(12) UK Patent Application (19) GB (11) 2611154 (13) A

(43) Date of A Publication 29.03.2023

(21) Application No: 2210451.7

(22) Date of Filing: 15.07.2022

(30) Priority Data:
(31) 2021124103 (32) 29.07.2021 (33) JP
(31) 2022039640 (32) 14.03.2022 (33) JP

(71) Applicant(s):
Canon Kabushiki Kaisha
30-2 Shimomaruko, 3-Chome, Ohta-ku,
146-8501 Tokyo, Japan

(72) Inventor(s):
Tohru Ishibashi

(74) Agent and/or Address for Service:
Canon Europe Limited
European Intellectual Property Group,
4 Roundwood Avenue, Stockley Park, Uxbridge,
Middlesex, UB11 1AF, United Kingdom

(51) INT CL:
H04N 23/611 (2023.01) ***G06F 1/16*** (2006.01)
G06F 3/01 (2006.01) ***H04N 23/50*** (2023.01)
H04N 23/69 (2023.01)

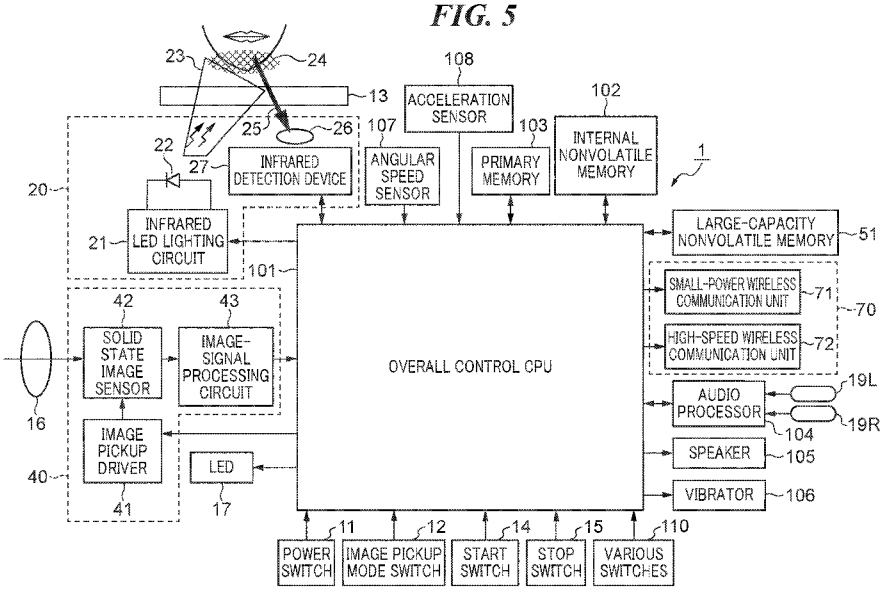
(56) Documents Cited:
EP 3163422 A1 **US 20150310263 A1**

(58) Field of Search:
INT CL **G02B, G06F, G06V, H04N**
Other: **WPI, EPODOC**

(54) Title of the Invention: **Image pickup apparatus used as action camera, control method therefor, and storage medium storing control program therefor**
Abstract Title: **Imaging apparatus including user observation direction detection**

(57) An image pickup apparatus comprises an observation direction detection unit 20 worn on a body part other than a head of a user, detecting an observation direction of the user. An image pickup (capture) unit 40 is worn on a body of the user and picks up an image. An image output unit 70 outputs an image in an image recording frame corresponding to the observation direction in the image picked up by the image pickup unit. A determination unit 101 determines if a part of the body of the user (e.g. jaw, 134, Fig 24) appears in the image, and, when the part of the body appears in the image, restricts the image recording frame such that a part of the body of the user does not appear in an output image. Also, in a similar system also using a lens in the image pickup, a unit determines a frame position of an image recording frame corresponding to the observation direction in the image; and the unit determines the (output) frame position inside an effective projection area that is projected by the image pickup lens onto the image sensor

