first optical fiber is used for transmitting the reference light from the light source to the spectrometer main unit; the second optical fiber is used for transmitting the detection light from the light source to a sample; and the third optical fiber is used for transmitting the detection light with sample information from the sample to the spectrometer main unit. The spectrometer main unit comprises a slit piece, a collimating lens, a plane grating, an imaging lens, a cylindrical lens and an area array detector, which are sequentially arranged along a light path. The emergent light of the first and second optical fibers enters the slit piece. The reference light and the detection light are simultaneously displayed and received, and the influence of light source fluctuation, stray light and electrical noise is effectively eliminated.

(19)中华人民共和国国家知识产权局

(12)发明专利

(10)授权公告号 CN 103048046 B
(45)授权公告日 2015.02.25

(21)申请号 201210563398.0

(22)申请日 2012.12.21

(73)专利权人 浙江大学
地址 310027 浙江省杭州市西湖区浙大路38号

(72)发明人 刘康 庄振锋 余飞鸿

(74)专利代理机构 杭州天勤知识产权代理有限公司 33224
代理人 胡红娟

(51)Int.Cl.
G01J 3/42(2006.01)
G01N 21/25(2006.01)

(56)对比文件
US 6204919 B1, 2001.03.20,
CN 202126393 U, 2012.01.25,
CN 2323371 Y, 1999.06.09,
CN 2662247 Y, 2004.12.08,
程梁. 微型光谱仪系统的研究及其应用.《中国博士学位论文全文数据库 工程科技Ⅱ辑》. 2008,
谢炜 等. 一种微型光纤光谱仪的研制及其性能测试.《中国计量学院学报》. 2012,

审查员 丁文

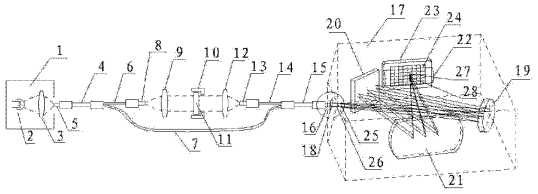
权利要求书1页 说明书5页 附图1页

(54)发明名称

双光束光谱仪

(57)摘要

本发明公开了一种双光束光谱仪，包括用于发出参考光和探测光的光源，以及光谱仪主机，还设有：第一光纤，用于将来自光源的参考光输送至光谱仪主机；第二光纤，用于将来自光源的探测光输送至样品；第三光纤，用于将来自样品的已带有样品信息的探测光输送至光谱仪主机；所述光谱仪主机包括沿光路依次布置的狭缝片、准直镜、平面光栅、成像镜、柱面镜和面阵探测器；所述第一光纤和第三光纤的出射光线均进入所述狭缝片。本发明将参考光和探测光同时显示并接收，有效消除了光源波动、杂散光、电噪声的影响。



CN 103048046 B

1. 一种双光束光谱仪，包括用于发出参考光和探测光的光源，以及光谱仪主机，其特征在于，还设有：

第一光纤，用于将来自光源的参考光输送至光谱仪主机；

第二光纤，用于将来自光源的探测光输送至样品；

第三光纤，用于将来自样品的已带有样品信息的探测光输送至光谱仪主机；

所述光谱仪主机包括沿光路依次布置的狭缝片、准直镜、平面光栅、成像镜、柱面镜和面阵探测器；所述第一光纤和第三光纤的出射光线均进入所述狭缝片；

所述第一光纤、第二光纤和第三光纤组成双芯光纤，该双芯光纤具有贴近光源的第一双芯端口，以及靠近狭缝片的第二双芯端口。

2. 如权利要求 1 所述的双光束光谱仪，其特征在于，所述第一光纤和第二光纤的输入端组成所述的第一双芯端口，第一光纤和第三光纤的输出端组成第二双芯端口，所述第二光纤的输出端为第一单芯端口，所述第三光纤的输入端为第二单芯端口；所述的第一双芯端口、第二双芯端口、第一单芯端口和第二单芯端口均为 SMA905 接口，其出射或接收的光数值孔径为 0.22。

3. 如权利要求 2 所述的双光束光谱仪，其特征在于，所述第一双芯端口和第二双芯端口的两个纤芯直径相同，且两个纤芯沿端面直径方向对称排列。

4. 如权利要求 3 所述的双光束光谱仪，其特征在于，所述纤芯的直径为 100um 或 200um。

5. 如权利要求 4 所述的双光束光谱仪，其特征在于，所述两个纤芯中心距离为 600um、800um、1000um、1200um 或 1400um。

6. 如权利要求 5 所述的双光束光谱仪，其特征在于，所述光源包括发光灯泡，以及用于将光束聚焦到第一双芯端口端面的光束整形透镜。

7. 如权利要求 6 所述的双光束光谱仪，其特征在于，所述狭缝片设置为单缝或双缝。

8. 如权利要求 7 所述的双光束光谱仪，其特征在于，所述单缝位于狭缝片中芯，其缝宽 10um ～ 100um，狭缝长度 1mm；所述双缝位于狭缝片的中心，且竖直排列，其缝宽 10um ～ 100um，单缝长度 400um。

9. 如权利要求 8 所述的双光束光谱仪，其特征在于，所述面阵探测器 CCD、CMOS 或者 PDA 器件。

双光束光谱仪

技术领域

[0001] 本发明属于光谱测量领域，涉及一种可以同时显示和分析参考光和探测光的双光束光谱仪。

背景技术

[0002] 光谱仪是进行光谱研究和分析的基本光学检测仪器，通过对透射、反射、吸收光谱的测量来实现对光成分的分析、材料属性的分析、物质成分的鉴定等。目前，光谱仪广泛应用于光学检测、生物化学分析、冶金工业、环境检测、大气遥感、天文研究等领域，对于光谱测量的准确性要求也越来越高。

[0003] 光谱仪按照其仪器的光路结构通常可以分为单光束光谱仪和双光束光谱仪两类。单光束光谱仪采用单束复色光分别两次测量参考光和探测光来进行光谱测量和分析。该种光谱仪无法同时显示和测量参考光和探测光，其光路结构无法抵消光源波动带来的误差，同时由于需要取放被测样品会导致光束采集系统的机械位置变动而进一步引入测量误差；但是单光束光谱仪结构简单，体积可以做的很小，便于携带，并且由于是采用单束光照明被测样品，光强相比较双光束光谱仪的强，信噪较高，仪器灵敏度高，价格较低。双光束光谱仪运用两束单色光同时测量和显示参考光和探测光，可以一定程度上抵消光源波动、杂散光和电路噪声带来的影响，在用于定点测量时，具有更好的光度准确度。双光路光谱仪内部运用机械转动机构来对单色波长进行扫描致使测量速度大大受限，另外双光束的机构是将同一束光分成两束降低了参考光的光强致使信噪比下降，这类仪器结构复杂，价格昂贵。

[0004] 国际上对于光谱仪中单光束和双光束的优劣看法不一：一种认为双光束光谱仪可以抵消一部分杂散光、电路噪声、光源波动对光谱仪稳定性的影响，光谱测量的结果准确性更高；另一种则认为由于光谱预处理算法的发展，单光束光谱仪的可靠性可以用软件来进行补偿，其性噪比高、体积小、测量快速、价格低廉的特点使其更有优势。

发明内容

[0005] 为克服传统单光束光谱仪和双光束光谱仪存在的问题和不足，本发明提供了一种能快速测量、具有双光路结构的双光束光谱仪，其内部没有转动机械部件，采集面阵探测器同时采集参考光和探测光，实现对光谱的准确、快速测量。

[0006] 一种双光束光谱仪，包括用于发出参考光和探测光的光源，以及光谱仪主机，其特征在于，还设有：

[0007] 第一光纤，用于将来自光源的参考光输送至光谱仪主机；

[0008] 第二光纤，用于将来自光源的探测光输送至样品；

[0009] 第三光纤，用于将来自样品的已带有样品信息的探测光输送至光谱仪主机；

[0010] 所述光谱仪主机包括沿光路依次布置的狭缝片、准直镜、平面光栅、成像镜、柱面镜和面阵探测器；所述第一光纤和第三光纤的出射光线均进入所述狭缝片。

[0011] 所述第一光纤、第二光纤和第三光纤组成双芯光纤，该双芯光纤具有贴近光源的

第一双芯端口，以及靠近狭缝片的第二双芯端口。

[0012] 采用双芯光纤可以有效的将光源光分成两束，形成参考光和探测光，并最后同时由光谱仪探测器接收。这种光纤连接的模式，结构紧凑，成本低，有效避免了开放光路装调的困难，适应了系统微型化的需求。

[0013] 所述第一光纤和第二光纤的输入端组成所述的第一双芯端口，第一光纤和第三光纤的输出端组成第二双芯端口，所述第二光纤的输出端为第一单芯端口，所述第三光纤的输入端为第二单芯端口；所述的第一双芯端口、第二双芯端口、第一单芯端口和第二单芯端口均为 SMA905 接口，其出射或接收的光数值孔径 (NA) 为 0.22。SMA905 和 NA0.22 为光谱仪器中最为常用的光纤接口方式和数值孔径，使用该种接口和数值孔径可以保证双芯光纤与光谱仪主机的连接。

[0014] 第二光纤和第三光纤之间依次设有第一光纤准直镜、样品架和第二光纤准直镜，第一光纤准直镜用于将第二光纤出射的光束准直后照射到样品上，第二光纤准直镜用于将带有样品信息的探测光聚焦到第二单芯端口并耦合进入第三单芯光纤。上述的第一光纤准直镜和第一光纤准直镜可以是单透镜、双胶合消色差透镜、双分离消色差透镜或自聚焦透镜。

[0015] 所述光源包括发光灯泡，以及用于将光束聚焦到第一双芯端口端面的光束整形透镜。发光灯泡根据测量波段可以选取氘灯（紫外可见波段）、卤钨灯（可见近红外波段）或者氙灯（紫外可见近红外波段）。

[0016] 所述第一双芯端口和第二双芯端口的两个纤芯直径相同，且两个纤芯沿端面直径方向对称排列。第一双芯端口中两个相同直径纤芯，可以保证从光源接收到同等光强的光用作参考光（第一光纤）和照明光束（第二光纤）。第二双芯端口中两个相同直径的纤芯，其中一个纤芯为第一光纤，另一个纤芯（第三光纤）必须保证与第一光纤纤芯相同，保证在无样品情况下第一光纤与第二、三光纤两路光路的能量同等传输。

[0017] 双芯光纤的设计中，纤芯的直径需要与两纤芯中心距离相配合。纤芯的直径决定了探测器像面上成像点的大小，纤芯的中心距离决定了两束光（第一光纤和第三光纤）在探测器上成像点的距离。如果两者设置不当，会造成两束光成像的串扰，无法再探测器上分辨两束光的光强。本发明选用了 100um 纤芯的光纤配合中心距离 800um，可以很清晰的在探测器上分辨出参考光和探测光。纤芯的中心距离不可以过大，否则也会影响成像质量，考虑到实际加工的工艺，纤芯和纤芯距离必须是偶数，故所述纤芯的直径为 100um 或 200um，所述两个纤芯中心距离为 600um、800um、1000um、1200um 或 1400um。

[0018] 所述狭缝片设置为单缝或双缝；所述单缝位于狭缝片中芯，其缝宽 10um ～ 100um；所述双缝位于狭缝片的中心，且竖直排列，其缝宽 10um ～ 100um。狭缝的缝宽与光谱仪的分辨率有关，缝宽越小分辨率越高采集到的光能也就越小，光谱仪的分辨率要求与测量要求有关。本实例选取了 25um 宽的狭缝片来构建光谱仪。单缝结构：狭缝长度需要不影响双芯端口两个纤芯的通光，本发明狭缝长度设置为 1mm；双缝结构：单缝的长度需要确保双芯端口的单个纤芯的通光，本发明将单缝长度设置为 400um。

[0019] 所述面阵探测器 CCD、CMOS 或者 PDA 器件。CCD(Charge-CoupledDevice) 中文全称：电荷耦合器件。CMOS(Complementary Metal OxideSemiconductor) 中文全称：互补金属氧化物半导体。PDA(Photo-Diode Arrary) 中文全称：光电二极管阵列。针对目前主流

的商品化成像器件，本实例选取了成像质量更好，噪声更小的 CCD 器件作为光谱仪的光电探测器。

[0020] 本发明的优点是：

[0021] (1) 双光束光谱仪同时用面阵探测器接收并显示参考光和探测光，有效消除了光源波动、杂散光、电噪声的影响，避免了单光束光谱仪需要两次测量带来的测量误差；

[0022] (2) 本发明的双光束光谱仪不包含机械扫描转动结构，测量速度快，体积小，成本低，可以适合于各种条件下的光谱测量。

附图说明

[0023] 图 1 为本发明双光束光谱仪的光学结构示意图。

[0024] 图 2 为本发明的双芯光纤和狭缝片连接示意图。

[0025] 图 3 为本发明的面阵探测器成像结果示意图。

[0026] 图 4 为本发明的双芯端口和单芯端口示意图。

具体实施方式

[0027] 下面结合附图对本发明的双光束光谱仪作进一步的说明。

[0028] 如图 1 所示，一种双光束光谱仪包括光源 1、第一光纤 7、第二光纤 6、第三光纤 14 和光谱仪主机 17，光谱仪主机 17 包括沿光路依次布置的狭缝片 18、准直镜 19、平面光栅 20、成像镜 21、柱面镜 22 和面阵探测器 23。

[0029] 光源 1 包括发光灯泡 2 和光束整形透镜 3；光束整形透镜 3 用于将发光灯泡 2 发出的探测光和参考光聚焦到光纤端面上，有效提高了光源效率和光纤耦合效率。

[0030] 第一光纤 7、第二光纤 6 和第三光纤 14 组成双芯光纤 4 和双芯光纤 15，双芯光纤 4 具有贴近光源 1 的第一双芯端口 5，双芯光纤 15 具有靠近狭缝片 18 的第二双芯端口 16；第一双芯端口 5 包括第一光纤 7 的输入端和第二光纤 6 的输入端，第二双芯端口 16 包括第一光纤 7 的输出端和第三光纤 14 的输出端；第二光纤 6 的输出端为第一单芯端口 8，第三光纤 14 的输入端为第二单芯端口 13。

[0031] 如图 2 所示，第一双芯端口 5 和第二双芯端口 16 的两个纤芯直径相同，可以为 75um、100um 或 200um；且两个纤芯沿端面直径方向对称排列，纤芯中心距离可以是 600um、800um 或 1400um，本发明优选为 100um 纤芯的光纤配合中心距离为 800um。

[0032] 第一单芯端口 8 和第二单芯端口 13 具有单个光纤纤芯，纤芯位于端面中心，纤芯直径可以为 75um、100um 或 200um。

[0033] 第一光纤 7、第二光纤 6 和第三光纤 14 的纤芯通光波段为 200 ～ 1100nm，且纤芯为普通多模光纤。

[0034] 第二光纤 6 和第三光纤 14 之间依次设有第一光纤准直镜 9、样品架 10 和第二光纤准直镜 12，第一光纤准直镜 9 用于将第二光纤 6 出射的光束准直后照射到样品 11 上，第二光纤准直镜 12 用于将带有样品信息的探测光聚焦到第二单芯端口 13 并耦合进入第三光纤 14。