FIG. 5



GB 2611154 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG. 1A

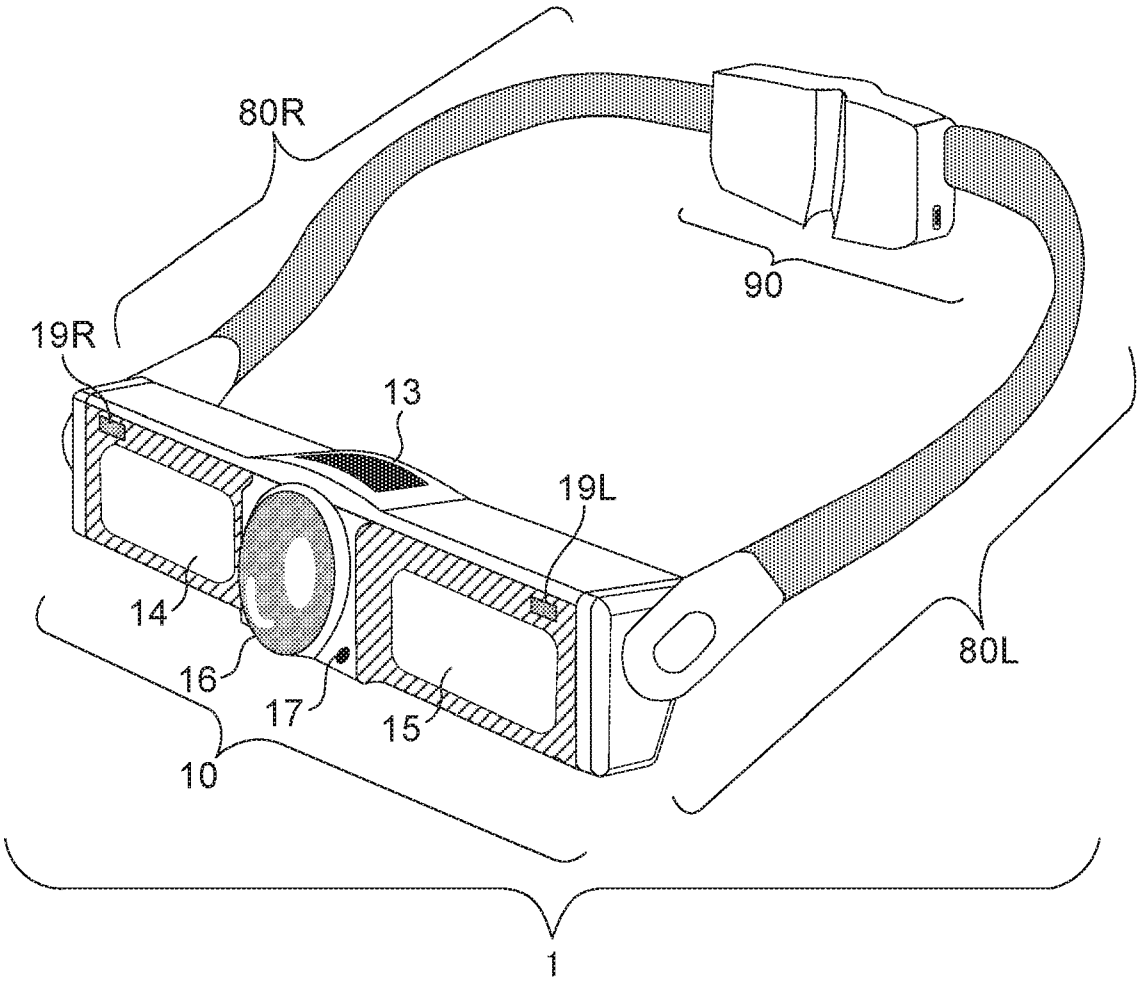


FIG. 1B