[0035] 第一光纤准直镜 9 和第二光纤准直镜 12 可以是单透镜、双胶合消色差透镜、双分离消色差透镜或自聚焦透镜。

[0036] 光谱仪主机 17 为尔尼特纳光学结构，第二双芯端口 16 紧贴狭缝片 18，如图 3 所示，狭缝片 18 的缝可以为单缝 30 或双缝 29。若采用单缝 30 的狭缝片 18，单缝 30 应位于狭缝片中心，缝宽 10um ～ 100um，狭缝长度 1mm ；若采用双缝 29 的狭缝片，双缝 29 的两个狭缝位于狭缝片的中心，竖直排列，缝宽 10um ～ 100um，单缝长度 400um。狭缝的宽度与光谱仪的分辨率有关，缝宽的选取取决于光谱测量的分辨率要求。

[0037] 准直镜 19 为球面发射镜 ；成像镜 21 可以是球面反射镜，也可以是校正慧差的抛物面反射镜，且成像镜表面镀铝，具有较高的能量利用率。

[0038] 平面光栅 20 可以是平面刻划光栅或平面全息光栅 ；本发明优选为平面全息光栅，其具有更好的色散效率和更低的杂散光。

[0039] 由于面阵探测器 23 接收到的是色散后的狭缝像（长条形），必须使用柱面镜 22 会聚光谱仪非色散方向的光，将长条形的像斑会聚到一点，提高光能利用率并保证参考光和探测光不会在面阵探测器 23 上相互重叠和串扰。该柱面镜 22 可以是普通柱面镜、楔形柱面镜或者自由曲面柱面镜，其材料可以是石英玻璃或 K9 玻璃。

[0040] 面阵探测器 23 可以是 CCD、CMOS 或者 PDA 器件，面阵探测器 23 光谱范围可以是紫外、可见、近红外波段范围。本发明采用 SONY 公司的 ICX285AL（黑白）探测器，具有较好的分辨率和灵敏度。面阵探测器 23 的光敏元表面 24 如图 4 所示，认为该面阵探测器 23 接收到的上半部分光谱 31 均为色散后的探测光，下半部分光谱 32 均为色散后的参考光。

[0041] 上述的装置工作过程如下 ：

[0042] 发光灯泡 2 发出的参考光和探测光在光束整形透镜 3 作用下，经第一双芯端口 4 分别进入第一光纤 7 和第二光纤 6，参考光从第二双芯端口 16 出射至狭缝片 18，探测光经第一单芯端口 8 出射并通过第一光纤准直镜 9 作用后照射到样品 11 上，第二光纤准直镜 12 将来自样品 11 的且带有样品信息的探测光聚焦到第二单芯端口 12 并耦合进入第三光纤 14 传输，然后带有样品信息的探测光经第二双芯端口 16 出射至狭缝片 18，参考光和探测光沿狭缝长度方向竖直排列，两束光经过准直镜 19 后平行入射到平面光栅 20 上，平面光栅 20 将两束光色散后由成像镜 21 成像，柱面镜 22 将两束光在非色散方向聚焦，并在面阵探测器 23 的光敏元表面 24 上同时成像为参考光谱 27 和探测光谱 28。

[0043] 本发明的双光束光谱仪，参考光和探测光的光能损耗不一致，即在光路中不放置样品 11 时，面阵探测器 23 接收到的两路光能信号 27 和 28 不相等，所以，在进行样品透过率计算时需要进行补偿，补偿系数 η 定义为 ：

[0044]

$$\eta = \frac{I_{sample_c}(\lambda_i)}{I_{ref_c}(\lambda_i)}$$

[0045] 式中，$I_{sample_c}(\lambda_i)$表示不放置样品 11 时光谱仪接收的探测光的光谱分布，$I_{ref_c}(\lambda_i)$表示同一时间参考光的光谱分布。最终计算样品透过率光谱分布需要将加上该补偿系数 η ：

[0046]

$$T(\lambda_i) = \eta \cdot \frac{I_{sample}(\lambda_i)}{I_{ref}(\lambda_i)}$$

[0047] 式中，Isample(λi)表示带有样品信息的探测光的光谱分布，Iref(λi)表示参考光的光谱分布；样品测量之前需要对光谱仪进行波长定标。

[0048] 本发明最终可以将参考光和探测光同时显示并接收，有效消除了光源波动、杂散光、电噪声的影响，并解决了单光束光谱仪需要两次测量的不便和误差。本发明的光谱仪不包含机械扫描转动结构，测量速度快。本发明结合一般单光束光谱仪和双光束光谱仪特点的同时解决了两者的技术缺陷，可以快速精确进行光谱测量。

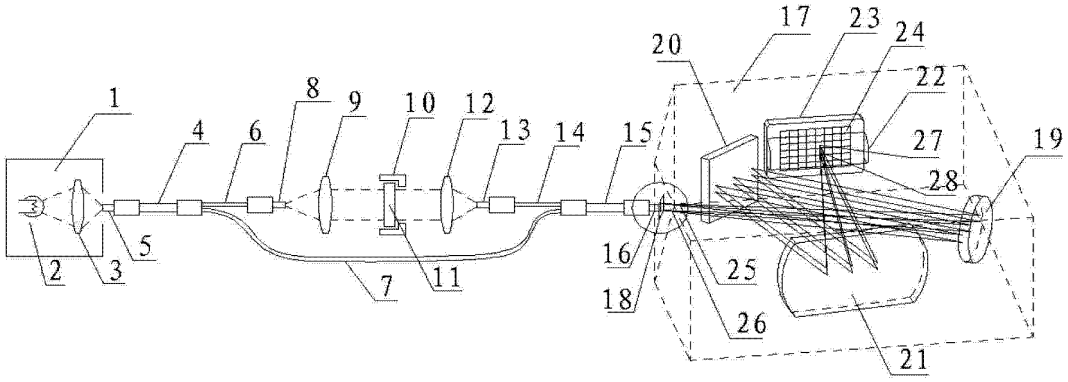

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图 1

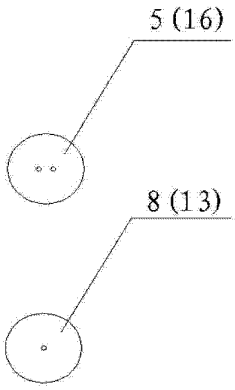

5 (16)
8 (13)

图 2

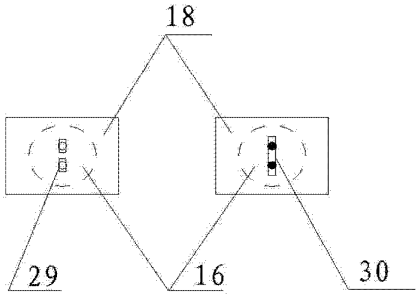

18
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16
30

图 3

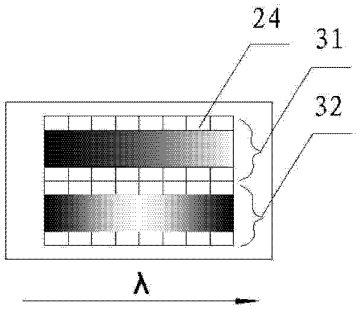

24
31
32
λ

图 4

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2878
	Examiner Name	Cheryl P Gibson Baylor
	Attorney Docket Number	103033-1252977

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1.	11086013		Aug 10, 2021	Pacala et al.	

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	2.	20150115131		4/30/2015	Webster, et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	3.	2007103590	JP		4/19/2007	Nikon Corp.		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	4.	U.S. Patent Application No. 16/584,515, Notice of Allowance, mailed August 13, 2021, 10 pages	
	5.	U.S. Patent Application No. 17/317,809, Notice of Allowance, mailed August 18, 2021, 33 pages	
	6.	U.S. Patent Application No. 16/046,643, Notice of Allowance, mailed August 18, 2021, 18 pages	

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	Examiner Name	Cheryl P Gibson Baylor
	Attorney Docket Number	103033-1252977

EXAMINER SIGNATURE			
Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document.
[4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2021-08-20
Name/Print	William L. Shaffer	Registration Number	37,234

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
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	Art Unit	2878
	Examiner Name	Cheryl P Gibson Baylor
	Attorney Docket Number	103033-1252977

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

JP2007103590A IMAGE PICK-UP DEVICE, FOCUS DETECTOR AND IMAGE PICK-UP SYSTEM

[0001] The present invention relates to an image sensor capable of acquiring a captured image and acquiring a shooting condition (state) such as focus detection, a focus detection apparatus including the same, and an imaging system.

[0002] It has been proposed that pixel cells for captured images are two-dimensionally arranged on a substrate of an image sensor, and pixel cells for focus detection are arranged in a predetermined layout therein (for example, Patent Documents 1 and 2). See). Further, in Patent Document 1, the focus detection by the phase difference detection method is taken as an example, and the pixel cell is made the same size as the pixel cell for the photographed image. In Patent Document 2, the focus detection of the contrast detection method is taken as an example, and the pixel cell is made smaller in size than the pixel cell for the photographed image.
特開２００３−２５００８０号公報特開２００４−３６１６１１号公報

[0003] However, in the imaging device described above, the size of the focus detection pixel cell is the same as that of the captured image pixel cell (or smaller than the captured image pixel cell), so that the focus detection responsiveness is reduced at low luminance. There was a problem. This problem is not limited to focus detection pixel cells, and can occur in the same manner when pixel cells for distance measurement, photometry, and the like are arranged. An object of the present invention is to provide an imaging device, a focus detection device, and an imaging system that can improve responsiveness at low luminance when acquiring imaging conditions (for example, performing focus detection or distance measurement). .

[0004] An imaging device according to the present invention includes a first pixel cell including a first photoelectric conversion unit that generates an electric charge according to incident light and an optical that collects incident light in the imaging device that captures an image by a photographing optical system. A second pixel cell including an element and a second photoelectric conversion unit that generates an electric charge according to light condensed by the optical element, and having a cell size larger than that of the first pixel cell. The first pixel cell and the second pixel cell are two-dimensionally arranged on the substrate.

[0005] Moreover, it is preferable that the cell size of the second pixel cell is an integer multiple of the first pixel cell. The first and second pixel cells each include an optical element that collects incident light on the first and second photoelectric conversion units, and the optical element of the second pixel cell is the first pixel cell. The aperture size is preferably larger than the optical element of the pixel cell.

[0006] An imaging element according to the present invention includes an optical element that collects incident light in an imaging element that captures an image by a photographing optical system, and a first photoelectric conversion that generates an electric charge according to the light collected by the optical element. A second pixel including a first pixel cell that includes a first pixel cell, an optical element that condenses incident light, and a second photoelectric conversion unit that generates a charge in accordance with the light collected by the optical element A first pixel cell and a second pixel cell are two-dimensionally arranged on a substrate, and an optical element of the second pixel cell is an optical element of the first pixel cell. The opening size is larger than that.

[0007] The optical element of the first pixel cell preferably has an aperture size smaller than 20 μm. In addition, each of the second pixel cells includes a plurality of the second photoelectric conversion units, and each of the plurality of second photoelectric conversion units via the optical element of the second pixel cell, It is preferably substantially conjugate with the exit pupil of the photographing optical system.

[0008] In addition, it is preferable that two of the plurality of second photoelectric conversion units form a pair, and filters of different colors are arranged in each of the two second photoelectric conversion units forming the pair. Further, it is preferable that a focus adjustment state of the photographing optical system is detected based on a photoelectric output obtained by the second pixel cell. In addition, the optical element includes an optical element that collects incident light and a third photoelectric conversion unit that generates an electric charge according to the light collected by the optical element, and the cell size is different from that of the second pixel cell. It is preferable to further include a third pixel cell.

[0009] Moreover, it is preferable that the cell size of the third pixel cell is equal to that of the first pixel cell. Further, it is preferable that a focus adjustment state of the photographing optical system is detected based on a photoelectric output obtained by the second pixel cell and the third pixel cell. The focus detection apparatus of the present invention includes the above-described image sensor and detection means for performing focus detection based on the output of the second pixel cell.

[0010] A focus detection apparatus of the present invention includes the above-described imaging device, and a detection unit that performs focus detection based on at least one of the output of the second pixel cell and the output of the third pixel cell. is there. An imaging system of the present invention includes the above-described focus detection device and a photographing optical system disposed on the object side of the imaging element, and the detection unit performs focus detection of the photographing optical system.

[0011] In addition, the captured image is displayed based on the output of the first pixel cell, and the display of the position of the second pixel cell is superimposed on the captured image as a region where the detection unit performs focus detection. Preferably means are provided. In addition, an image signal at the position of the first pixel cell is generated based on the output of the first pixel cell, and an image signal at the position of the second pixel cell is generated by the second pixel cell. It is preferable that the image forming apparatus includes a generation unit configured to generate by interpolation processing based on the output of the surrounding first pixel cell.

[0012] In addition, when generating the image signal at the position of the second pixel cell, the generating unit generates each color component of the image signal by the interpolation process, and the luminance component of the image signal is converted to the second pixel. It is preferable to generate based on the output of the cell.

[0013] According to the present invention, it is possible to improve the responsiveness at the time of low luminance when acquiring photographing conditions (states) (for example, performing focus detection, distance measurement, photometry, etc.).

[0014] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings. (First Embodiment) Here, an image pickup device capable of acquiring a photographed image and acquiring information related to focus detection will be described. Further, description will be given by taking focus detection by the phase difference detection method as an example. The information related to focus detection is one of various conditions (shooting conditions) when acquiring a shot image, and corresponds to the defocus amount of the shooting optical system arranged on the object side of the image sensor. When the photographing optical system is in focus (ideally defocus amount = 0), a clear subject image is formed on the image sensor.

[0015] The image sensor 10 of the first embodiment includes a pixel cell 11 for a photographed image shown in FIG. 1A and a pixel cell 12 for focus detection shown in FIG. 1B, as shown in FIG. 1C. And arranged on a substrate. In FIG. 1C, each pixel cell 11 and 12 is hatched for easy understanding. FIGS. 1A to 1C are schematic views seen from the photographic optical system side. In addition to the pixel cells 11 and 12, the imaging element 10 is provided with a vertical scanning circuit, a horizontal scanning circuit, and the like (not shown).

[0016] In the present embodiment, each of the pixel cells 11 and 12 has a square shape. In addition, the focus detection pixel cell 12 has a larger cell size than the captured image pixel cell 11, and the four pixel cells 11 can be densely arranged in the size of one pixel cell 12. It is a size. That is, the cell size of the focus detection pixel cell 12 is four times the cell size of the captured image pixel cell 11. In this case, the length A12 of one side of the pixel cell 12 is twice the length A11 of one side of the pixel cell 11.

[0017] On the substrate of the image sensor 10, the pixel cells 11 for captured images are two-dimensionally arranged almost densely, and focus detection pixel cells 12 are periodically embedded therein. The arrangement of the pixel cells 11 is a substantially square lattice. The pixel cell 11 for a captured image (FIG. 1A) is provided with a circular microlens 13 and a rectangular photoelectric conversion unit 14. The microlens 13 is an optical element that collects incident light and guides it to the photoelectric conversion unit 14. The photoelectric conversion unit 14 is a photodiode that generates an electric charge according to the light collected by the microlens 13. Although not shown, any one of RGB color filters is disposed between the microlens 13 and the

photoelectric conversion unit 14. The color filters of the plurality of pixel cells 11 have a predetermined RGB array (for example, a Bayer array).

[0018] In the pixel cell 11, the power of the microlens 13 is set so that an output proportional to the size of the exit pupil of the photographing optical system (that is, the aperture diameter of the photographing optical system) can be obtained. For this purpose, it is necessary to guide the light beam from the entire exit pupil to the photoelectric conversion unit 14 regardless of the exit pupil size, and the exit pupil size when the aperture diameter is maximized (for example, F1.4). The power of the microlens 13 is set based on this.