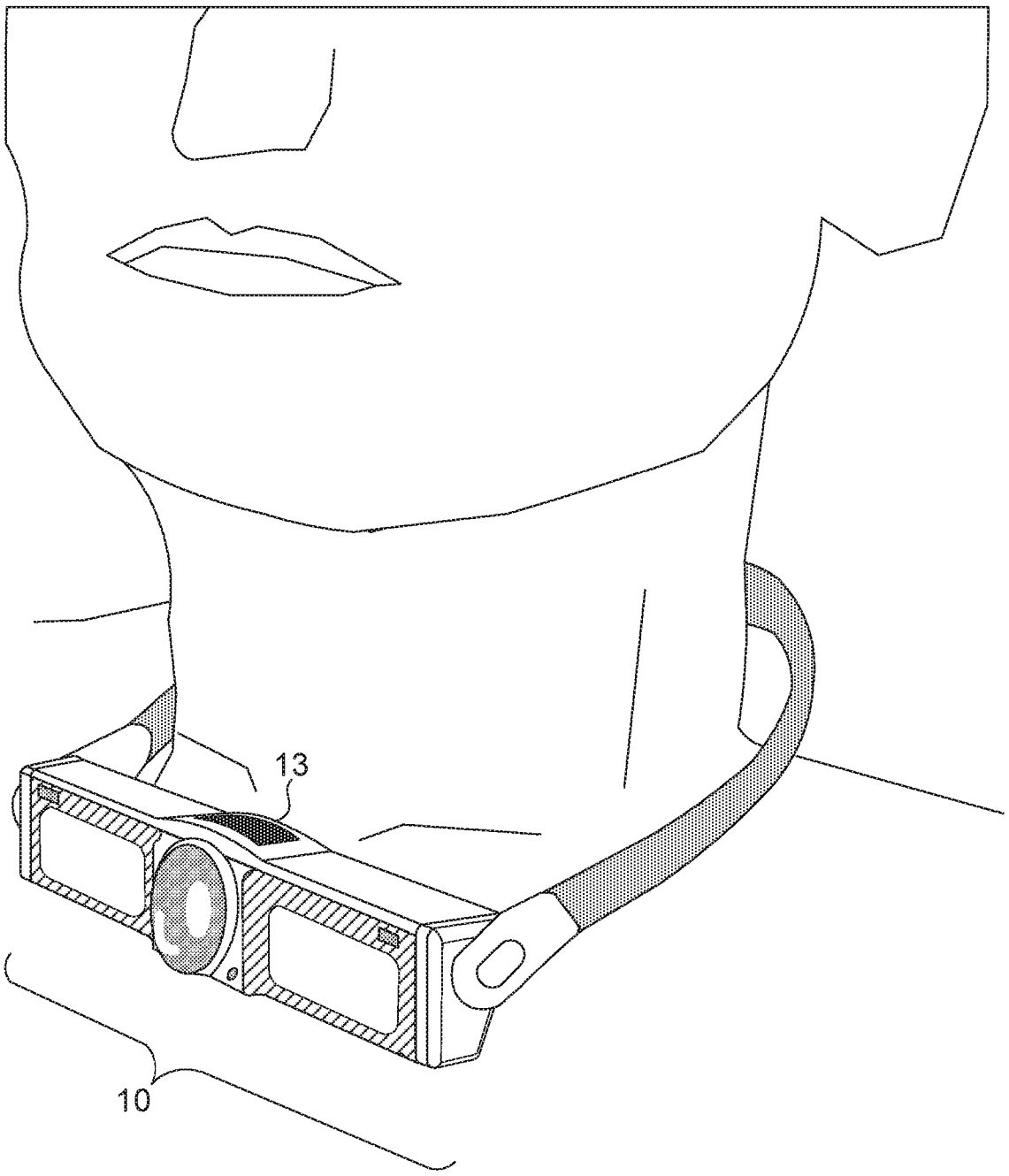
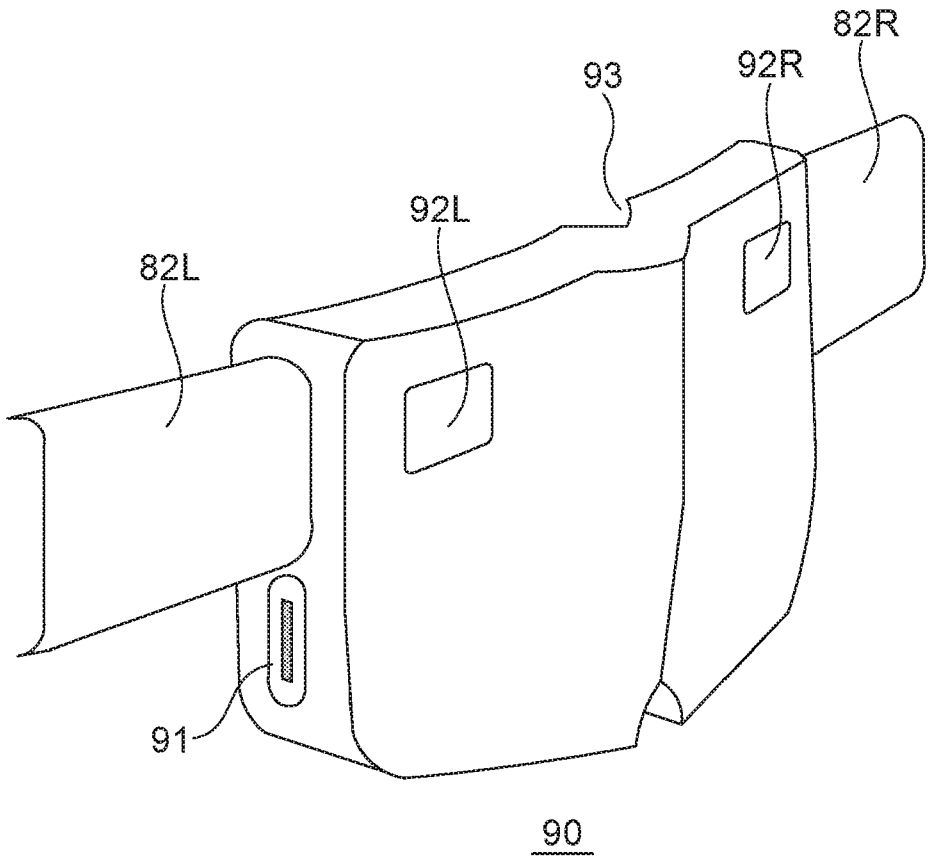
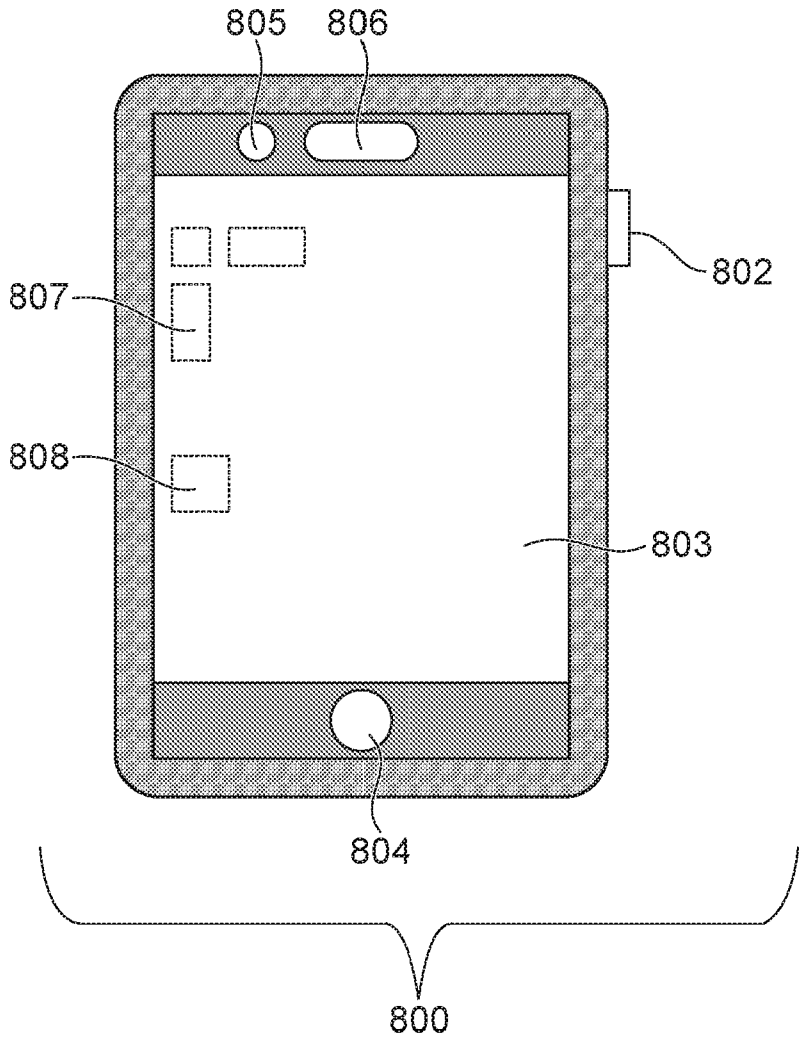


FIG. 1C



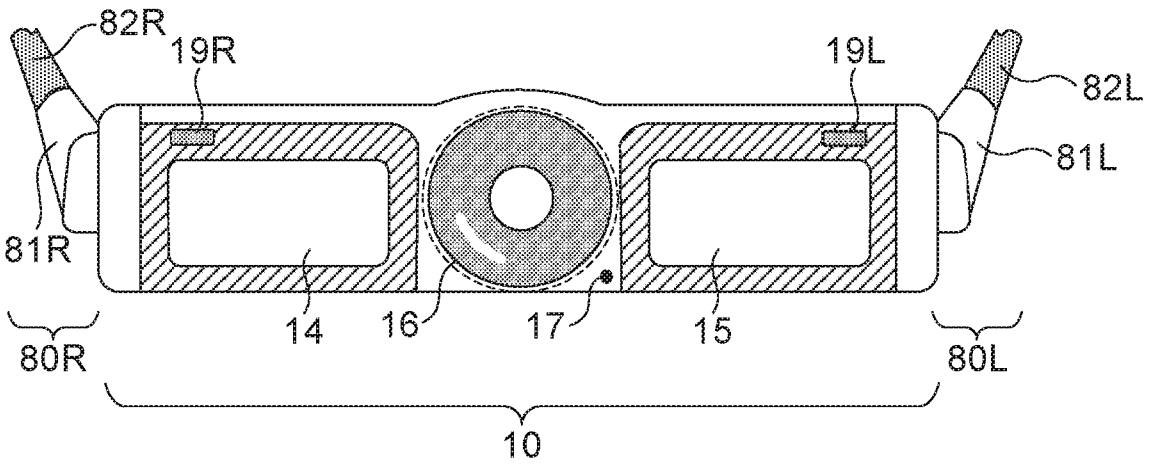
12 12 22

FIG. 1D



12 12 22

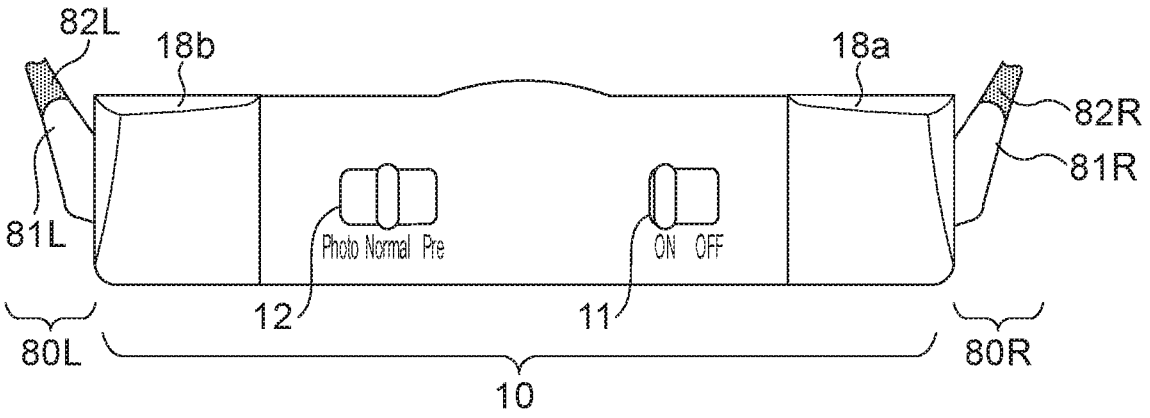
FIG. 2A



12 12 22

FIG. 2B

FIG. 2C



12 12 22

FIG. 2D

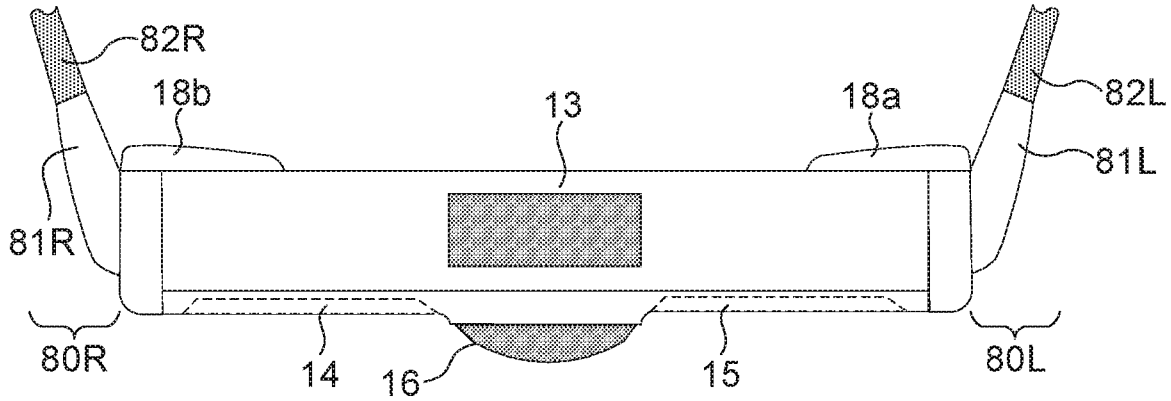
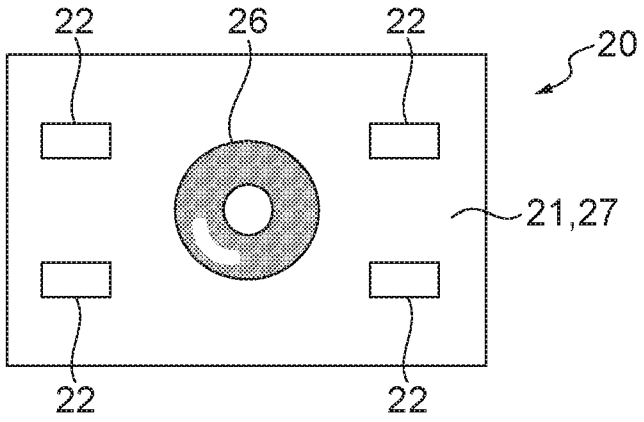