[0019] The pixel cell 12 for focus detection (FIG. 1B) is provided with a circular microlens 15 and two photoelectric conversion units 16 and 17 having a rectangular shape. The microlens 15 is an optical element that collects incident light and guides it to the photoelectric conversion units 16 and 17. The photoelectric conversion units 16 and 17 are photodiodes that generate charges in accordance with the light collected by the microlens 15, respectively. These two photoelectric conversion units 16 and 17 form a pair and are used for focus detection by the phase difference detection method using the microlens 15.

[0020] In addition, as can be seen from the cross-sectional view of FIG. 2, the pair of photoelectric conversion units 16 and 17 includes a surface p + layer 23 and an n layer 24 of the substrate 22, respectively. A gate insulating film 25 (SiO2 film) is formed on the surface of the substrate 22. Such a cross-sectional structure is similar to the above-described pixel cell 11 for a captured image. In the focus detection pixel cell 12, an infrared cut filter 21 is disposed between the pair of photoelectric conversion units 16 and 17 and the microlens 15 in order to remove infrared light unnecessary for focus detection. Is done. Incidentally, since the pair of photoelectric conversion units 16 and 17 are not provided with a color filter, light beams in the entire wavelength region of visible light are incident.

[0021] Further, in this pixel cell 12, in order to realize focus detection by the phase difference detection method, the pair of photoelectric conversion units 16 and 17 and the exit pupil of the photographing optical system are conjugated via the micro lens 15. . That is, the power of the microlens 15 is set so that the pair of photoelectric conversion units 16 and 17 can be projected onto the exit pupil of the photographing optical system. Such a conjugate relationship is illustrated in FIG. In FIG. 3A, the exit pupil 18 is indicated by a thick dotted line. When the exit pupil 18 is viewed from the direction of the optical axis 19 of the photographing optical system (not shown), it is substantially circular as shown in FIG. The regions 8A and 8B in the exit pupil 18 are regions where the pair of photoelectric conversion units 16 and 17 are projected by the microlens 15 and have a substantially rectangular shape.

[0022] The regions 8A and 8B are arranged substantially symmetrically about the optical axis 19. Then, the light beam that has passed through the region 8 □/ b□ A of the exit pupil 18 enters one photoelectric conversion unit 16, and the light beam that has passed through the region 8 □/ b□ B enters the other photoelectric conversion unit 17. That is, the light beam passing through the exit pupil 18 can be divided into two and guided to the photoelectric conversion units 16 and 17 (pupil division method). It should be noted that when focus detection is performed using the phase difference detection method, when the pair of regions 8A and 8B partially protrudes from the exit pupil 18, light beams guided to the pair of photoelectric conversion units 16 and 17 (light beams used for focus detection). As a result, the focus detection accuracy deteriorates. Accordingly, in the pixel cell 12 for focus detection, the microlens 15 is arranged so that the pair of regions 8A and 8B are accommodated in the exit pupil 18 regardless of the size of the exit pupil 18 (that is, the aperture diameter of the photographing optical system). The power is set. Therefore, the power of the microlens 15 is set based on the size of the exit pupil 18 when the aperture diameter is minimum (for example, F2.8 or F5.6).

[0023] Furthermore, in this embodiment, the microlenses 13 and 15 are circular (FIGS. 1A and 1B), and the respective opening sizes (diameters) are the lengths A11 and A12 of one side of the pixel cells 11 and 12, respectively. Configured to be equal. Accordingly, by making the length A12 of one side of the pixel cell 12 longer than the length A11 of one side of the pixel cell 11 as described above, the aperture size of the microlens 15 for focus detection is set to that of the microlens 13 for the photographed image. It can be larger than the opening size. The aperture area can be increased by increasing the aperture size, and many light beams can be incident on the pair of photoelectric conversion units 16 and 17 through the microlens 15.

[0024] Further, the charge accumulated in the photoelectric conversion unit 14 of the pixel cell 11 for the captured image and the charge accumulated in the pair of photoelectric conversion units 16 and 17 of the pixel cell 12 for focus detection are, for example, FIG. It can be read out by the MOS type circuit configuration

shown in FIG. FIG. 4 shows 4 × 4 pixels (that is, 12 pixel cells 11 and 1 pixel cell 12) of the pixel cell 11, and a readout circuit thereof.

[0025] Since the focus detection pixel cell 12 includes the two photoelectric conversion units 16 and 17, the circuit portion of the pixel cell 12 corresponds to two pixel cells 11 for the captured image. Further, since the cell size of the pixel cell 12 corresponds to four times that of the pixel cell 11, the locations 30 (1), 30 (2) adjacent to the circuit portion of the pixel cell 12 and corresponding to two pixel cells 11.) Becomes empty. These locations 30 (1) and 30 (2) may be dummy.

[0026] The photoelectric conversion unit 14 of the captured image pixel cell 11 and the pair of photoelectric conversion units 16 and 17 of the focus detection pixel cell 12 are respectively a transfer switch MOS transistor 31 and a reset MOS transistor 32. The source follower amplifier MOS transistor 33 and the horizontal selection switch MOS transistor 34 are connected to the vertical output line V. The MOS transistors 31, 32, and 34 are connected to the vertical scanning circuit 41 through control lines R, P, and S, respectively. The vertical scanning circuit 41 controls on / off of the MOS transistors 31 and 33 and the like.

[0027] Further, a load MOS transistor 35 is connected to one end of the vertical output line V, and a horizontal output line H is connected via an output storage capacitor 37 and a horizontal transfer MOS transistor 38. An output amplifier 43 is connected to one end of the horizontal output line H. Further, a horizontal scanning circuit 42 is connected to the MOS transistor 38. The MOS transistor 35 constitutes a source follower similar to the MOS transistor 33 and is connected to a control circuit (not shown) via a control line L. The horizontal scanning circuit 42 controls on / off of the MOS transistor 38.

[0028] When accumulating charges in the photoelectric conversion units 14, 16, and 17, first, the control line L is set to high level to reset the vertical output line V, and then the control line L is set to low level. Next, the vertical scanning circuit 41 sets the control lines R and P to the high level to reset the photoelectric conversion units 14, 16 and 17, and then sets the control lines R and P to the low level. By this operation, the photoelectric conversion units 14, 16, and 17 are reset to a predetermined potential, and charge accumulation in the photoelectric conversion units 14, 16, and 17 is started.

[0029] When reading the charges of the photoelectric conversion units 14, 16, and 17, first, the vertical scanning circuit 41 sets the control line P to the high level to turn on the MOS transistor 31, and the charges of the photoelectric conversion units 14, 16, and 17 are changed. Applied to the gate of the MOS transistor 33. Further, the control line S is set to the high level to turn on the MOS transistor 34, and the charge on the horizontal line is selected as a reading target. At this time, the MOS transistor 33 generates an amplified signal in accordance with the amount of charge applied to its gate, and outputs it to the output storage capacitor 37 via the vertical output line V.

[0030] Each output stored in the output storage capacitor 37 is transferred to the horizontal output line H via the MOS transistor 38 in response to a scanning timing signal from the horizontal scanning circuit 42 to the MOS transistor 38. Further, the signal is transferred to the output amplifier 43 through the horizontal output line H, and read out through the signal amplification in the output amplifier 43. The output of the pixel cell 11 read out in this manner is caused by the electric charge accumulated in the photoelectric conversion unit 14, and is used for displaying a captured image in the imaging system including the imaging device 10 of the first embodiment. It is done. Further, the output of the pixel cell 12 is caused by the electric charges accumulated in the pair of photoelectric conversion units 16 and 17, and in the focus detection apparatus and the imaging system including the imaging device 10 of the first embodiment, the phase difference detection method is used. Used for focus detection.

[0031] When performing phase difference detection type focus detection based on the output of the pixel cell 12, the first subject image is captured from the output related to one of the plurality of pixel cells 12 and the other photoelectric conversion unit 17. The second subject image is taken in from the output related to, and the positional phase difference between the two subject images (that is, the positional deviation amount in the arrangement direction of the pair of photoelectric conversion units 16 and 17) is obtained by, for example, correlation calculation. Then, by converting this phase difference into a defocus amount (that is, a positional deviation amount in the optical axis direction) of the photographing optical system, information related to focus detection is generated.

[0032] In the imaging device 10 of the first embodiment, the aperture size of the focus detection microlens 15 is set to be used for a captured image in order to make the cell size of the focus detection pixel cell 12 larger than

the cell size of the captured image pixel cell 11. The opening size of the microlens 13 can be made larger, and the opening area can be increased accordingly. Therefore, as compared with the case where the focus detection pixel cell 12 has the same cell size as that of the captured image pixel cell 11 (or a cell size smaller than the pixel cell 11), a large amount of light flux passes through a pair of microlenses 15. The light can enter the photoelectric conversion units 16 and 17. As a result, an output level necessary for focus detection can be secured in a normal charge accumulation time even at low luminance, and responsiveness at low luminance can be improved.

[0033] Furthermore, in the image sensor 10 of the first embodiment, even when the cell size of the pixel cell 11 for photographed images is reduced (for example, when the pixel size is reduced to the wavelength order) as the number of pixels increases, the pixels for the photographed images are used. Compared with the microlens 13 of the cell 11, the aperture size of the microlens 15 of the focus detection pixel cell 12 can be ensured, and the influence of diffraction in the microlens 15 can be reduced.

[0034] Here, in order to explain the relationship between the aperture size of the microlens 15 and the influence of diffraction on the microlens 15, diffraction simulations (FIGS. 5 to 9) were performed. The simulation condition assumes a circular exit pupil 18 corresponding to F2.8 (FIG. 5A), assumes an XY coordinate system with the optical axis 19 of the imaging optical system as the origin, and starts from the exit pupil 18. The distance to the microlens 15 is 100 mm, and the size of the rectangular photoelectric conversion unit 16 (FIG. 5B) conjugate to the exit pupil 18 is X = −2 to −12 mm, and Y = −10 to 10 mm. . This size is such that the photoelectric conversion unit 16 is projected in a substantially inscribed manner on the exit pupil 18 in an ideal case where there is no influence of diffraction as in the diffraction image 8C shown in FIG. is there. The wavelength was 500 nm.

[0035] Further, when the microlens 15 is circular (see FIG. 1B) and the opening size (diameter) of the microlens 15 is 20 μm, 10 μm, 4 μm, and 2 μm, the results are shown in FIGS. FIGS. 6A to 9A are schematic shapes of a diffraction image 8C of the photoelectric conversion unit 16 by the microlens 15 having each opening size. FIG. 6B to FIG. 9B are intensity distributions at Y = 0 of each diffraction image 8C.

[0036] As shown in FIGS. 6A and 6B, when the aperture size (diameter) of the microlens 15 is 20 μm, the influence of diffraction is small, and most of the diffraction image 8C (about 96%) is F2. 8 within the exit pupil 18. Further, as shown in FIGS. 7A and 7B, when the aperture size (diameter) of the microlens 15 is 10 μm, the influence of diffraction increases, and a part (base) of the diffraction image 8C is F2.8. It protrudes from the exit pupil 18. The portion included in the exit pupil 18 is about 92%.

[0037] Further, as shown in FIGS. 8A and 8B, when the aperture size (diameter) of the microlens 15 is 4 μm, the influence of the diffraction is further increased, and the edge of the diffraction image 8C is staggered, and the diffraction image 8C. Protrudes from the exit pupil 18 of F2.8. The portion included in the exit pupil 18 is about 81%. Further, as shown in FIGS. 9A and 9B, when the aperture size (diameter) of the microlens 15 is 2 μm, the influence of diffraction further increases, and the diffraction image 8C spreads in a circular shape, and the diffraction image 8C. About half of the projection protrudes from the exit pupil 18 of F2.8. The portion included in the exit pupil 18 is about 60%.

[0038] As can be seen from this simulation, when the aperture size (diameter) of the microlens 15 becomes 20 μm or less, the projection performance of the microlens 15 deteriorates, and the shape of the diffraction image 8C projected on the exit pupil 18 is affected by the influence of diffraction. The collapse starts, and a part of the diffraction image 8C starts to spread outside the exit pupil 18. As the aperture size of the microlens 15 becomes smaller, the influence of diffraction increases, and about half of the diffraction image 8C protrudes outside the exit pupil 18 at a diameter of 2 μm as shown in FIGS.

[0039] That is, the influence of diffraction in the microlens 15 becomes prominent when the aperture size (diameter) is smaller than 20 μm. For this reason, when the aperture size (diameter) of the microlens 13 of the pixel cell 11 for captured images is smaller than 20 μm, the aperture size of the microlens 15 of the focus detection pixel cell 12 is smaller than that of the microlens 13. It is particularly effective to ensure a large value, and the influence of diffraction on the microlens 15 can be reliably reduced.

[0040] If the influence of diffraction in the microlens 15 can be reduced, the portion included in the exit pupil 18 in the pair of regions 8A and 8B (FIG. 3) projected onto the exit pupil 18 by the microlens 15 is increased (For example, FIG. 8 → FIG. 6), and the vignetting of the light beam used for focus detection can be suppressed. For this reason, the intensity distribution shapes of the two subject images described above can be substantially

matched, and an error in computation (for example, correlation computation) when obtaining the positional phase difference between the two subject images can be reduced. Therefore, it is possible to avoid a situation in which the focus detection accuracy is lowered as the number of pixels is increased.

[0041] Furthermore, when the aperture size (diameter) of the microlens 15 is larger than 20 μm, the pair of photoelectric conversion units 16 and 17 can be accurately projected onto the exit pupil 18 by the microlens 15 (see FIG. 5A). In other words, the projection can be performed so that the pair of regions 8A and 8B can be accommodated in the exit pupil 18, and the light flux used for focus detection can be eliminated to maintain good focus detection accuracy.

[0042] Further, in the image sensor 10 of the first embodiment, the cell size of the focus detection pixel cell 12 is set to four times the cell size of the captured image pixel cell 11 (see FIG. 1). Compared to the basic circuit configuration in the case where the image sensor is configured only from the pixel cells 11, it is not necessary to make a significant change. For this reason, even when the cell size of the focus detection pixel cell 12 is increased, the circuit configuration of the image sensor 10 is facilitated. Further, the microlens 15 can be easily manufactured. Further, no special change is required for the operation control of the image sensor 10.

[0043] (Second Embodiment) Here, an image pickup system 40 including the image pickup device 10 (FIGS. 1 to 4) will be described with reference to FIGS. As shown in FIG. 10, the imaging system 40 according to the second embodiment includes a photographing optical system 41, an aperture 42, an imaging element 10, a signal processing unit 43, an AD conversion unit 44, a signal processing unit 45, a memory unit 46, and timing generation. A unit 47, a control unit 48, interfaces (IF) 49 and 50, and an operation unit 51 are provided.

[0044] The photographing optical system 41 includes a lens group that forms a subject image on the image pickup surface of the image pickup device 10 and includes a focusing lens. The diaphragm 42 adjusts the amount of light flux that passes through the photographing optical system 41. The image sensor 10 captures a subject image by the photographing optical system 41 and outputs a signal for a photographed image and a signal for focus detection. The signal processing unit 43 includes a gain variable amplifier that amplifies the output of the image sensor 10 and a gain correction circuit that corrects the gain value. The AD converter 44 converts the signal (analog signal) after passing through the signal processor 43 into a digital signal. The signal processing unit 45 performs various corrections on the data output from the AD conversion unit 44. The memory unit 46 temporarily stores data after passing through the signal processing unit 45.