FIG. 2E



12 12 22

FIG. 2F

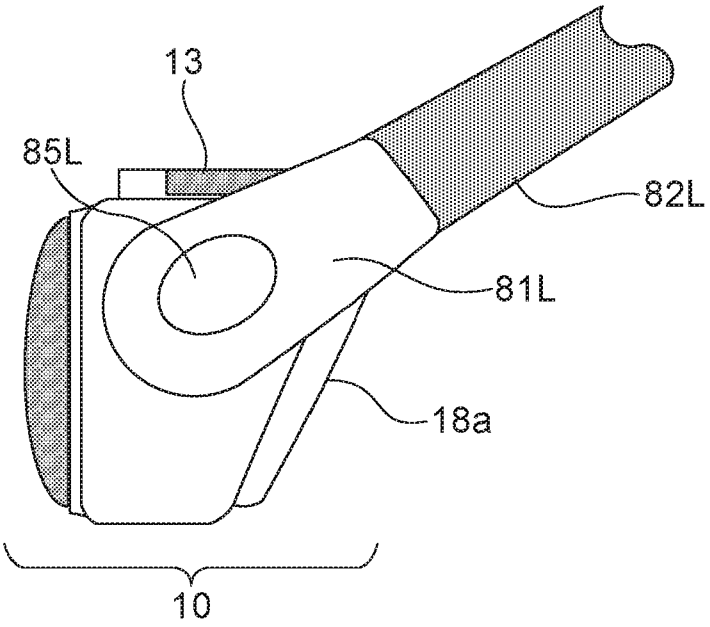


FIG. 3A

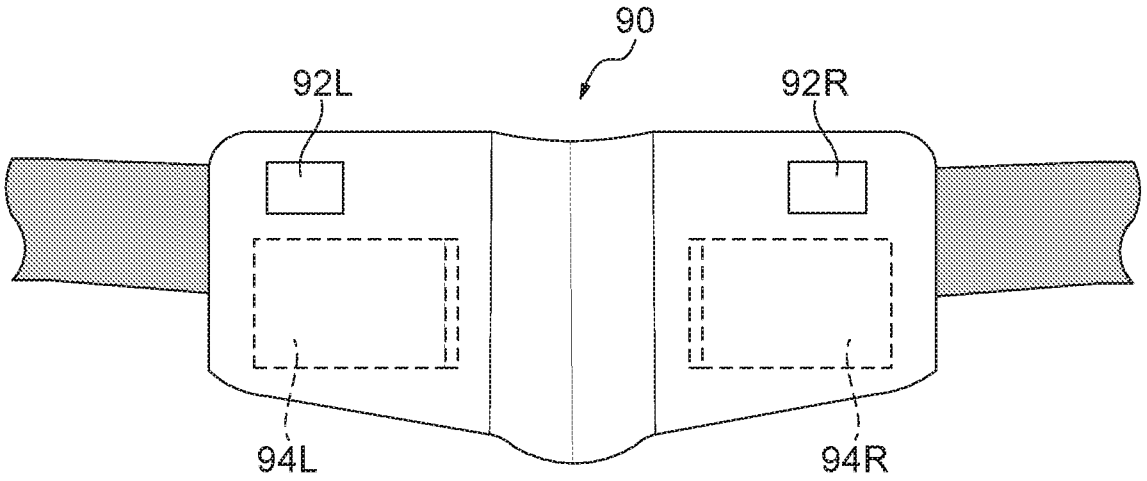


FIG. 3B

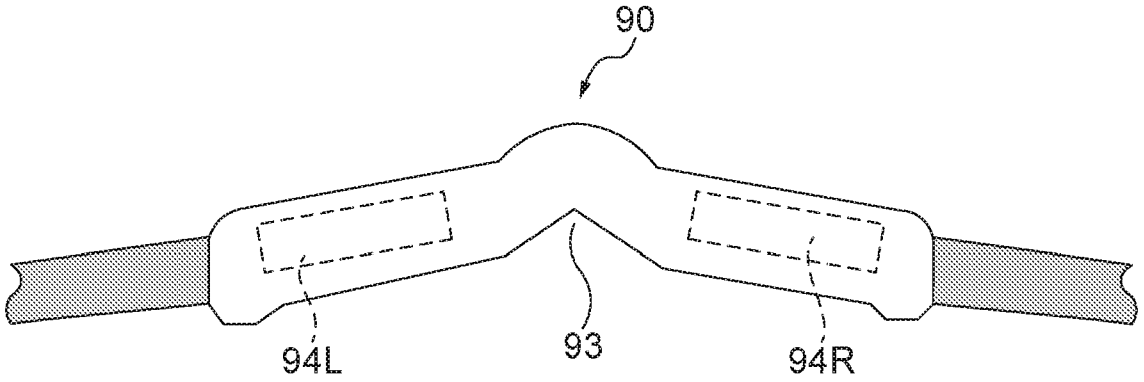
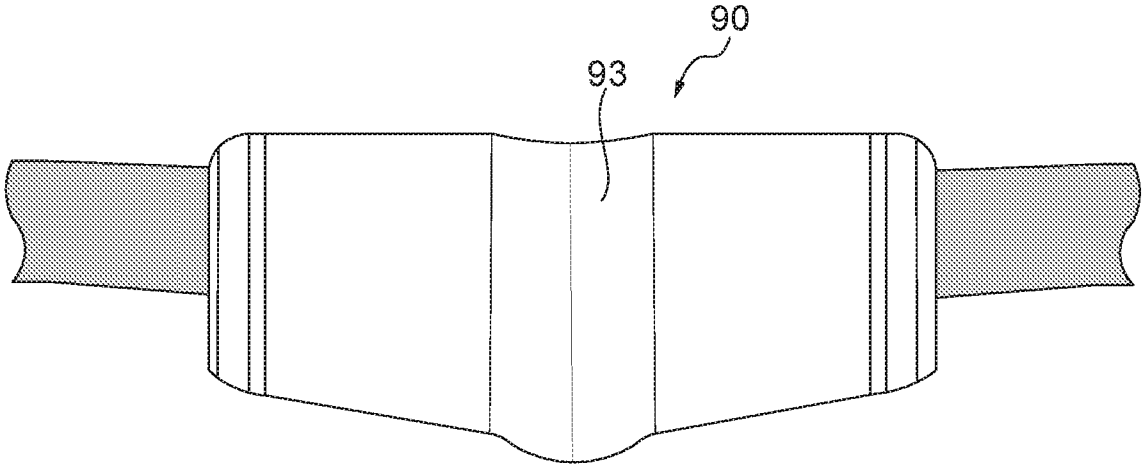
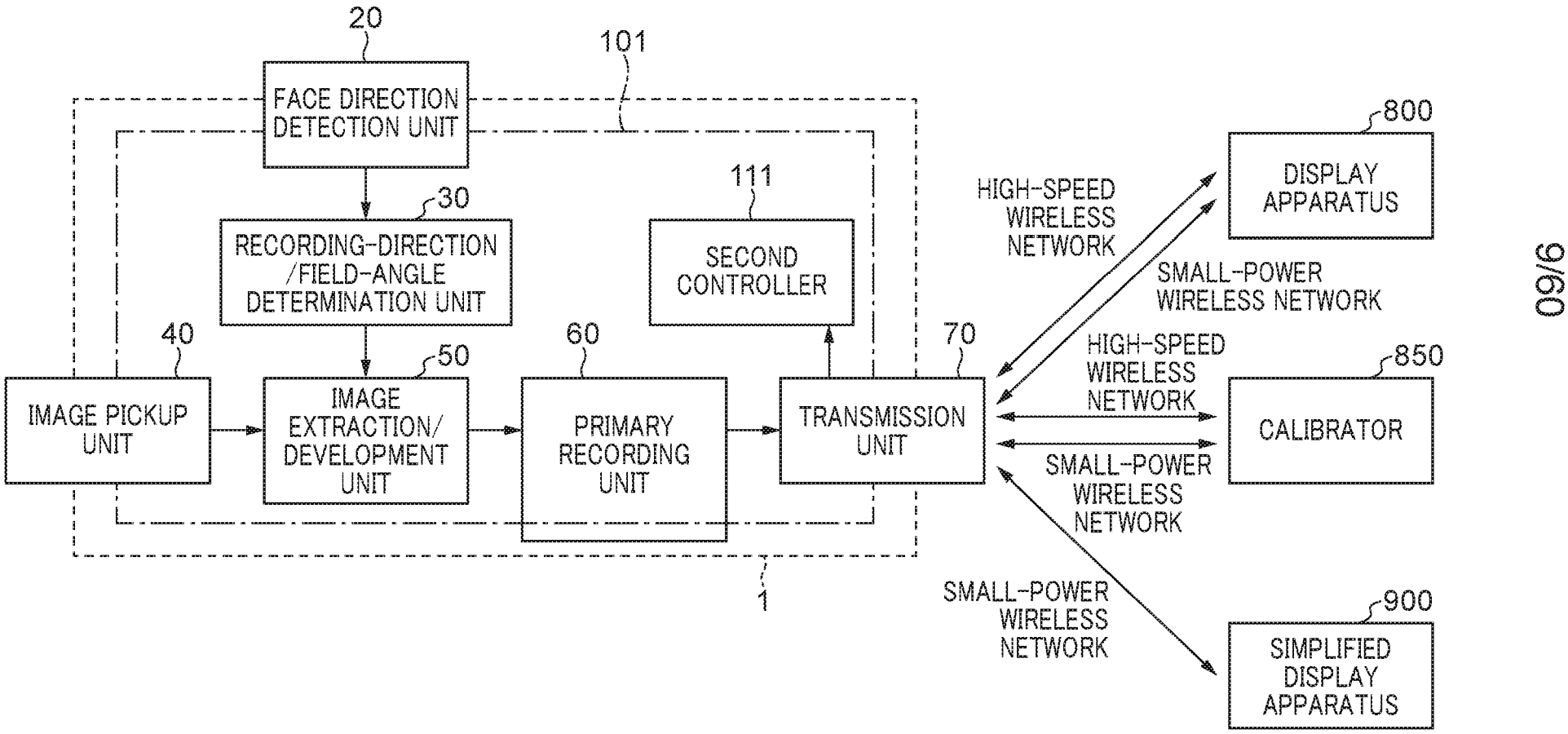


FIG. 3C



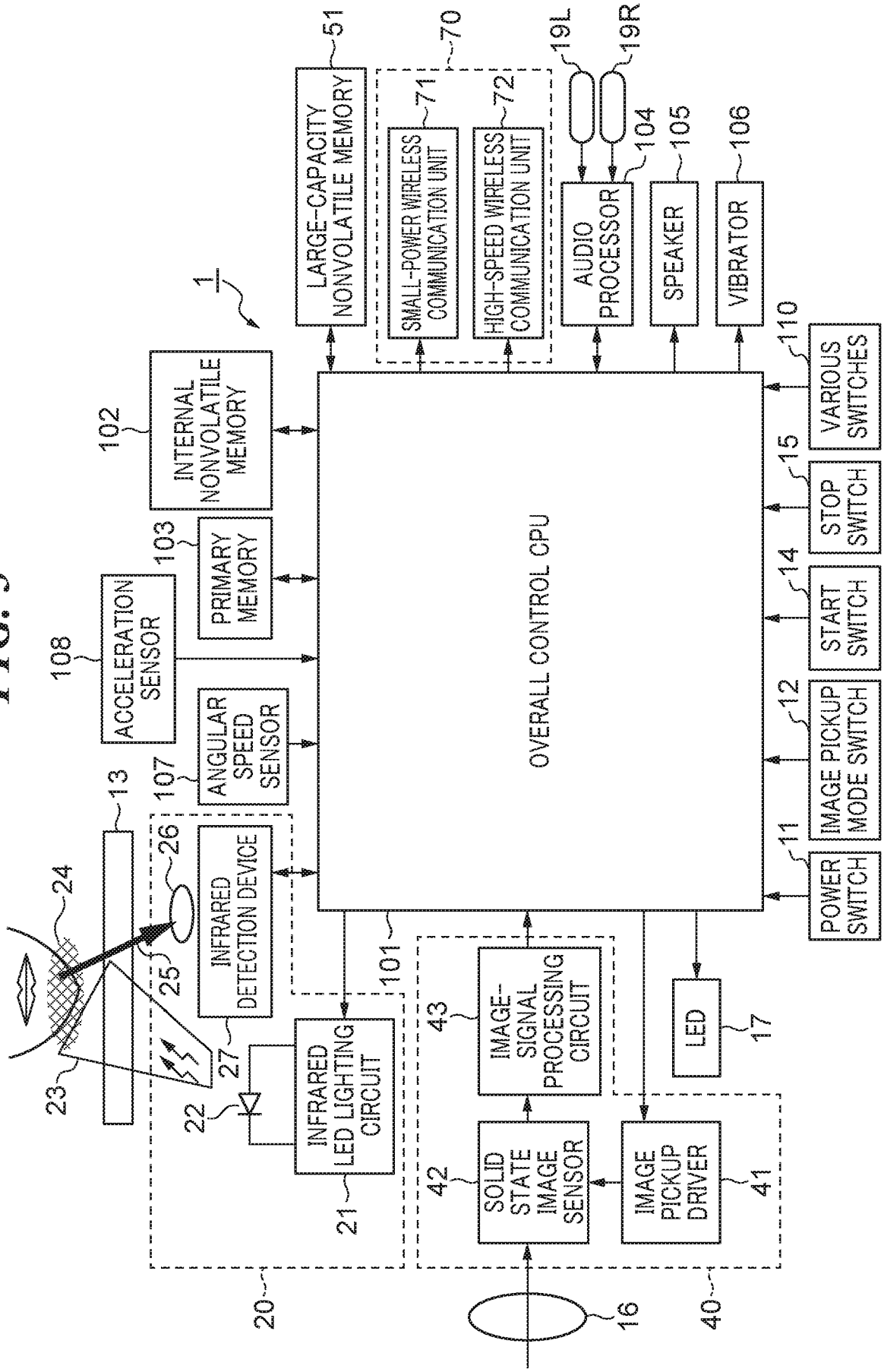
12 12 22

FIG. 4


20
101
FACE DIRECTION DETECTION UNIT
30
RECORDING-DIRECTION /FIELD-ANGLE DETERMINATION UNIT
111
SECOND CONTROLLER
40
50
60
70
IMAGE PICKUP UNIT
IMAGE EXTRACTION/ DEVELOPMENT UNIT
PRIMARY RECORDING UNIT
TRANSMISSION UNIT
1
HIGH-SPEED WIRELESS NETWORK
SMALL-POWER WIRELESS NETWORK
HIGH-SPEED WIRELESS NETWORK
SMALL-POWER WIRELESS NETWORK
SMALL-POWER WIRELESS NETWORK
800
DISPLAY APPARATUS
850
CALIBRATOR
900
SIMPLIFIED DISPLAY APPARATUS

12 12 22

FIG. 5


1
OVERALL CONTROL CPU
INTERNAL NONVOLATILE MEMORY
102
PRIMARY MEMORY
103
ACCELERATION SENSOR
108
ANGULAR SPEED SENSOR
107
INFRARED DETECTION DEVICE
INFRARED LED LIGHTING CIRCUIT
21
SOLID STATE IMAGE SENSOR
42
IMAGE PICKUP DRIVER
41
IMAGE-SIGNAL PROCESSING CIRCUIT
43
LED
17
101
20
40
16
13
22
23
24
25
26
27
LARGE-CAPACITY NONVOLATILE MEMORY
51
70
SMALL-POWER WIRELESS COMMUNICATION UNIT
71
HIGH-SPEED WIRELESS COMMUNICATION UNIT
72
19L
19R
AUDIO PROCESSOR
104
SPEAKER
105
VIBRATOR
106
110
VARIOUS SWITCHES
STOP SWITCH
15
START SWITCH
14
IMAGE PICKUP MODE SWITCH
12
POWER SWITCH
11