[0045] The timing generator 47 outputs various timing signals to the image sensor 10, signal processors 43 and 45, and AD converter 44. The control unit 48 performs various calculations and overall control of the imaging system 40. The IF 49 performs data recording and reading with respect to the removable recording medium 9A. The recording medium 9A is, for example, a semiconductor memory. The IF 50 communicates with an external computer (not shown). The operation unit 51 outputs a command corresponding to an operation from the outside to the control unit 48.

[0046] An operation (FIG. 11) of the imaging system 40 of the second embodiment will be described. First (step S1), after the main power supply is turned on, the control system power supply is turned on, and the imaging system circuit such as the AD converter 44 is turned on. Thereafter, the control unit 48 opens the aperture 42 in order to control the exposure amount. The output from the image sensor 10 is stored in the memory unit 46 after passing through the signal processing unit 43, the AD conversion unit 44, and the signal processing unit 45.

[0047] When the focus adjustment (steps S2 to S4) is started, the phase difference detection method is firstly performed using the data corresponding to the output of the focus detection pixel cell 12 among the data stored in the memory unit 46. Focus detection is performed (step S2). That is, for example, the positional phase difference between the two subject images described above is obtained by a well-known correlation calculation, and the defocus amount of the photographing optical system 41 is calculated.

[0048] Next (step S3), it is determined based on this defocus amount whether or not the photographing optical system 41 is in focus. If it is not yet in focus (step S3 is No), based on the defocus amount. The focusing lens of the photographing optical system 41 is driven and moved toward the in-focus position (step S4). Thereafter, the process returns to step S2, and the focus adjustment (steps S2 to S4) is repeated until the defocus amount becomes zero.

[0049] If it is determined that the photographing optical system 41 is in focus (Yes in Step S3), the process proceeds to Step S5, and when it is detected that the release button of the operation unit 51 is pressed, the

photographing operation is executed. (Step S6). That is, the output from the image sensor 10 is stored in the memory unit 46 via the AD conversion unit 44 or the like. Next, the control unit 48 generates an image signal by using data corresponding to the output of the pixel cell 11 for the photographed image among the data stored in the memory unit 46 by the photographing operation of Step S6 (Step S7).). An image signal at the position of the pixel cell 11 of the image sensor 10 is generated based on the data of the pixel cell 11. The image signal at the position of the focus detection pixel cell 12 is generated by interpolation processing based on the data of the pixel cells 11 around the pixel cell 12.

[0050] An example of image signal generation will be described. Here, it is assumed that the RGB array of the color filters of the plurality of pixel cells 11 is a Bayer array as shown in FIG. In this case, an image signal for one pixel at the position of the pixel cell 11 is obtained from the outputs of four adjacent pixel cells 11 (for example, G11a, B11, R11, G11b) by the following equations (1) to (4). Can be generated according to In the expressions (1) to (4), the output of each pixel cell 11 is I (G11a), I (B11), I (R11), I (G11b). Equation (1) is the luminance component Iy11 of the image signal. Expressions (2) to (4) are the green component Ig11, red component Ir11, and blue component Ib11 of the image signal, respectively. k1 to k3 are predetermined coefficients.

[0051] Iy11 = k1 × [I (G11a) + I (G11b)] + k2 × I (R11) + k3 × I (B11) (1) Ig11 = [I (G11a) + I (G11b)] / Iy11 (2) Ir11 = I (R11) / Iy11 (3) Ib11 = I (B11) / Iy11 (4) Further, an image signal for one pixel at the position of the pixel cell 12 may be generated by the following interpolation processing. it can. First, assuming that the four pixel cells 11 (G22a, B22, R22, G22b) shown in FIG. 12B are arranged at the position of the pixel cell 12, the pixel cells 11 in four directions around the pixel cell 12 are arranged. (G12a, G21a, G23a, G32a,...) Are substituted into the following equations (5) to (8) to output the pixel cell 11 (G22a, B22, R22, G22b) in FIG. The data corresponding to is obtained. Calculations of equations (5) to (8) correspond to averaging processing.

[0052] I (G22a) = [I (G12a) + I (G21a) + I (G23a) + I (G32a)] / 4 (5) I (G22b) = [I (G12b) + I (G21b) + I (G23b) + I (G32b)] / 4 ... (6) I (R22) = [I (R12) + I (R21) + I (R23) + I (R32)] / 4 ... (7) I (B22) = [I (B12) + I (B21) + I (B23) + I (B32)] / 4 (8) Then, using the results of the expressions (5) to (8), the position of the pixel cell 12 is determined according to the following expressions (9) to (12). The image signal for one pixel can be generated. Equation (9) is the luminance component Iy22 of the image signal. Expressions (10) to (12) are the green component Ig22, red component Ir22, and blue component Ib22 of the image signal, respectively.

[0053] Iy22 = k1 × [I (G22a) + I (G22b)] + k2 × I (R22) + k3 × I (B22) (9) Ig22 = [I (G22a) + I (G22b)] / Iy22 (10) Ir22 = I (R22) / Iy22 (11) Ib22 = I (B22) / Iy22 (12) When the generation of the image signal (processing in step S7 in FIG. 11) is completed in this way, these data are also stored in the memory unit 46. Is written to. Then, for the next photographing operation, the process returns to the process of step S2 and the processes such as focus detection are repeated. On the other hand, the image signals (luminance component, green component, red component, blue component) stored in the memory unit 46 are recorded on the recording medium 9A through the IF 49 under the control of the control unit 48. Further, the image signal may be processed by being output to an external computer or the like via the IF 50.

[0054] As described above, in the imaging system 40 of the second embodiment, focus detection of the imaging optical system 41 is performed based on the output of the pixel cell 12 for focus detection provided in the imaging device 10 (step S2 in FIG. 11). Therefore, it is possible to adjust the focus of the photographing optical system 41 with good responsiveness and accuracy even at low luminance. As a result, it is possible to obtain a focused image quickly even at low luminance.

[0055] Furthermore, in the imaging system 40 of the second embodiment, color filters are provided in the pair of photoelectric conversion units 16 and 17 of the pixel cell 12 in order to generate an image signal at the position of the focus detection pixel cell 12 by interpolation processing. Even if it is not, a good captured image can be obtained. (Modification 1) Here, a modification of the generation of the image signal at the position of the pixel cell 12 will be described.

[0056] When the outputs of the four pixel cells 11 (G22a, B22, R22, G22b) shown in FIG. 12B are obtained by interpolation processing, the pixel cells 11 (G11a, G12a, G13a, G21a) around the pixel cell 12 are displayed. , G23a, G31a, G32a, G33a, etc.) may be used for averaging processing similar to the above equations (5) to (8). Furthermore, weighting according to the relative position between the pixel cell 12 and the surrounding pixel cell 11 may be performed during the averaging process. By performing such processing, the accuracy of the interpolation processing is improved.

[0057] Further, when the luminance component Iy22 is generated from the image signal at the position of the pixel cell 12, not the output of the four pixel cells 11 (G22a, B22, R22, G22b) obtained by the interpolation process, but the pixel cell 12 Output may be used. For example, if the outputs of the pair of photoelectric conversion units 16 and 17 of the pixel cell 12 are I (W22a) and I (W22b) (FIG. 12C), and these are substituted into the following equation (13), the luminance Component Iy22 can be produced. k4 is a predetermined coefficient.

[0058] Iy22 = k4 × [I (W22a) + I (W22b)] (13) In this case, the color components Ig22, Ir22, and Ib22 of the image signal are output from the pixel cell 12 in the above equations (10) to (12). Substituting the luminance component Iy22 (Equation (13)) obtained from the above and the outputs of the four pixel cells 11 (G22a, B22, R22, G22b) obtained by the interpolation process.

[0059] Thus, by generating the luminance component Iy22 of the image signal at the position of the pixel cell 12 based on the output of the pixel cell 12, the accuracy in generating the luminance component Iy22 and the color components Ig22, Ir22, and Ib22 is improved. improves. (Third Embodiment) Here, the digital still camera 60 of FIG. 13 will be described as a specific example of the imaging system 40 including the imaging device 10 (FIGS. 1 to 4).

[0060] The digital still camera 60 includes an interchangeable lens 61 and a camera body 62 and is coupled by a mount unit 63. The interchangeable lens 61 is provided with a photographing optical system (64, 65), a diaphragm 66, driving units 67, 68, and a lens CPU 69. The photographing optical system (64, 65) includes a lens 65 for focusing. The drive unit 67 drives the lens 65 for focusing. The drive unit 68 drives the diaphragm 66. The lens CPU 69 controls the operation of the drive units 67 and 68.

[0061] The camera body 62 is provided with the imaging device 10, a focus detection unit 71, a body CPU 72, a liquid crystal display element 73, an eyepiece lens 74, and a liquid crystal driving unit 75. The image sensor 10 is disposed on the planned imaging plane of the photographing optical system (64, 65) of the interchangeable lens 61. The focus detection unit 71 performs focus detection of the imaging optical system (64, 65) based on the output of the pixel cell 12 of the image sensor 10. The body CPU 72 performs overall operation control of the digital still camera 60. The liquid crystal display element 73 and the eyepiece lens 74 constitute a liquid crystal viewfinder. The liquid crystal driving unit 75 drives the liquid crystal display element 73 in accordance with an instruction from the body CPU 72.

[0062] The body CPU 72 and the lens CPU 69 are connected to various information (lens characteristics information such as an open F value, focus adjustment information for lens driving, and information for aperture control via an electrical contact 76 provided on the mount 63.). In the digital still camera 60 of the third embodiment, when the focus detection unit 71 performs focus detection of the imaging optical system (64, 65) based on the output of the pixel cell 12 of the image sensor 10, the focus detection unit 71 performs imaging for the body CPU 72. A defocus amount representing the focus adjustment state of the optical system (64, 65) is output. The body CPU 72 determines whether or not the photographing optical system (64, 65) is in an in-focus state based on the defocus amount. If the in-focus state is not in focus, the lens CPU 69 drives the lens according to the defocus amount. Output information.

[0063] The lens CPU 69 controls the drive unit 67 based on the lens drive information, and moves the focusing lens 65 toward the in-focus position. Further, the body CPU 72 generates an image signal based on the output of the pixel cell 11 of the image sensor 10, outputs this image signal to the liquid crystal drive unit 75, and displays a photographed image on the liquid crystal display element 73 of the liquid crystal viewfinder. Let At this time, it is preferable to perform an interpolation process similar to the above to generate and display an image signal at the position of the focus detection pixel cell 12.

[0064] As described above, in the digital still camera 60 according to the third embodiment, the focus detection of the imaging optical system (64, 65) of the interchangeable lens 61 is performed based on the output of the focus detection pixel cell 12 of the image sensor 10. Therefore, it is possible to adjust the focus of the photographing optical system (64, 65) with good responsiveness and accuracy even at low luminance. As a result, it is possible to obtain a focused image quickly even at low luminance.

[0065] (Fourth Embodiment) Here, an example of an image pickup device having two types of pixel cells for focus detection will be described with reference to FIGS. The image sensor 80 of the fourth embodiment is provided with a pixel cell 81 shown in FIG. 14A in addition to the pixel cells 11 and 12 shown in FIGS. In other words, the imaging element 80 is provided with the pixel cell 11 for a captured image and two types of pixel

cells 12 and 81 for focus detection. The configuration and operation of the pixel cells 11 and 12 shown in FIGS. 1A and 1B are the same as described above, and a description thereof is omitted here.

[0066] FIG. 14B shows a layout of the pixel cells 11, 12, 81. On the substrate of the image sensor 80, the pixel cells 11 for captured images are two-dimensionally arranged almost densely (square lattice shape), and one pixel cell 12 for focus detection is periodically embedded therein, The other pixel cells 81 for focus detection are arranged almost densely in a predetermined area. The pixel cell 81 shown in FIG. 14A has a square shape like the pixel cells 11 and 12. The pixel cell 81 has a cell size different from that of the focus detection pixel cell 12 and is the same as the pixel cell 11 for captured image. The length A81 of one side of the pixel cell 81 is equal to the length A11 of one side of the pixel cell 11. In other words, the newly provided focus detection pixel cell 81 is smaller than the focus detection pixel cell 12 described above. In the following description, the small pixel cell 81 and the large pixel cell 12 are referred to as necessary.

[0067] A small pixel cell 81 is provided with a circular microlens 82 and two rectangular photoelectric conversion units 83 and 84. The microlens 82 is an optical element that collects incident light and guides it to the photoelectric conversion units 83 and 84, and the opening size (diameter) thereof is equal to the length A 81 of one side of the pixel cell 81. The photoelectric conversion units 83 and 84 are photodiodes that generate charges in accordance with the light collected by the microlens 82, respectively. These two photoelectric conversion units 83 and 84 form a pair and are used for phase difference detection type focus detection using the microlens 82. For this reason, the pair of photoelectric conversion units 83 and 84 are arranged in a conjugate manner with the exit pupil of the photographing optical system (not shown) via the microlens 82 (see FIG. 3).

[0068] The cross-sectional structure of the pixel cell 81 (FIG. 15) is the same as the cross-sectional structure of the pixel cell 12 (FIG. 2), and the photoelectric conversion units 83 and 84 are formed on the surface p + layer 23 and the n layer 24 of the substrate 22. The gate insulating film 25 is formed on the surface of the substrate 22, and the infrared cut filter 21 is disposed between the photoelectric conversion units 83 and 84 and the microlens 82. Further, in the pixel cell 81, a pair of photoelectric conversion portions 83 and 84 are formed with the floating diffusion (FD) portion 2 A of the P-type well of the substrate 22 interposed therebetween. Then, in order to read out the charges accumulated in the pair of photoelectric conversion units 83 and 84 individually (or by adding) through the FD unit 2A, the transfer switch MOS transistors 85, 86 is provided. The MOS transistors 85 and 86 are connected to a vertical scanning circuit (not shown) via control lines P ′ and P ″ shown in FIG.

[0069] Therefore, the charges accumulated in the pair of photoelectric conversion units 83 and 84 can be transferred individually (or added) to the FD unit 2A in accordance with on / off of the MOS transistors 85 and 86 by the vertical scanning circuit. it can. For example, when one of the MOS transistors 85 is selectively turned on, only the charge of the photoelectric conversion unit 83 corresponding to the MOS transistor 85 is selectively transferred to the FD unit 2A. If both MOS transistors 85 and 86 are simultaneously turned on, the charges of the pair of photoelectric conversion units 83 and 84 are simultaneously transferred to the FD unit 2A and added there.

[0070] Further, the FD portion 2A is connected to the control line R ′ via the reset MOS transistor 87, and is connected to the control line S ′ and the vertical via the source follower amplifier MOS transistor 88 and the horizontal selection MOS transistor 89. Connected to the output line V. For this reason, the charge transferred to the FD unit 2A is amplified via the MOS transistor 88 and transferred to the vertical output line V via the MOS transistor 89.

[0071] The circuit configuration shown in FIG. 16 corresponds to one small pixel cell 81, and this pixel cell 81 has the same cell size as the pixel cell 11 for a captured image. For this reason, when the circuit portion of the pixel cell 81 is incorporated in the circuit configuration of FIG. Note that the control lines P ′, P ″, R ′, and S ′ in FIG. 16 are provided in common or independently with the control lines P, R, and S in FIG. 4, respectively.

[0072] Since the image sensor 80 of the fourth embodiment has two types of pixel cells 12 and 81 for focus detection, the two types of pixel cells 12 and 81 are selectively used according to various shooting conditions, and a focus suitable for the shooting conditions. Detection can be performed. For example, when it is desired to ensure the focus detection response at low luminance, it is preferable to use the output of the large pixel cell 12. Further, when it is desired to increase the accuracy of focus detection at high luminance, it is preferable to use the output of the small pixel cell 81. Since the small pixel cell 81 has a fine detection pitch, it is suitable for a fine subject.

[0073] Further, in the image sensor 80 of the fourth embodiment, the cell size of the large pixel cell 12 is four times the cell size of the captured image pixel cell 11 and the cell size of the small pixel cell 81 is the cell size of the pixel cell 11. Therefore, it is not necessary to make a significant change compared to the basic circuit configuration in the case where the image sensor is configured only from the pixel cell 11 for the captured image. For this reason, the circuit configuration of the image sensor 80 is facilitated. Further, the microlenses 15 and 82 can be easily manufactured.

[0074] (Fifth Embodiment) Here, the operation of an imaging system (see FIGS. 10 and 13) provided with an imaging device 80 of the fourth embodiment will be described with reference to the flowchart of FIG. The operation procedure shown in FIG. 17 is provided with steps S11 to S13 instead of step S2 in FIG. Here, focus adjustment (steps S11 to S13, S3, S4) will be described.

[0075] In step S11, it is determined based on the output of a photometric sensor (not shown) provided in the imaging system whether or not the luminance of the subject is smaller than a predetermined value. If the luminance is smaller than the predetermined value (step S11 is Yes), focus detection is performed using the output of the large pixel cell 12 with high low luminance performance (step S13). On the other hand, when the luminance is equal to or higher than the predetermined value (No in step S11), focus detection is performed using the output of the small pixel cell 81 with high focus detection accuracy (step S12).

[0076] Therefore, in the imaging system of the fifth embodiment, focus adjustment can be performed with good responsiveness at low luminance, and focus adjustment can be performed with high accuracy at high luminance. Moreover, such proper use can be performed automatically. At high luminance, focus detection may be performed using both the pixel cells 12 and 81 having two large and small cell sizes.

[0077] (Modification 2) Here, an example will be described in which two types of focus detection pixel cells 12 and 81 (FIG. 14) having different cell sizes are switched in accordance with manual settings, various camera settings, interchangeable lens characteristics, and the like. . When switching according to the focus adjustment mode, a small pixel cell 81 is selected with priority given to focus detection accuracy during one-shot AF (mode in which the lens is locked after focusing), and continuous AF (after focusing) is selected. It is conceivable that the large pixel cell 12 is selected with priority given to responsiveness in the mode in which the lens is driven by following the back and forth movement of the subject without locking the lens.

[0078] When switching according to the still image / moving image shooting mode, the small pixel cell 81 is selected with priority given to the focus detection accuracy in the still image shooting mode (still image shooting mode), and the moving image shooting mode (video It is conceivable to select the large pixel cell 12 in order to give priority to responsiveness in the image capturing mode). When switching according to the shooting mode of single shooting / continuous shooting, a small pixel cell 81 is selected with priority given to focus detection accuracy in the single shooting mode (mode for shooting images one by one), and the continuous shooting mode is selected. It is conceivable that the large pixel cell 12 is selected with priority given to responsiveness in the case of (a mode in which images are continuously captured).

[0079] When switching according to the portrait / sports shooting mode, the small pixel cell 81 is prioritized with focus detection accuracy in the portrait shooting mode (shooting mode suitable for shooting a stationary subject). It is conceivable to select the large pixel cell 12 with priority given to responsiveness in the sports shooting mode (shooting mode suitable for shooting a moving subject).

[0080] When switching according to the aperture value at the time of shooting, a small pixel cell 81 is selected with priority on focus detection accuracy when the aperture value is brighter than a predetermined value, and a large size with priority on responsiveness when darker than the predetermined value. It is conceivable to select the pixel cell 12. When switching according to the photographing magnification, when the photographing magnification is smaller than a predetermined value, the small pixel cell 81 is selected with priority on focus detection accuracy, and when larger than the predetermined value, the large pixel cell is given priority on responsiveness. It is conceivable to select 12.

[0081] When switching according to the open F value of the attached interchangeable lens, when the open F value is brighter than the predetermined value, the small pixel cell 81 is selected giving priority to the focus detection accuracy, and when it is darker than the predetermined value, responsiveness is selected. It is conceivable to select the large pixel cell 12 with priority given to. When switching according to the focal length of the attached interchangeable lens, priority is given to focus detection accuracy when the focal length is

shorter than a predetermined value, and small pixel cells 81 are selected, and priority is given to response when the focal length is longer than the predetermined value. Then, it is conceivable to select a large pixel cell 12.

[0082] When switching according to non-use / use of the strobe, the small pixel cell 81 is selected with priority given to the focus detection accuracy when shooting without using the strobe, and responsiveness when shooting using the strobe. It is conceivable to select the large pixel cell 12 with priority given to. When switching between using / not using a tripod, the small pixel cell 81 is selected with priority given to focus detection accuracy when shooting with the camera fixed to a tripod, etc., and the camera is not fixed to the tripod. It is conceivable to select the large pixel cell 12 with priority given to responsiveness when hand-held.

[0083] (Modification 3) Here, a modification of the layout of each pixel cell in the image sensor 10 (FIG. 1C) and the image sensor 80 (FIG. 14B) will be described. As shown in FIG. 18, the pixel cells 11 for photographed images may be arranged almost densely, and the focus detection pixel cells 12 may be shifted in every other row in a staggered manner. In the case of such a layout, even if the size of the pattern of the subject image (for example, a linear pattern) is approximately the same as the arrangement pitches D1 and D2 of the pixel cells 12, focus detection can be performed regardless of the position.

[0084] As shown in FIG. 19, the pixel cells 11 for photographed images may be arranged almost densely, and the pixel cells 12 for focus detection may be arranged almost densely in a predetermined region therein. In the case of such a layout, even if the size of the pattern of the subject image (for example, a dot pattern) is approximately the same as the arrangement pitch D1 of the pixel cells 12, focus detection can be performed regardless of the position. As shown in FIG. 20, the pixel cells 11 for photographed images are arranged almost densely, the pixel cells 12 for focus detection are arranged almost densely in a predetermined area, and are shifted by a half pitch for each row. May be. In this case, even if the size of the pattern of the subject image (for example, a linear pattern or a dot pattern) is approximately the same as the arrangement pitches D3 and D1 of the pixel cells 12, focus detection can be performed regardless of the position.

[0085] As shown in FIG. 21, a pixel cell 26 having a cell size different from that of the pixel cell 12 is provided for focus detection, and the length A26 of one side of the pixel cell 26 is the length of one side of the pixel cell 11 for a photographed image. It may be 2.5 times A11. The cell size of the pixel cell 26 is 6.25 times that of the pixel cell 11. In FIG. 21, the pixel cells 11 for captured images are arranged substantially densely, and the pixel cells 26 are arranged substantially densely in a predetermined region therein. As described above, the cell size of the focus detection pixel cell is not limited to an integer multiple of the captured image pixel cell 11 and can be freely set. When the effect of mitigating the influence of diffraction is insufficient, a desired effect can be obtained by appropriately adjusting the ratio of the cell sizes of the focus detection pixel cell and the captured image pixel cell 11. it can.

[0086] As shown in FIG. 22, a pixel cell 27 having a different aspect ratio is provided for focus detection, and the length A27 of one side of the pixel cell 27 in the horizontal direction is twice the length A11 of one side of the pixel cell 11 for the photographed image. The length A28 in the vertical direction may be equal to the length A11 of the pixel cell 11. The cell size of the pixel cell 27 is twice that of the pixel cell 11. Since the vertical length A27 of the focus detection pixel cell 27 is equal to that of the captured image pixel cell 11, the image quality can be maintained even when interpolation processing is performed when generating the image signal. Further, it is not necessary to change the circuit configuration by arranging the pixel cell 27.

[0087] As shown in FIG. 23, two types of pixel cells 12 and 81 for focus detection (see FIG. 14) are arranged almost densely in a predetermined region in which the pixel cells 11 for captured images are arranged almost densely. The large pixel cells 12 may be arranged in a staggered manner by shifting every other column (see FIG. 18), and the small pixel cells 81 may be disposed substantially densely therebetween. As shown in FIG. 24, the pixel cells 12 for focus detection may be arranged in a line frame shape while the pixel cells 11 for captured images are arranged almost densely. In this case, a captured image is displayed on the screen of the liquid crystal viewfinder of the imaging system based on the output of the pixel cell 11, and the position of the pixel cell 12 is superimposed on the captured image as a focus detection area (focus frame). It is preferable to display. The focus frame display is performed by, for example, fixed data. Thus, since the position of the pixel cell 12 is displayed as the focus frame, it is not necessary to generate an image signal at the position of the pixel cell 12 by interpolation processing from the output of the surrounding pixel cells 11 or the like.

[0088] (Modification 4) Here, a modification of the photoelectric conversion unit of the pixel cell for focus detection will be described. As in the pixel cell 90 for focus detection shown in FIG. 25, four photoelectric conversion units 91 to 94 may be provided. In this case, any two of the four photoelectric conversion units 91 to

94 can be selectively combined to form a pair of photoelectric conversion units that can be used for phase difference detection type focus detection. In the focus detection by the phase difference detection method, the positional phase difference between the two subject images (that is, the positional deviation amount in the arrangement direction of the pair of photoelectric conversion units) is obtained by, for example, correlation calculation. For this reason, the focus detection in a different direction can be performed according to the arrangement direction of the selected pair of photoelectric conversion units.

[0089] For example, when performing horizontal focus detection in the figure, the outputs of the photoelectric conversion units 91 and 93 or the outputs of the photoelectric conversion units 92 and 94 are used. Further, the addition output of the photoelectric conversion units 91 and 92 and the addition output of the photoelectric conversion units 93 and 94 may be used. When performing vertical focus detection, the outputs of the photoelectric conversion units 91 and 92 or the outputs of the photoelectric conversion units 93 and 94 are used. Further, the addition output of the photoelectric conversion units 91 and 93 and the addition output of the photoelectric conversion units 92 and 94 may be used. In the case of focus detection in the upward and diagonal direction, each output of the photoelectric conversion units 91 and 94 is used. In the case of focus detection in the upward and diagonal direction, the outputs of the photoelectric conversion units 92 and 93 are used. In this manner, multidirectional focus detection can be performed with one type of pixel cell 90.

[0090] Furthermore, like the pixel cell 100 for focus detection shown in FIG. 26, six photoelectric conversion units 101 to 106 may be provided, and any one of RGB color filters may be provided for each. In this case, the two photoelectric conversion units 101 and 104 arranged along the focus detection direction (lateral direction in the figure) have the same R color component, the photoelectric conversion units 102 and 105 have the same G color component, and the photoelectric conversion units 103 and 104. Reference numeral 106 denotes the same B color component.

[0091] When performing focus detection by the phase difference detection method using the pixel cell 100, the addition output of the three photoelectric conversion units 101 to 103 arranged along the direction perpendicular to the focus detection direction is obtained, and the photoelectric conversion unit 104 is obtained. ˜106 are obtained, and the positional phase difference between the two subject images (here, the amount of positional deviation in the horizontal direction in the figure) is obtained from these two addition outputs by, for example, correlation calculation.

[0092] Further, when generating an image signal at the position of the pixel cell 100, the addition output (R color component) of the two photoelectric conversion units 101 and 104 arranged along the focus detection direction is obtained, and the photoelectric conversion unit 102 is also obtained. , 105 and the addition output (B color component) of the photoelectric conversion units 103 and 106 are obtained. Then, these three addition outputs may be substituted into the equations (9) to (12) instead of the respective color components (equations (5) to (8)) obtained by the interpolation processing described above.

[0093] Similarly, like the pixel cell 110 for focus detection shown in FIG. 27, six photoelectric conversion units 111 to 116 are arranged along the focus detection direction (horizontal direction in the figure), and any one of RGB is respectively arranged. Two color filters may be provided. In this case, the two photoelectric conversion units 113 and 114 that are symmetrical with respect to the center of the pixel cell 110 have the same R color component, the photoelectric conversion units 112 and 115 have the same G color component, and the photoelectric conversion units 111 and 116 have the same B color. Let it be a color component.

[0094] When performing focus detection by the phase difference detection method using the pixel cell 110, the addition outputs of the three photoelectric conversion units 111 to 113 arranged along the focus detection direction are obtained, and the photoelectric conversion units 114 to 116 are also detected. The addition output is obtained, and the positional phase difference (here, the amount of positional deviation in the horizontal direction in the figure) of the two subject images is obtained from these two addition outputs by, for example, correlation calculation. Further, when generating the image signal at the position of the pixel cell 110, the addition output (R color component) of the two photoelectric conversion units 113 and 114 symmetrical to the center of the pixel cell 110 is obtained and the photoelectric conversion is performed. The addition output (G color component) of the units 112 and 115 is obtained, and the addition output (B color component) of the photoelectric conversion units 111 and 116 is further obtained. Then, these three addition outputs may be substituted into the equations (9) to (12) instead of the respective color components (equations (5) to (8)) obtained by the interpolation processing described above.

[0095] Therefore, when generating an image signal at the position of the pixel cell 100 (or the pixel cell 110), it is not necessary to interpolate from the output of the pixel cell 11 for the captured image around the pixel cell 100 (or the pixel cell 110). Even if the pixel cells 100 (or the pixel cells 110) are arranged almost densely in a large area, the image quality does not deteriorate. Further, when focus detection is performed using the pixel cell 100 (or the pixel cell 110), focus detection may be performed for each color component without adding the output of each color component of RGB. In this way, accurate focus detection can be performed even when the photographic optical system has chromatic aberration. In addition, focus detection can be performed on a subject having a color change even at the same brightness. Further, a color component used for focus detection may be selected manually or automatically, and focus detection may be performed using the output of the selected color component. In this way, it is possible to selectively perform focus detection for a subject of a specific color.

[0096] Furthermore, when focus detection is performed using the pixel cell 110 of FIG. 27, the color component used for focus detection may be changed according to the open F value of the attached interchangeable lens. For example, the B color component photoelectric conversion units 111 and 116 located on the outer side take in the light beam that has passed outside the exit pupil of the photographing optical system, so that a lens with a brighter open F value than a predetermined value is mounted or high. It is preferably used when focus detection accuracy is required. Since the photoelectric conversion units 113 and 114 for the R color component located inside capture the light beam that has passed near the center of the exit pupil, the defocus amount becomes large when a lens with an open F value that is darker than a predetermined value is attached. It is preferably used when a lens (a lens with a long focal length) is attached.

[0097] In the above example, the pair of photoelectric conversion units 16, 17, 91 to 94,... Of the pixel cell for focus detection are each rectangular, but the present invention is not limited to this. For example, as in the pixel cell 120 illustrated in FIG. 28, it is conceivable that the pair of photoelectric conversion units 121 and 122 are each substantially semicircular, and the two are combined into a substantially circular shape. In this case, the light beam inside the exit pupil (predetermined F value) of the photographing optical system can be taken into the photoelectric conversion units 121 and 122 without waste and used for focus detection. This is advantageous in terms of securing the amount of light at the time of focus detection. The size of the photoelectric conversion units 121 and 122 is irrelevant to securing the light amount.

[0098] (Modification 5) Here, a modification of the microlenses 13, 15,... Of the pixel cell will be described. In the above example, the example in which the aperture size (diameter) of the microlenses 13 and 15 is equal to the lengths A11 and A12 of one side of the pixel cells 11 and 12 has been described, but the present invention is not limited to this. The opening size of the microlens may be smaller than the length of one side of the pixel cell. In this case, even if the pixel cell for the captured image and the pixel cell for focus detection have the same cell size, the aperture size of the micro lens in the pixel cell for focus detection is set to be smaller than the aperture size of the micro lens in the pixel cell for captured image. By increasing the size, the same effect as described above can be obtained.