12 12 22

FIG. 6

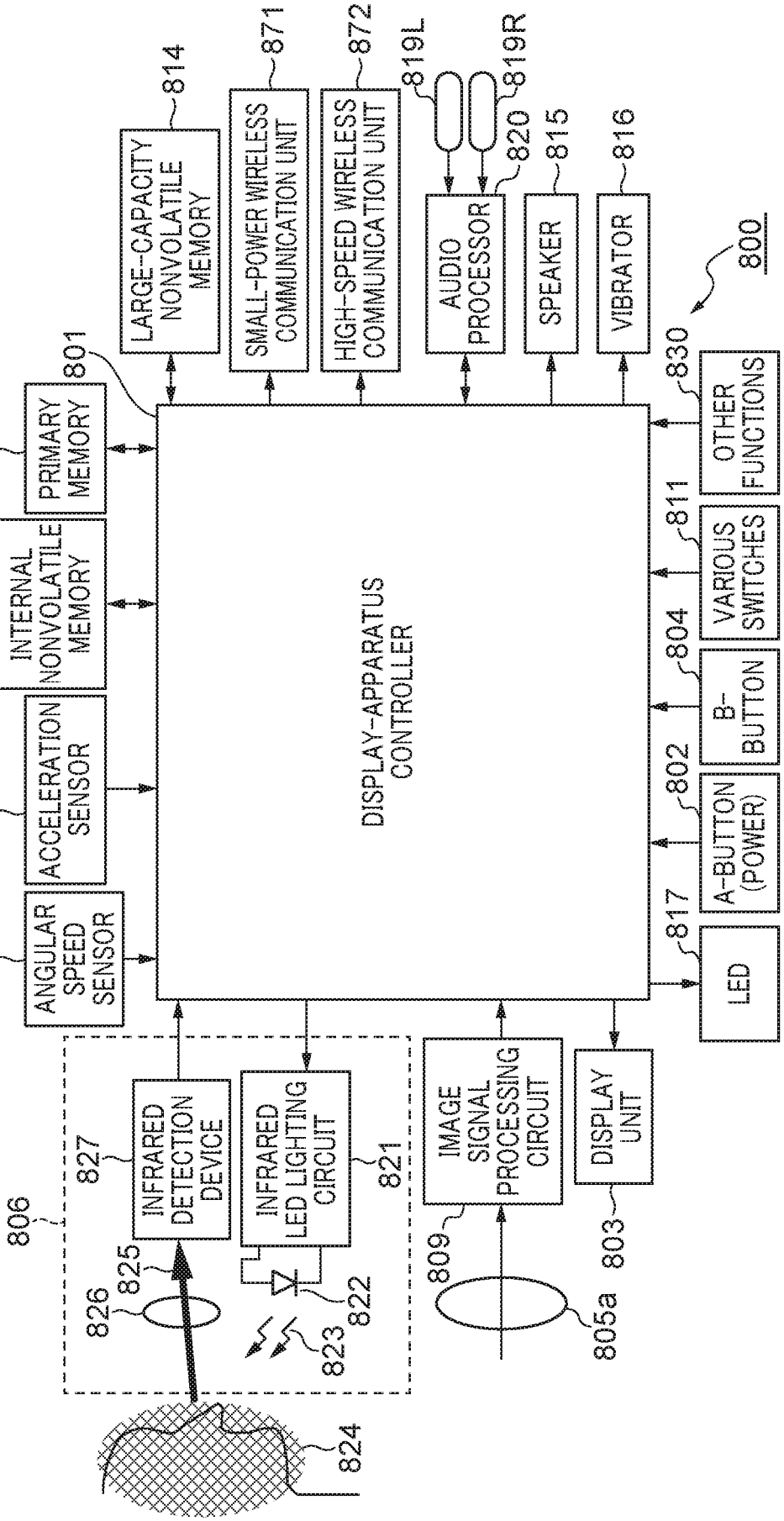
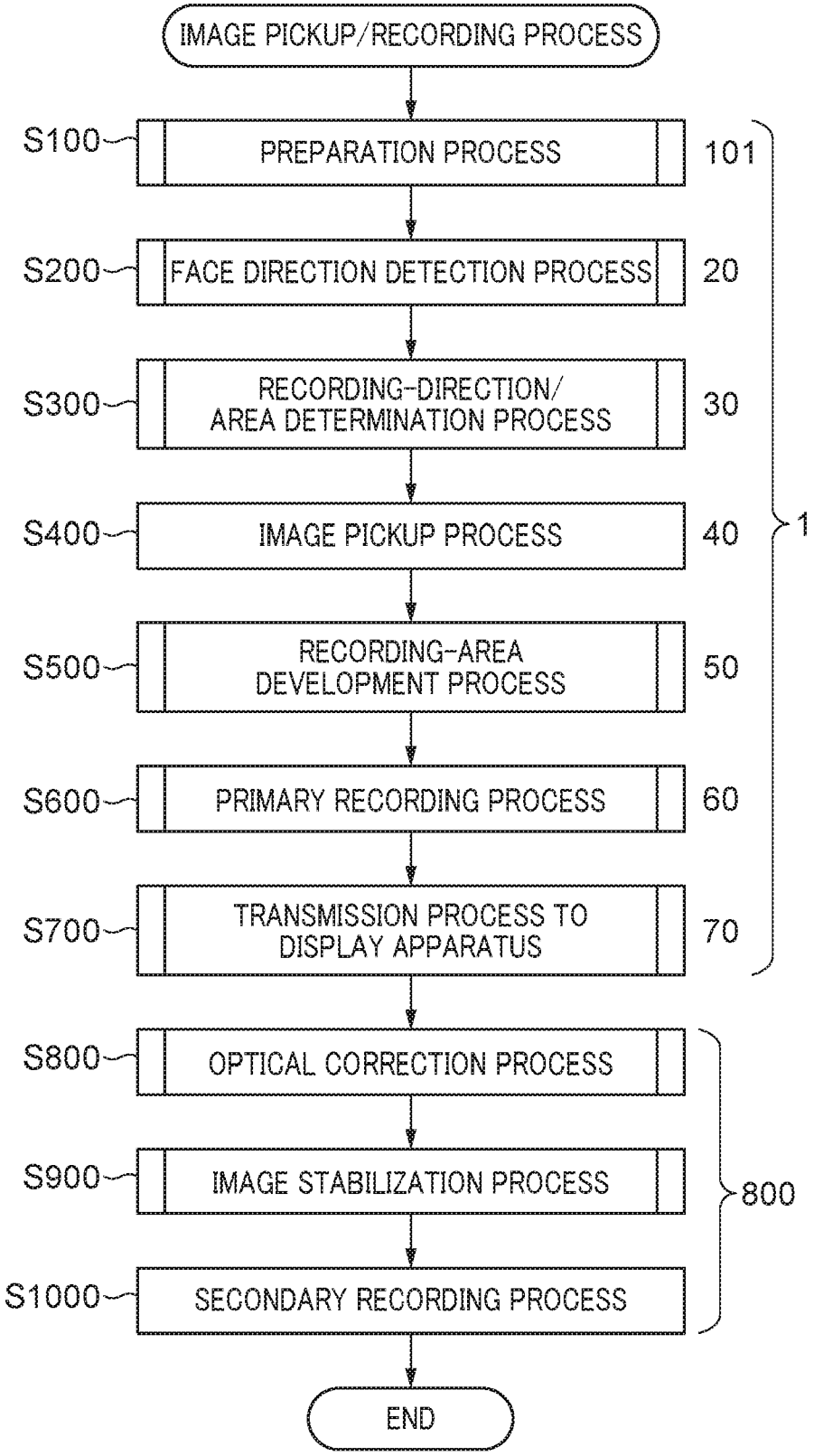
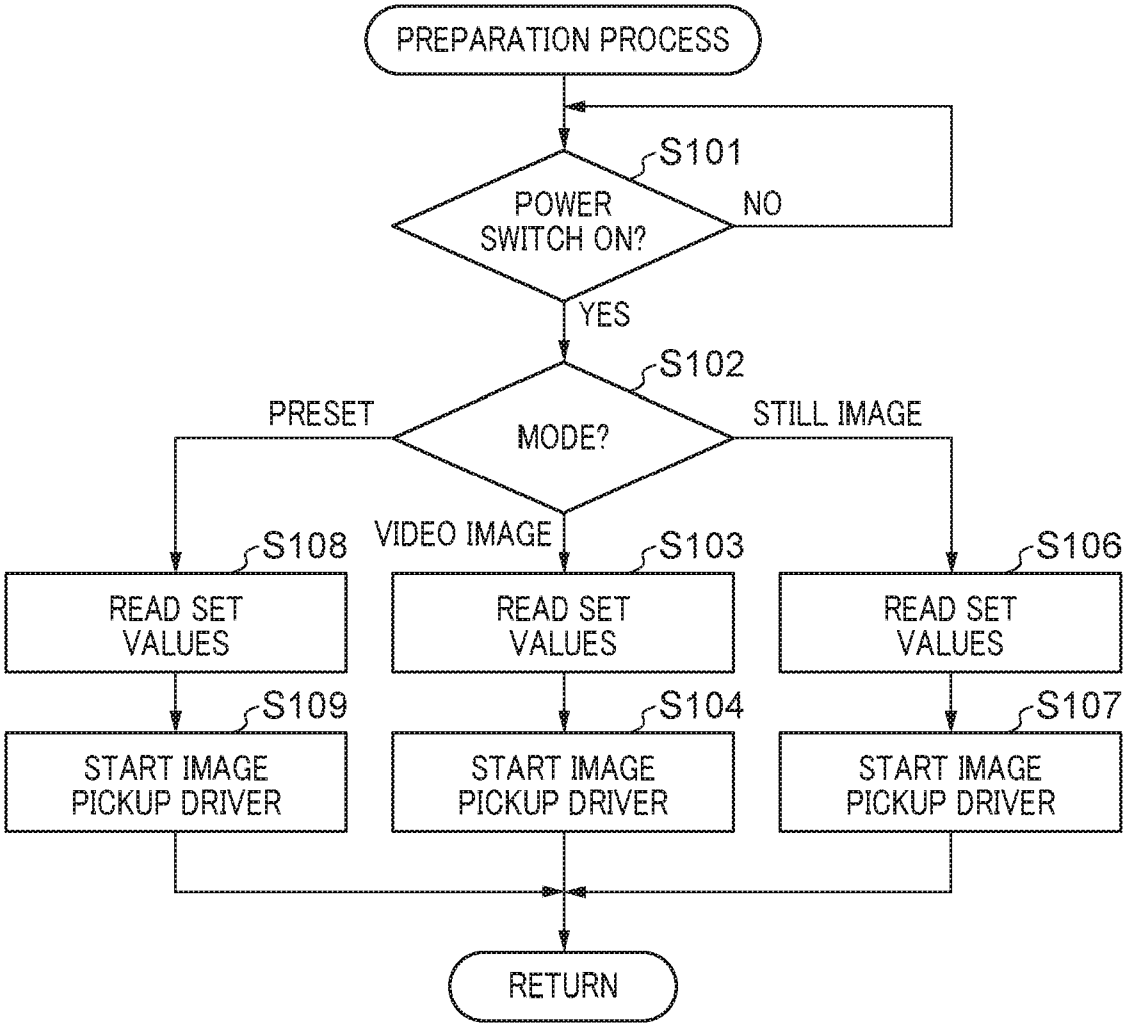