[0099] In the above example, the microlens has a circular shape inscribed in the square pixel cell, but the present invention is not limited to this. For example, as shown in FIGS. 29 (a) and 29 (b), a circular four-direction portion (hatched portion) larger than the pixel cell is cut off, and a square central portion is cut out and formed into the same shape as the pixel cell. A microlens may be used. It can be applied to microlenses for photographed images and focus detection. In this case, the opening size of the microlens corresponds to the length of one side of the square shape. In this way, the light beam incident on the image sensor can be used for shooting, focus detection, and the like without waste.

[0100] Further, in the focus detection pixel cell 27 having a different aspect ratio as shown in FIG. 22, a circular portion in two vertical directions (hatching portions) larger than the pixel cell 27 is hatched as shown in FIG. 29C. A microlens that is cut off one by one and cut out at a rectangular central portion and shaped into the same shape as the pixel cell 27 may be used. Even in this case, the light beam incident on the image sensor can be used for focus detection without waste.

[0101] In the above example, the microlens is used as an optical element that condenses incident light to the pixel cell and guides it to the photoelectric conversion unit. However, the present invention is not limited to this. Instead of the microlens, a gradient index optical element or a reflective optical element may be used. However, since the microlens is easy to manufacture, it is advantageous in terms of cost. Furthermore, in the above example, an optical element such as a microlens is provided in the pixel cell for a captured image, but the present invention can be applied to a case where this is omitted.

[0102] (Modification 6) Here, another modification will be described. In the above example, the square pixel cells are arranged in a square lattice shape, but the present invention is not limited to this. The present invention can also be applied when the pixel cell is rectangular or hexagonal. When the pixel cell has a hexagonal shape, it can be considered that the pixel cells are arranged in a two-dimensional honeycomb shape with a half-pitch shift for each row. The focus detection pixel cell may be replaced with a plurality of adjacent captured image pixel cells.

[0103] In the above example, the phase detection pixel cell for focus detection is described as an example, but the present invention is not limited to this. In addition, the present invention can be applied to a case where a pixel cell for focus detection using a contrast detection method is provided. In the case of the contrast detection method, the number of photoelectric conversion units in the pixel cell may be one, but the outputs of two or more photoelectric conversion units may be added. Furthermore, in the above-described example, the example of the image sensor including the pixel cell for the captured image and the pixel cell for focus detection has been described, but the present invention is not limited to this. The present invention can also be applied to a case where a pixel cell for distance measurement, photometry, light adjustment, or the like is disposed instead of the pixel cell for focus detection (or in combination with the pixel cell for focus detection). Even in the case of a pixel cell for distance measurement, photometry, dimming, etc., the responsiveness at low luminance can be improved by making the cell size larger than the pixel cell for the photographed image.

[0104] As an image sensor having a pixel cell for distance measurement, for example, when the object to be measured is irradiated with pulse-modulated laser light or the like, the reflected light from the object to be measured is detected for each pixel cell. One can be considered (International Publication No. 97/01111). In order to measure the distance to the object to be measured, the round trip time of light is measured for each pixel cell, and this is converted into a distance. A special metering or dimming filter (such as a visual sensitivity filter) is placed in the photometric pixel cell that measures the subject brightness or the dimming pixel cell that detects the strobe light reflected from the subject. In addition, a special circuit configuration that can monitor the amount of accumulated charge in a non-destructive manner in real time is added. When such a special circuit configuration is added to the pixel cell for photometry or dimming, the pixel cell for photometry or dimming is made larger than the pixel cell for photographed image, so The chip area can be increased, which is advantageous in terms of circuit layout.

[0105] In the above example, pixel cells for captured images are arranged two-dimensionally, and pixel cells for acquiring imaging conditions (focus detection, distance measurement, photometry, dimming, etc.) are arranged therein. However, the present invention is not limited to this. A pixel cell for a photographed image may be arranged one-dimensionally, and a pixel cell for obtaining a photographing condition may be arranged therein. Furthermore, in the above example, the MOS type imaging device (see FIG. 4 of the circuit configuration) has been described as an example, but the present invention is not limited to this. In addition, the present invention can be applied to a CCD type image pickup device.

[0106] In the above example, a digital still camera (see FIG. 13) has been described as a specific example of the imaging system, but the present invention is not limited to this. In addition, the present invention can be applied to the case where the above-described imaging device is incorporated in an imaging system such as a digital microscope or a surveillance camera.

[0107] It is a figure which shows the structure of the image pick-up element 10 of 1st Embodiment. 2 is a diagram showing a cross-sectional structure of a pixel cell 12. FIG. 3 is a diagram for explaining a conjugate relationship between a pair of photoelectric conversion units 16 and 17 and an exit pupil 18. FIG. 1 is a diagram illustrating a circuit configuration of an image sensor 10. It is a figure explaining the conditions of a diffraction simulation. It is a figure explaining the result of diffraction simulation (when opening size of micro lens 15 is 20 micrometers). It is a figure explaining the result of diffraction simulation (when opening size of micro lens 15 is 10 micrometers). It is a figure explaining the result of diffraction simulation (when opening size of micro lens 15 is 4 micrometers). It is a figure explaining the result of diffraction simulation (when opening size of micro lens 15 is 2 micrometers). It is a block diagram which shows the structure of the imaging system 40 of 2nd Embodiment. 3 is a flowchart showing an operation procedure of the imaging system 40. FIG. 4 is a diagram for explaining generation of an image signal in the image sensor 10. It is the schematic which shows the structure of the digital still camera 60 of 3rd Embodiment. It is a figure which shows the structure of the image pick-up element 80 of 4th Embodiment. 2 is a diagram showing a cross-sectional structure of a pixel cell 81. FIG. 2 is a diagram illustrating a circuit configuration of a pixel cell 81. FIG. It is a flowchart which shows the operation | movement procedure of the imaging system of 5th Embodiment. It is a figure which shows the modification of

the layout of a pixel cell. It is a figure which shows the modification of the layout of a pixel cell. It is a figure which shows the modification of the layout of a pixel cell. It is a figure which shows the modification of the layout of a pixel cell. It is a figure which shows the modification of the layout of a pixel cell. It is a figure which shows the modification of the layout of a pixel cell. It is a figure which shows the modification of the layout of a pixel cell. It is a figure which shows the modification of the photoelectric conversion part of the pixel cell for focus detection. It is a figure which shows the modification of the photoelectric conversion part of the pixel cell for focus detection. It is a figure which shows the modification of the photoelectric conversion part of the pixel cell for focus detection. It is a figure which shows the modification of the photoelectric conversion part of the pixel cell for focus detection. It is a figure which shows the modification of a micro lens.

Explanation of symbols

[0108] 10,80 Image sensor; 11,12,26,27,81,90,100,110,120 Pixel cell; 13,15,82 Microlens; 14,16,17,83,84,91-94,101 106, 111-116, 121, 122 Photoelectric conversion unit; 18 Exit pupil; 40 Imaging system; 41, 64, 65 Imaging optical system; 60 Digital still camera

CLAIMS

1. In an imaging device that captures an image by a photographing optical system, a first pixel cell including a first photoelectric conversion unit that generates a charge according to incident light, an optical element that collects incident light, and the optical element A second photoelectric conversion unit that generates a charge in response to the collected light, and has a second pixel cell having a larger cell size than the first pixel cell, and the first pixel cell is provided on the substrate. An image sensor, wherein the pixel cell and the second pixel cell are two-dimensionally arranged.

The image sensor according to claim 1, wherein the second pixel cell has an integer cell size that is an integral multiple of the first pixel cell.

2. The image sensor according to claim 1, wherein each of the first and second pixel cells includes an optical element that condenses incident light on the first and second photoelectric conversion units, and the second pixel cell. The optical element has an aperture size larger than that of the optical element of the first pixel cell.

An image pickup device that picks up an image by a photographing optical system includes a first optical element that collects incident light and a first photoelectric conversion unit that generates electric charge according to the light collected by the optical element. A second pixel cell including a pixel cell, an optical element that condenses incident light, and a second photoelectric conversion unit that generates an electric charge according to the light condensed by the optical element; The first pixel cell and the second pixel cell are two-dimensionally arranged, and the optical element of the second pixel cell has a larger aperture size than the optical element of the first pixel cell. An image sensor characterized by the above.

5. The image pickup device according to claim 1, wherein an opening size of the optical element of the first pixel cell is smaller than 20 μm. 6.

6. The imaging device according to claim 1, wherein each of the second pixel cells includes a plurality of the second photoelectric conversion units, and the plurality of second photoelectric conversion units. Each of the imaging elements is substantially conjugate with the exit pupil of the photographing optical system via the optical element of the second pixel cell.

The imaging device according to claim 6, wherein two of the plurality of second photoelectric conversion units form a pair, and each of the two second photoelectric conversion units forming the pair includes filters of different colors. An image sensor in which is arranged.

8. The imaging device according to claim 1, wherein a focus adjustment state of the photographing optical system is detected based on a photoelectric output obtained by the second pixel cell. Image sensor.

9. The image pickup device according to claim 1, wherein an optical element that condenses incident light and a third photoelectric conversion that generates electric charge according to the light collected by the optical element And a third pixel cell having a cell size different from that of the second pixel cell.

The imaging device according to claim 9, wherein the third pixel cell has a cell size equal to that of the first pixel cell.

11. The imaging device according to claim 9, wherein a focus adjustment state of the photographing optical system is detected based on a photoelectric output obtained by the second pixel cell and the third pixel cell. An image sensor.

A focus detection apparatus comprising: the image pickup device according to claim 8; and a detection unit that performs focus detection based on an output of the second pixel cell.

12. A focus, comprising: the imaging device according to claim 11; and a detection unit configured to perform focus detection based on at least one of an output of the second pixel cell and an output of the third pixel cell. Detection device.

A focus detection apparatus according to claim 12 or 13, and a photographing optical system disposed on the object side of the image sensor, wherein the detection means performs focus detection of the photographing optical system. Imaging system.

15. The imaging system according to claim 14, wherein a captured image is displayed based on an output of the first pixel cell, and the position of the second pixel cell is used as an area where the detection unit performs focus detection. An imaging system comprising display means for displaying an image superimposed on the image.

16. The imaging system according to claim 14, wherein an image signal at the position of the first pixel cell is generated based on an output of the first pixel cell, and an image signal at the position of the second pixel cell. An imaging system comprising: generating means for generating an image by interpolation processing based on an output of the first pixel cell around the second pixel cell.

17. The imaging system according to claim 16, wherein the generation unit generates each color component of the image signal by the interpolation processing when generating the image signal at the position of the second pixel cell, A luminance component is generated based on an output of the second pixel cell.

Electronic Acknowledgement Receipt

EFS ID:	43634174
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
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Filing Date:	18-MAY-2021
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Application Type:	Utility under 35 USC 111(a)

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		IDS-P001USC5-1252977.pdf	203463 63ac3d8ad472a7d6ec1c05273f9d52eaa1c3aeb4	yes	5

	Multipart Description/PDF files in .zip description				
	Document Description		**Start**	**End**	
	Transmittal Letter		1	2	
	Information Disclosure Statement (IDS) Form (SB08)		3	5	
Warnings:					
Information:					
2	Non Patent Literature	2021-08-13_16584515-NOA.pdf	550554 bc1c1538bbb400460351cbac3fa35faf3c3090fa	no	10
Warnings:					
Information:					
3	Non Patent Literature	2021-08-18_17317809_NOA.pdf	1442215 2924560690d0ff1ad0b86ee009722938fed2d68b	no	33
Warnings:					
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4	Non Patent Literature	JP2007103590A_Translation.pdf	244160 881f65888367c4c8e5b83a7edec6c1aacff20329	no	17
Warnings:					
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5	Non Patent Literature	2021-08-18_16046643_NOA.pdf	798838 11f1fb283928a0bd9e41daa7a87e082f62b58464	no	18
Warnings:					
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		Total Files Size (in bytes):	3239230		

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.

I hereby certify that this correspondence is being filed via EFS-Web with the United States Patent and Trademark Office on August 30, 2021.

KILPATRICK TOWNSEND & STOCKTON LLP

By: /La Renda Meyer-Johnson/

PATENT
Attorney Docket No.: 103033-1252977-P001USC5
Client Ref. No.: P001USC5

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Confirmation No.: 1014
Angus Pacala	Examiner: Cheryl P Gibson Baylor
Application No.: 17/323,962	Technology Center/Art Unit: 2878
Filed: May 18, 2021	
For: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD	**INFORMATION DISCLOSURE STATEMENT**
Customer No.: 20350	

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

Commissioner:

The references cited on attached form PTO/SB/08A are being called to the attention of the Examiner. In accordance with the provisions of 37 CFR §1.98(a)(2), copies of any cited U.S. Patents and U.S. Patent Application Publications are not provided. Copies of the remaining cited references are provided.

It is respectfully requested that the cited references be expressly considered during the prosecution of this application and the references be made of record therein and appear among the "references cited" on any patent to issue therefrom.

As provided for by 37 CFR §1.97(g) and (h), no inference should be made that the information and references cited are prior art merely because they are in this statement and no

representation is being made that a search has been conducted or that this statement encompasses all the possible relevant information. This Information Disclosure Statement is being filed *before* the mailing date of the first Office Action on the merits

Applicant believes that ***no fee*** is required for submission of this statement. However, if any fees are due for the submission of this Information Disclosure Statement, please deduct those fees from Deposit Account No. 20-1430.

Respectfully submitted,

/ William L. Shaffer /

William L. Shaffer
Registration No. 37,234

KILPATRICK TOWNSEND & STOCKTON LLP

Attachment

UNITED STATES PATENT AND TRADEMARK OFFICE

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977	1014

20350 7590 08/31/2021

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER	
LEE, JOHN R	

ART UNIT	PAPER NUMBER
2878	

NOTIFICATION DATE	DELIVERY MODE
08/31/2021	ELECTRONIC

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

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

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

KTSDocketing2@kilpatrick.foundationip.com
ipefiling@kilpatricktownsend.com

PTOL-90A (Rev. 04/07)

Office Action Summary	Application No. 17/323,962	Applicant(s) PACALA et al.	
	Examiner JOHN R LEE	Art Unit 2878	AIA (FITF) Status Yes

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

Period for Reply

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

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

Status

1)☑ Responsive to communication(s) filed on 05/18/2021.

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

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

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

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

Disposition of Claims*

5) ☑ Claim(s) 1-25 is/are pending in the application.

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

6) ☐ Claim(s) _____ is/are allowed.

7) ☑ Claim(s) 1-25 is/are rejected.

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

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

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

Application Papers

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

11)☑ The drawing(s) filed on 05/18/2021 is/are: a)☑ accepted or b)☐ objected to by the Examiner.

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

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

Priority under 35 U.S.C. § 119

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

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

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

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

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

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

Attachment(s)

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

2) ☑ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date See Continuation Sheet.

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

4) ☐ Other: _____.

Continuation of Attachment(s) 2) Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date: 05/18/2021; 06/09/2021; 07/12/2021; and 07/29/2021.

Notice of Pre-AIA or AIA Status

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

Double Patenting

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

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on nonstatutory double patenting provided the reference application or patent either is shown to be commonly owned with the examined application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. See MPEP § 717.02 for applications subject to examination under the first inventor to file provisions of the AIA as explained in MPEP § 2159. See MPEP § 2146 *et seq.* for applications not subject to examination under the first inventor to file provisions of the AIA. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

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

Claims 1-25 provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-9 and 11-31 of copending Application No. 17/317,809 (reference application). Although the claims at issue are not identical, they are not patentably distinct from each other because of the reasons discussed below.

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

Claim 1 of the present application is covered by claim 1 of the copending reference application. Regarding the recitation of “a plurality of optical emitters arranged behind the bulk transmitting optic:” recited in line 4 and “a bulk imaging optic disposed adjacent to the bulk transmitting optic” recited in line 8 of the present application, it is pointed out that these are clearly the only operational choices for these features and so they would have been obvious to persons having ordinary skill in the art for arranging the optics notes above.

through the bulk imaging optic after being reflected from surfaces within the field; and an optical filter disposed in an optical path of the plurality of pixels, the optical filter configured to allow a set of wavelengths of electromagnetic radiation, including the operating wavelength, to pass through

the optical filter while blocking electromagnetic radiation outside the set of wavelengths from reaching the plurality of pixels.

Claim 2 is covered by claim 23 of the copending reference application.

Claim 3 is covered by claim 14 of the copending reference application.

Claim 4 is covered by claim 9 of the copending reference application.

Claim 5 is covered by claim 4 of the copending reference application.

Claim 6 is covered by claim 1 of the copending reference application.

Claim 7 is covered by claim 2 of the copending reference application.

Claim 8 is covered by claim 1 of the copending reference application.

Claim 9 is covered by claim 8 of the copending reference application.

Claim 10 is covered by claim 18 of the copending reference application since it is well known to process output form a sensor using a signal processing circuit per se.

Claim 11 is covered by claim 18 of the copending reference application.

Claim 12 is covered by claim 17 of the copending reference application.

Claim 13 is covered by claim 29 of the copending reference application.

Claim 14 is covered by claims 1 and 23 the copending reference application in the same manner as claim 1 for the same features.

Claim 15 is covered by claim 5 of the copending reference application.

Claim 16 is covered by claim 6 of the copending reference application.

Claim 17 is covered by claim 1 of the copending reference application.

Claim 18 is covered by claim 7 of the copending reference application.

Claim 19 is covered by claim 9 of the copending reference application.

Claim 20 is covered by claims 1, 9 (for the telecentric lens), and 23 (for the distance data) of the copending reference application. While the copending claims do not state a “lidar” system per se,

persons having ordinary skill in the art would recognize that the system of claims 1, 9, and 23 would be a kind of lidar system since claims using a laser for distance measuring.

Claim 21 is covered by claim 18 of the copending reference application.

Claim 22 is covered by claim 9 of the copending reference application.

Claim 23 is covered by claim 1 of the copending reference application.

Claim 24 is covered by claim 29 of the copending reference application.

Claim 25 is covered by claim 1 of the copending reference application since the spots recited in line 6 of claim 1 of copending claim 1 form an emission region in the field recited in line 6 of copending claim 1.

Conclusion

The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Patent no. US 11,086,013 B2 discloses similar systems as that of the present application.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to JOHN R. LEE whose telephone number is (571)272-2477. The examiner can normally be reached on Monday - Friday, 8:00 am - 5 pm.

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

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Georgia Epps can be reached on (571) 272- 2328. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained

from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see https://ppair-my.uspto.gov/pair/PrivatePair. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/JOHN R LEE/
Primary Examiner, Art Unit 2878

Notice of References Cited	Application/Control No. 17/323,962	Applicant(s)/Patent Under Reexamination PACALA et al.	
	Examiner JOHN R LEE	Art Unit 2878	Page 1 of 1

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	B					
	C					
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	E					
	F					
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	H					
	I					
	J					
	K					
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*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
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	O					
	P					
	Q					
	R					
	S					
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Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	Art Unit
	JOHN R LEE	2878

CPC - Searched*		
Symbol	Date	Examiner
H04N13/0217, H04N13/0207, H04N13/0203, H04N13/0495, H04N13/0488, G02B3/0056, G02B3/0037, G02B3/0006, G02B5/005, G02B5/208, G02B5/20, G02B27/2214, G02B27/22, G01J1/08, G02B6/002, G01J1/02, G01J1/0266, G01J1/029, H04N13/218, G02B30/27, G02B27/46	08/11/2021	jl

CPC Combination Sets - Searched*		
Symbol	Date	Examiner

US Classification - Searched*			
Class	Subclass	Date	Examiner

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

Search Notes		
Search Notes	Date	Examiner
Inventor name search.	08/11/2021	jl
Assignee search.	08/11/2021	jl
Consulted SN: 62/232,222; 15/276,532; 15/419,053; 15/861,330; 15/880,491; PCT/US17/39306; 62/112,553; 62/227,558; 15/934,338; 16/584,515; 16/046,643; and 17/317,809.	08/11/2021	jl
EAST; see search history print out.	08/11/2021	jl

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	Art Unit
	JOHN R LEE	2878

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

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	**Art Unit**
	JOHN R LEE	2878

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

CLAIMS

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

CLAIM		DATE								
Final	Original	08/26/2021								
	1	✓								
	2	✓								
	3	✓								
	4	✓								
	5	✓								
	6	✓								
	7	✓								
	8	✓								
	9	✓								
	10	✓								
	11	✓								
	12	✓								
	13	✓								
	14	✓								
	15	✓								
	16	✓								
	17	✓								
	18	✓								
	19	✓								
	20	✓								
	21	✓								
	22	✓								
	23	✓								
	24	✓								
	25	✓								

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

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	Application Number	
	Filing Date	Herewith
	First Named Inventor	Angus Pacala
	Art Unit	Unknown
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

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Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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	Examiner Name	Not yet assigned
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	Art Unit	Unknown
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

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	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977-P001USC5

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	Attorney Docket Number	103033-1252977-P001USC5

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	Art Unit	Unknown
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EXAMINER SIGNATURE

Examiner Signature	/JOHN R LEE/	Date Considered	08/11/2021

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document.
[4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

KILPATRICK TOWNSEND 74800723 1

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
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S211	47	(H04N13/0488).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S212	12,197	(G02B3/0056).CPC.	US-PGPUB; USPAT; USOCR;	OR	ON	2021/08/11 13:46

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S213	2,766	(G02B3/0037).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S214	4,562	(G02B3/0006).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S215	8,529	(G02B5/005).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S216	17,869	(G02B5/208).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S217	12,089	(G02B5/20).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S218	3,075	(G02B27/2214).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S219	1,177	(G02B27/22).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S220	150,249	((3d or "3-d" or (three adj dimension$4)) same (image or imager or imaging or distance)) and (pixel or array) and (aperture or stop or pinhole or (pin adj hole))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S221	90,924	S220 and ((bulk with optic$4) or lens or objective)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46

S222	5,162	S221 and (collimating with lens)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S223	1,742	S221 and (diffusing or diffuser) with (detect$4 or sens$4 or pixel or photodetect$4 or photosens$4 or spad or pd)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S224	292	S222 and S223	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S225	275	(S222 or S223) and (single with photon with avalanche)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:46
S226	107	(S222 or S223) and (resonan$4 with cavity with (photodiode or diode))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S227	6,515	(S222 or S223) and (transmit$4 or emitt$4 or laser or led)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S228	153	(resonan$4 adj cavity adj (photodiode or diode))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S229	2,514	(G01J1/08).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S230	5,763	(G02B6/002).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S231	3,802	(G01J1/02).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2021/08/11 13:47

			JPO; DERWENT; IBM_TDB			
S232	1,608	(G01J1/0266).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S233	224	(G01J1/029).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S234	3,227	(H04N13/218).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S235	17,313	(G02B30/27).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S236	3,587	(G02B27/46).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/08/11 13:47
S237	2	(("20110038459") or ("20080037114")).PN.	US-PGPUB; USPAT	OR	OFF	2021/08/11 16:14

8/26/2021 12:08:50 PM
C:\Users\jlee\Documents\EAST\Workspaces\17323962_faom_3.wsp

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	Not yet assigned
	Attorney Docket Number	103033-1252977

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1	11025885		Jun 1, 2021	Pacala et al.	

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code [4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	2.	Application No. 17/317,809, filed May 11, 2021, 81 pages	
	3.	15/880,491 , "Corrected Notice of Allowability", April 28, 2021, 2 pages	

EXAMINER SIGNATURE

Examiner Signature	/JOHN R LEE/	Date Considered	08/11/2021

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.R.L/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	
	Attorney Docket Number	103033-1252977-P001USC5

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code [4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	2011063347	WO		May 26, 2011	Pelican Imaging Corporation		
	2	20120137432	KR		Dec 20, 2012	Qualcomm Incorporated		
	3	20130038388	KR		Apr 17, 2013	Fraunhofer-Gesellschaft Zur Foerderung Der Angewandten Forschung E.V.		
	4	2015037211	WO		Mar 19, 2015	Sony Corporation		
	5	20150072439	KR		Jun 29, 2015	Qualcomm Incorporated		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]

EXAMINER SIGNATURE

Examiner Signature	/JOHN R LEE/	Date Considered	08/11/2021

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.R.L/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
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	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2636
	Examiner Name	
	Attorney Docket Number	103033-1252977-P001USC5

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code [1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code [1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code [4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	1	103048046	CN		Apr 17, 2013	Zhejiang University		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
		17/317,809 , "U.S. Patent Application No.", Optical System for Collecting Distance Information Within a Field, May 11, 2021, 40 pages	

EXAMINER SIGNATURE

Examiner Signature	/JOHN R LEE/	Date Considered	08/11/2021

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.R.L/

Bibliographic Data

Application No: 17/323,962

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /JOHN R LEE/ (Examiner's Signature) | (Initials)

Title: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
05/18/2021	348	2878	103033-P001USC5-1252977
RULE			

APPLICANTS

Ouster, Inc., San Francisco, CA,

INVENTORS

Angus PACALA, San Francisco, CA, UNITED STATES

Mark FRICHTL, San Francisco, CA, UNITED STATES

CONTINUING DATA

This application is a CON of 15880491 01/25/2018 PAT 11025885

15880491 is a CON of 15276532 09/26/2016 PAT 9992477

15276532 has PRO of 62232222 09/24/2015

FOREIGN APPLICATIONS

IF REQUIRED, FOREIGN LICENSE GRANTED**

05/25/2021

**** SMALL ENTITY ****

STATE OR COUNTRY

UNITED STATES

ADDRESS

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309
UNITED STATES

FILING FEE RECEIVED

$3,250

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977

CONFIRMATION NO. 1014

20350
Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

PUBLICATION NOTICE



Title:OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Publication No.US-2021-0274148-A1
Publication Date:09/02/2021

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently https://portal.uspto.gov/pair/PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

Doc Code: DIST.E.FILE **Document Description: Electronic Terminal Disclaimer - Filed**	PTO/SB/25 U.S. Patent and Trademark Office Department of Commerce

Electronic Petition Request	**TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION**
Application Number	17323962
Filing Date	18-May-2021
First Named Inventor	Angus PACALA
Attorney Docket Number	103033-P001USC5-1252977
Title of Invention	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

☒ Filing of terminal disclaimer does not obviate requirement for response under 37 CFR 1.111 to outstanding Office Action

☒ This electronic Terminal Disclaimer is not being used for a Joint Research Agreement.

Owner	Percent Interest
OUSTER, INC.	100%

The owner(s) of percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending reference Application Number(s)

17317809 filed on 05/11/2021

as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the reference application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said reference application, "as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application," in the event that any such patent granted on the pending reference application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

◉ Terminal disclaimer fee under 37 CFR 1.20(d) is included with Electronic Terminal Disclaimer request.

○ I certify, in accordance with 37 CFR 1.4(d)(4), that the terminal disclaimer fee under 37 CFR 1.20(d) required for this terminal disclaimer has already been paid in the above-identified application.	
Applicant claims the following fee status: ◉ Small Entity ○ Micro Entity ○ Regular Undiscounted I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.	
THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES I certify, in accordance with 37 CFR 1.4(d)(4) that I am: ◉ An attorney or agent registered to practice before the Patent and Trademark Office who is of record in this application Registration Number 37234 ○ A sole inventor ○ A joint inventor; I certify that I am authorized to sign this submission on behalf of all of the inventors as evidenced by the power of attorney in the application ○ A joint inventor; all of whom are signing this request	
Signature	/William L. Shaffer/
Name	William L. Shaffer

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this certification. See MPEP § 324.

Electronic Patent Application Fee Transmittal

Application Number:	17323962
Filing Date:	18-May-2021
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Filer:	William Leland Shaffer/LaRenda Meyer
Attorney Docket Number:	103033-P001USC5-1252977

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
STATUTORY OR TERMINAL DISCLAIMER	2814	1	170	170
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**170**

Doc Code: DISQ.E.FILE
Document Description: Electronic Terminal Disclaimer – Approved

Application No.: 17323962

Filing Date: 18-May-2021

Applicant/Patent under Reexamination: PACALA

Electronic Terminal Disclaimer filed on September 10, 2021

☒ APPROVED

This patent is subject to a terminal disclaimer

☐ DISAPPROVED

Approved/Disapproved by: Electronic Terminal Disclaimer automatically approved by EFS-Web

U.S. Patent and Trademark Office

Electronic Acknowledgement Receipt	
EFS ID:	43735197
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	10-SEP-2021
Filing Date:	18-MAY-2021
Time Stamp:	14:34:25
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$170
RAM confirmation Number	E202190E34224544
Deposit Account	201430
Authorized User	LaRenda Meyer
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Terminal Disclaimer-Filed (Electronic)	eTerminal-Disclaimer.pdf	43712 a1299d5396447ff04034f5ddd3272ea432fc53f4	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	37896 286625ab02e6973c3f9be5ad779ac3a95365495e	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	81608		

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.

I hereby certify that this correspondence is being filed via EFS-Web with the United States Patent and Trademark Office on September 10, 2021.

KILPATRICK TOWNSEND & STOCKTON LLP

By: /La Renda Meyer-Johnson/

PATENT
Attorney Docket No.: 103033-1252977-P001USC5
Client Ref. No.: P001USC5

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Angus Pacala, et al.

Application No.: 17/323,962

Filed: May 18, 2021

For: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

Customer No.: 20350

Confirmation No.: 1014

Examiner: John R Lee

Technology Center/Art Unit: 2878

AMENDMENT / RESPONSE TO OFFICE ACTION

Mail Stop: Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Commissioner:

In response to the Office Action mailed August 31, 2021, please enter the following amendments and consider the following remarks:

Remarks/Arguments begin on page 2 of this paper.

REMARKS/ARGUMENTS

Upon entry of the present amendment, claims 1-25 will be pending in this application. No new matter is added. Based on the following remarks, Applicant respectfully requests reconsideration and allowance of the pending claims.

Double Patenting

Claims 1-25 were rejected under the judicially-created doctrine of nonstatutory obviousness-type double patenting over claims 1-9 and 11-31 of U.S. Patent Application No. 17/317,809. To expedite prosecution of the present invention, Applicants are filing herewith a Terminal Disclaimer of the patent cited above, thereby obviating further such double patenting rejections. Thus, Applicants respectfully request such rejections be withdrawn.

CONCLUSION

In view of the foregoing, Applicant believes all claims now pending in this application are in condition for allowance. The issuance of a formal Notice of Allowance at an early date is respectfully requested.

Except for the issue fees payable under 37 C.F.R. § 1.18, the Director is authorized to charge any additional fees during pendency of this application, including any required extension of time fees, or credit any overpayment to Deposit Account Number 20-1430. This paragraph is intended to be a constructive petition for extension of time in accordance with 37 C.F.R. § 1.136(a)(3).

If the Examiner believes a telephone conference would expedite prosecution of this application, please contact the undersigned at 858-350-6104 or wshaffer@kilpatricktownsend.com.

Respectfully submitted,

/ William L. Shaffer /

William L. Shaffer
Registration No. 37,234

KILPATRICK TOWNSEND & STOCKTON LLP

Electronic Acknowledgement Receipt	
EFS ID:	43735331
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	10-SEP-2021
Filing Date:	18-MAY-2021
Time Stamp:	14:39:04
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		P001USC5-1252977-Response-NFOA.pdf	104612 54a8d72e021ffa32a8ed95fab0bb988f06e69cc6	yes	3

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Applicant Arguments/Remarks Made in an Amendment	2	3
Warnings:			
Information:			
	Total Files Size (in bytes):	104612	

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

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

20350 7590 09/29/2021

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER
LEE, JOHN R

ART UNIT	PAPER NUMBER
2878	

DATE MAILED: 09/29/2021

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977	1014

TITLE OF INVENTION: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$600	$0.00	$0.00	$600	12/29/2021

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20350 7590 09/29/2021

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977	1014

TITLE OF INVENTION: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$600	$0.00	$0.00	$600	12/29/2021

EXAMINER	ART UNIT	CLASS-SUBCLASS
LEE, JOHN R	2878	348-050000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1_____
2_____
3_____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑Issue Fee ❑Publication Fee (if required) ❑Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977	1014

20350 7590 09/29/2021

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

EXAMINER	
LEE, JOHN R	

ART UNIT	PAPER NUMBER
2878	

DATE MAILED: 09/29/2021

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 30 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

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

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

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

Notice of Allowability	Application No. 17/323,962	Applicant(s) PACALA et al.	
	Examiner JOHN R LEE	Art Unit 2878	AIA (FITF) Status Yes

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

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to the terminal disclaimer filed on 09/10/2021.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

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

3. ☑ The allowed claim(s) is/are 1-25 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

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

   Certified copies:

   a) ☐ All b) ☐ Some* c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☑ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 08/30/2021.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☑ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/JOHN R LEE/
Primary Examiner, Art Unit 2878

Notice of Pre-AIA or AIA Status

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

Terminal Disclaimer

The terminal disclaimer filed on 09/10/2021 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of any patent granted on application number 17/317,809 has been reviewed and is accepted. The terminal disclaimer has been recorded.

Reasons for Allowance

The following is an examiner's statement of reasons for allowance: Claims 1-25 are allowed by virtue of the terminal disclaimer filed on 09/10/2021 noted above.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to JOHN R. LEE whose telephone number is (571)272-2477. The examiner can normally be reached on Monday - Friday, 8:00 am - 5 pm.

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

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Georgia Epps can be reached on (571) 272- 2328. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

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

/JOHN R LEE/
Primary Examiner, Art Unit 2878

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	**Art Unit**
	JOHN R LEE	2878

CPC							
Symbol						**Type**	**Version**
H04N	/	13	/	218		F	2018-05-01
G02B	/	5	/	005		I	2013-01-01
G02B	/	3	/	0056		I	2013-01-01
G02B	/	5	/	208		I	2013-01-01
G02B	/	27	/	46		I	2013-01-01
G02B	/	30	/	27		I	2020-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	25	
/JOHN R LEE/ Primary Examiner, Art Unit 2878	18 September 2021	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20210918

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	Art Unit
	JOHN R LEE	2878

INTERNATIONAL CLASSIFICATION				
CLAIMED				
H04N	/	13	/	218
G02B	/	27	/	46
G02B	/	3	/	00
G02B	/	30	/	27
G02B	/	5	/	00
G02B	/	5	/	20
	/		/	

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	SUBCLASS

CROSS REFERENCES(S)						
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)					

NONE (Assistant Examiner)	(Date)	Total Claims Allowed: 25	
/JOHN R LEE/ Primary Examiner, Art Unit 2878 (Primary Examiner)	18 September 2021 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

U.S. Patent and Trademark Office — Part of Paper No.: 20210918

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	**Art Unit**
	JOHN R LEE	2878

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

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	25	
/JOHN R LEE/ Primary Examiner, Art Unit 2878	18 September 2021	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office Part of Paper No.: 20210918

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	Art Unit
	JOHN R LEE	2878

CPC - Searched*		
Symbol	**Date**	**Examiner**
H04N13/0217, H04N13/0207, H04N13/0203, H04N13/0495, H04N13/0488, G02B3/0056, G02B3/0037, G02B3/0006, G02B5/005, G02B5/208, G02B5/20, G02B27/2214, G02B27/22, G01J1/08, G02B6/002, G01J1/02, G01J1/0266, G01J1/029, H04N13/218, G02B30/27, G02B27/46	08/11/2021	jl
Above to date.	09/14/2021	jl

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

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

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	Art Unit
	JOHN R LEE	2878

Search Notes		
Search Notes	**Date**	**Examiner**
Inventor name search.	08/11/2021	jl
Assignee search.	08/11/2021	jl
Consulted SN: 62/232,222; 15/276,532; 15/419,053; 15/861,330; 15/880,491; PCT/US17/39306; 62/112,553; 62/227,558; 15/934,338; 16/584,515; 16/046,643; and 17/317,809.	08/11/2021	jl
EAST; see search history print out.	08/11/2021	jl
Updated above; see search history print out.	09/14/2021	jl

Interference Search			
US Class/CPC Symbol	**US Subclass/CPC Group**	**Date**	**Examiner**
	US-PGPUB and USPAT; see search history print out.	09/14/2021	jl

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	17/323,962	PACALA et al.
	Examiner	**Art Unit**
	JOHN R LEE	2878

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

CLAIMS

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

CLAIM		DATE								
Final	Original	08/26/2021	09/18/2021							
	1	✓	=							
	2	✓	=							
	3	✓	=							
	4	✓	=							
	5	✓	=							
	6	✓	=							
	7	✓	=							
	8	✓	=							
	9	✓	=							
	10	✓	=							
	11	✓	=							
	12	✓	=							
	13	✓	=							
	14	✓	=							
	15	✓	=							
	16	✓	=							
	17	✓	=							
	18	✓	=							
	19	✓	=							
	20	✓	=							
	21	✓	=							
	22	✓	=							
	23	✓	=							
	24	✓	=							
	25	✓	=							

EAST Search History

EAST Search History (Prior Art)

JL; updated.

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S246	161	Pacala-Angus$.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S247	118	Frichtl-Mark$.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S248	105	Ouster.as.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S249	236	(H04N13/0217).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S250	215	(H04N13/0207).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S251	436	(H04N13/0203).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S252	101	(H04N13/0495).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S253	47	(H04N13/0488).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S254	12,248	(G02B3/0056).CPC.	US-PGPUB; USPAT; USOCR;	OR	ON	2021/09/14 15:30

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S255	2,786	(G02B3/0037).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S256	4,575	(G02B3/0006).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:30
S257	8,586	(G02B5/005).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S258	17,958	(G02B5/208).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S259	12,169	(G02B5/20).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S260	3,062	(G02B27/2214).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S261	1,166	(G02B27/22).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S262	151,980	((3d or "3-d" or (three adj dimension$4)) same (image or imager or imaging or distance)) and (pixel or array) and (aperture or stop or pinhole or (pin adj hole))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S263	91,953	S262 and ((bulk with optic$4) or lens or objective)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31

S264	5,214	S263 and (collimating with lens)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S265	1,763	S263 and (diffusing or diffuser) with (detect$4 or sens$4 or pixel or photodetect$4 or photosens$4 or spad or pd)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S266	300	S264 and S265	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S267	284	(S264 or S265) and (single with photon with avalanche)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S268	112	(S264 or S265) and (resonan$4 with cavity with (photodiode or diode))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S269	6,579	(S264 or S265) and (transmit$4 or emitt$4 or laser or led)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S270	154	(resonan$4 adj cavity adj (photodiode or diode))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S271	2,526	(G01J1/08).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S272	5,780	(G02B6/002).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S273	3,804	(G01J1/02).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO;	OR	ON	2021/09/14 15:31

			JPO; DERWENT; IBM_TDB			
S274	1,611	(G01J1/0266).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S275	223	(G01J1/029).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S276	3,238	(H04N13/218).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S277	17,297	(G02B30/27).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:31
S278	3,592	(G02B27/46).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2021/09/14 15:32
S279	2	(("20110038459") or ("20080037114")).PN.	US-PGPUB; USPAT	OR	OFF	2021/09/14 15:32

EAST Search History (Interference)

JL

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S280	5,184	((3d or "3-d" or (three adj dimension$4)) same (image or imager or imaging or distance)) and (pixel or array) and (aperture or stop or pinhole or (pin adj hole))and ((bulk with optic$4) or lens or objective) and (collimating with lens)	US-PGPUB; USPAT	OR	ON	2021/09/14 15:32
S281	1,759	((3d or "3-d" or (three adj dimension$4)) same (image or imager or imaging or distance)) and (pixel or array) and (aperture or stop or pinhole or (pin adj hole))and ((bulk with optic$4) or lens or objective) and (diffusing or diffuser) with (detect$4 or sens$4 or pixel or photodetect$4 or photosens$4 or spad or pd)	US-PGPUB; USPAT	OR	ON	2021/09/14 15:32



S282	182	S280 and (single with photon with avalanche)	US-PGPUB; USPAT	OR	ON	2021/09/14 15:32
S283	95	S280 and (resonan$4 with cavity with (photodiode or diode))	US-PGPUB; USPAT	OR	ON	2021/09/14 15:32
S284	5,142	S280 and (transmit$4 or emitt$4 or laser or led)	US-PGPUB; USPAT	OR	ON	2021/09/14 15:32
S285	121	(resonan$4 adj cavity adj (photodiode or diode))	US-PGPUB; USPAT	OR	ON	2021/09/14 15:32

9/18/2021 2:22:12 PM
C:\Users\jlee\Documents\EAST\Workspaces\17323962_amd_3.wsp

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2878
	Examiner Name	Cheryl P Gibson Baylor
	Attorney Docket Number	103033-1252977

U.S. PATENTS

Examiner Initial*	Cite No	Patent Number	Kind Code[1]	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1.	11086013		Aug 10, 2021	Pacala et al.	

U.S. PATENT APPLICATION PUBLICATIONS

Examiner Initial*	Cite No	Publication Number	Kind Code[1]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	2.	20150115131		4/30/2015	Webster, et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initial*	Cite No	Foreign Document Number[3]	Country Code[2]	Kind Code[4]	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T[5]
	3.	2007103590	JP		4/19/2007	Nikon Corp.		

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[5]
	4.	U.S. Patent Application No. 16/584,515, Notice of Allowance, mailed August 13, 2021, 10 pages	
	5.	U.S. Patent Application No. 17/317,809, Notice of Allowance, mailed August 18, 2021, 33 pages	
	6.	U.S. Patent Application No. 16/046,643, Notice of Allowance, mailed August 18, 2021, 18 pages	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.R.L/

Doc code: IDS
Doc description: Information Disclosure Statement (IDS) Field

PTO/SB/08a (01-10)
Approved for use through 07/31/2012. OMB 0651-0031
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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)		
	Application Number	17/323,962
	Filing Date	May 18, 2021
	First Named Inventor	Angus Pacala
	Art Unit	2878
	Examiner Name	Cheryl P Gibson Baylor
	Attorney Docket Number	103033-1252977

EXAMINER SIGNATURE			
Examiner Signature	/JOHN R LEE/	Date Considered	09/18/2021

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1] See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. [2] Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). [3] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document.
[4] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [5] Applicant is to place a check mark here if English language translation is attached.

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e) (2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/ William L. Shaffer /	Date (YYYY-MM-DD)	2021-08-20
Name/Print	William L. Shaffer	Registration Number	37,234

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.R.L/

Bibliographic Data

Application No: 17/323,962

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /JOHN R LEE/ Examiner's Signature | Initials

Title: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
05/18/2021	348	2878	103033-P001USC5-1252977
RULE			

APPLICANTS

Ouster, Inc., San Francisco, CA,

INVENTORS

Angus PACALA, San Francisco, CA, UNITED STATES

Mark FRICHTL, San Francisco, CA, UNITED STATES

CONTINUING DATA

This application is a CON of 15880491 01/25/2018 PAT 11025885

15880491 is a CON of 15276532 09/26/2016 PAT 9992477

15276532 has PRO of 62232222 09/24/2015

FOREIGN APPLICATIONS

IF REQUIRED, FOREIGN LICENSE GRANTED**

05/25/2021

**** SMALL ENTITY ****

STATE OR COUNTRY

UNITED STATES

ADDRESS

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309
UNITED STATES

FILING FEE RECEIVED

$3,250

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20350 7590 09/29/2021

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

La Renda Meyer-Johnson	(Typed or printed name)
/LMeyerJohnson/	(Signature)
October 12, 2021	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/323,962	05/18/2021	Angus PACALA	103033-P001USC5-1252977	1014

TITLE OF INVENTION: OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$600	$0.00	$0.00	$600	12/29/2021

EXAMINER	ART UNIT	CLASS-SUBCLASS
LEE, JOHN R	2878	348-050000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☒ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Kilpatrick Townsend
2 & Stockton LLP
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE	(B) RESIDENCE: (CITY and STATE OR COUNTRY)
Ouster, Inc.	San Francisco, CA

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. Fees submitted: ☒ Issue Fee ☐ Publication Fee (if required) ☐ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ☐ Enclosed check ☐ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 20-1430

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature / William L. Shaffer / Date October 12, 2021

Typed or printed name William L. Shaffer Registration No. 37234

Electronic Patent Application Fee Transmittal

Application Number:	17323962
Filing Date:	18-May-2021
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Filer:	William Leland Shaffer/LaRenda Meyer
Attorney Docket Number:	103033-P001USC5-1252977

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	2501	1	600	600

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**600**

Electronic Acknowledgement Receipt	
EFS ID:	44013008
Application Number:	17323962
International Application Number:	
Confirmation Number:	1014
Title of Invention:	OPTICAL SYSTEM FOR COLLECTING DISTANCE INFORMATION WITHIN A FIELD
First Named Inventor/Applicant Name:	Angus PACALA
Customer Number:	20350
Filer:	William Leland Shaffer/LaRenda Meyer
Filer Authorized By:	William Leland Shaffer
Attorney Docket Number:	103033-P001USC5-1252977
Receipt Date:	12-OCT-2021
Filing Date:	18-MAY-2021
Time Stamp:	19:33:27
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$600
RAM confirmation Number	E20210BJ34040408
Deposit Account	201430
Authorized User	LaRenda Meyer
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	Issue Fee Payment (PTO-85B)	103033-P001USC5-Issue-Fee.pdf	852706 bfcdf7053bb31d3001a09935b666fe6aac710165	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	37897 f492ecee912e3b9443b5d44151a1fe1d2fb0f623	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	890603		

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

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.
National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
17/323,962	11/16/2021	11178381	103033-P001USC5-1252977	1014

20350 7590 10/27/2021

Kilpatrick Townsend & Stockton LLP - West Coast
Mailstop: IP Docketing - 22
1100 Peachtree Street
Suite 2800
Atlanta, GA 30309

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Patents Stakeholder Experience (OPSE), Stakeholder Support Division (SSD) at (571)-272-4200.

INVENTOR(s) (Please see PAIR WEB site http://pair.uspto.gov for additional inventors):

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