DISPLAY-APPARATUS CONTROLLER
800
801
LARGE-CAPACITY NONVOLATILE MEMORY
814
SMALL-POWER WIRELESS COMMUNICATION UNIT
871
HIGH-SPEED WIRELESS COMMUNICATION UNIT
872
AUDIO PROCESSOR
819L
819R
820
SPEAKER
815
VIBRATOR
816
OTHER FUNCTIONS
830
PRIMARY MEMORY
813
INTERNAL NONVOLATILE MEMORY
812
ACCELERATION SENSOR
808
ANGULAR SPEED SENSOR
807
VARIOUS SWITCHES
811
B-BUTTON
804
A-BUTTON (POWER)
802
LED
817
INFRARED DETECTION DEVICE
827
INFRARED LED LIGHTING CIRCUIT
821
IMAGE SIGNAL PROCESSING CIRCUIT
DISPLAY UNIT
803
806
825
826
822
823
824
809
805a

FIG. 7A



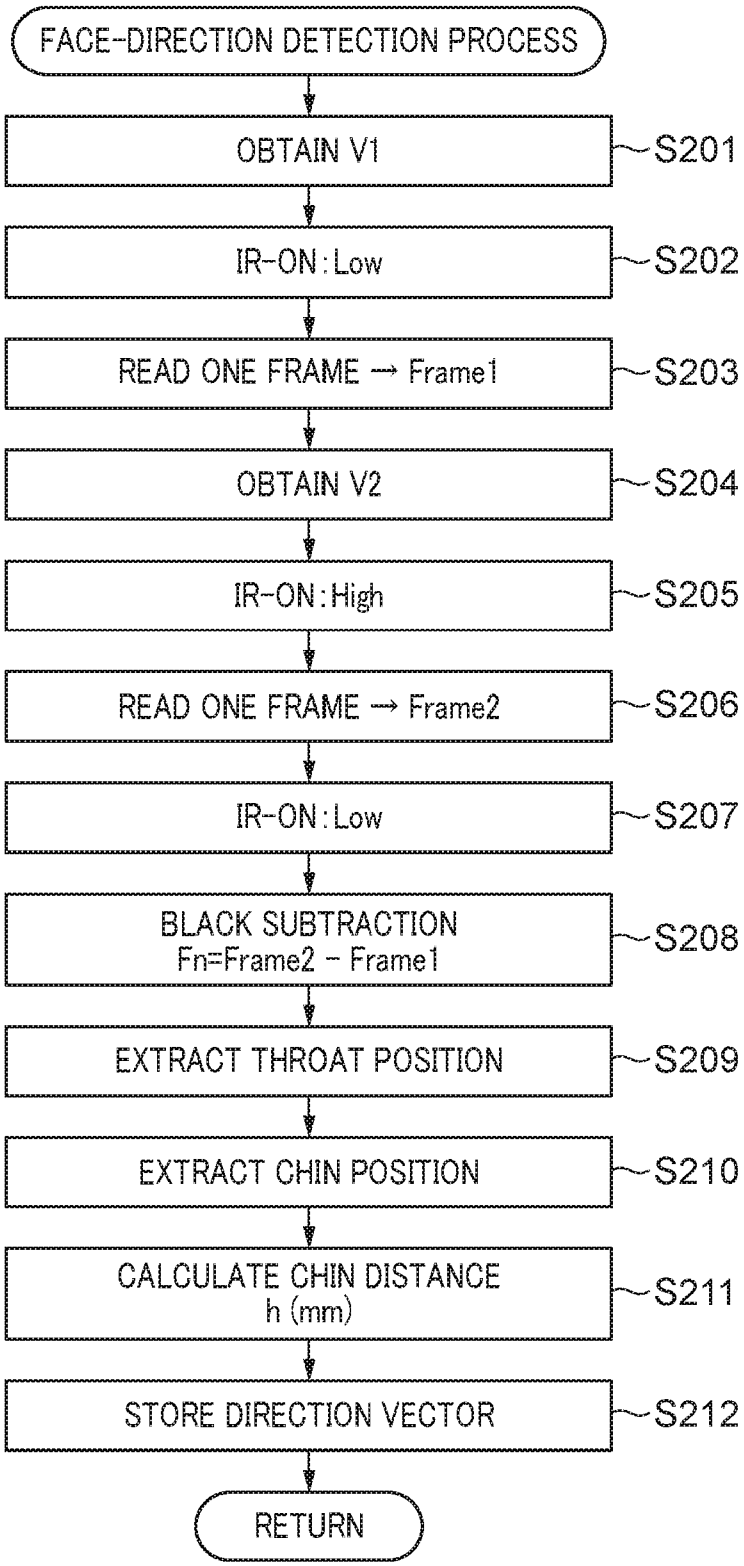
12 12 22

FIG. 7B



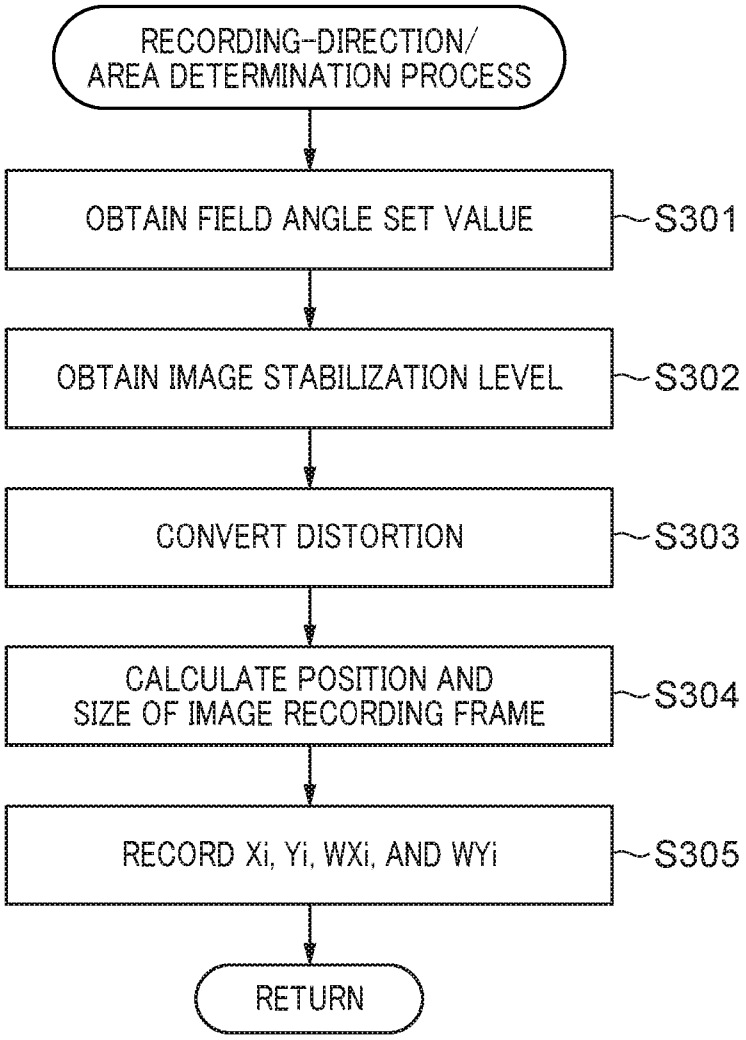
12 12 22

FIG. 7C



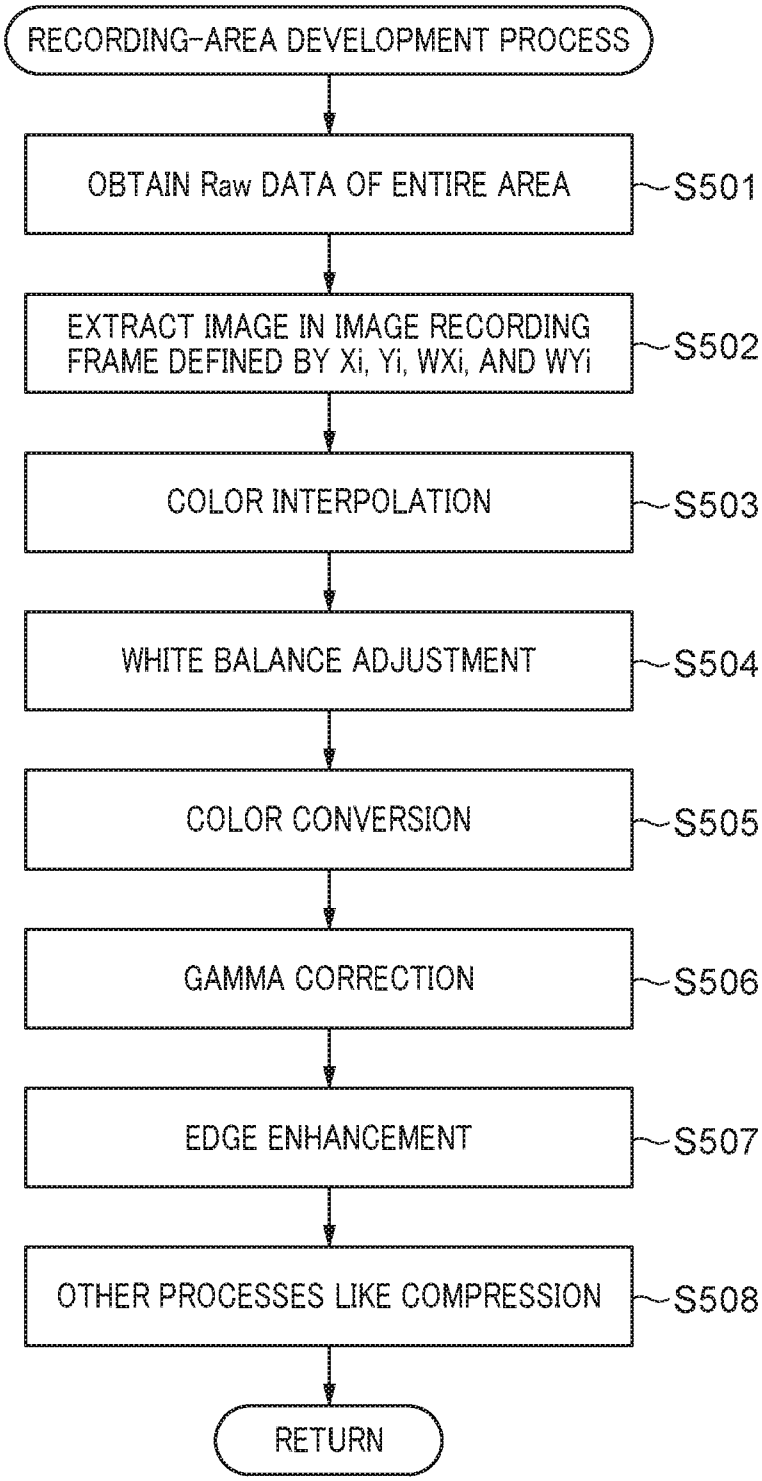
12 12 22

FIG. 7D



12 12 22

FIG. 7E



12 12 22

FIG. 7F

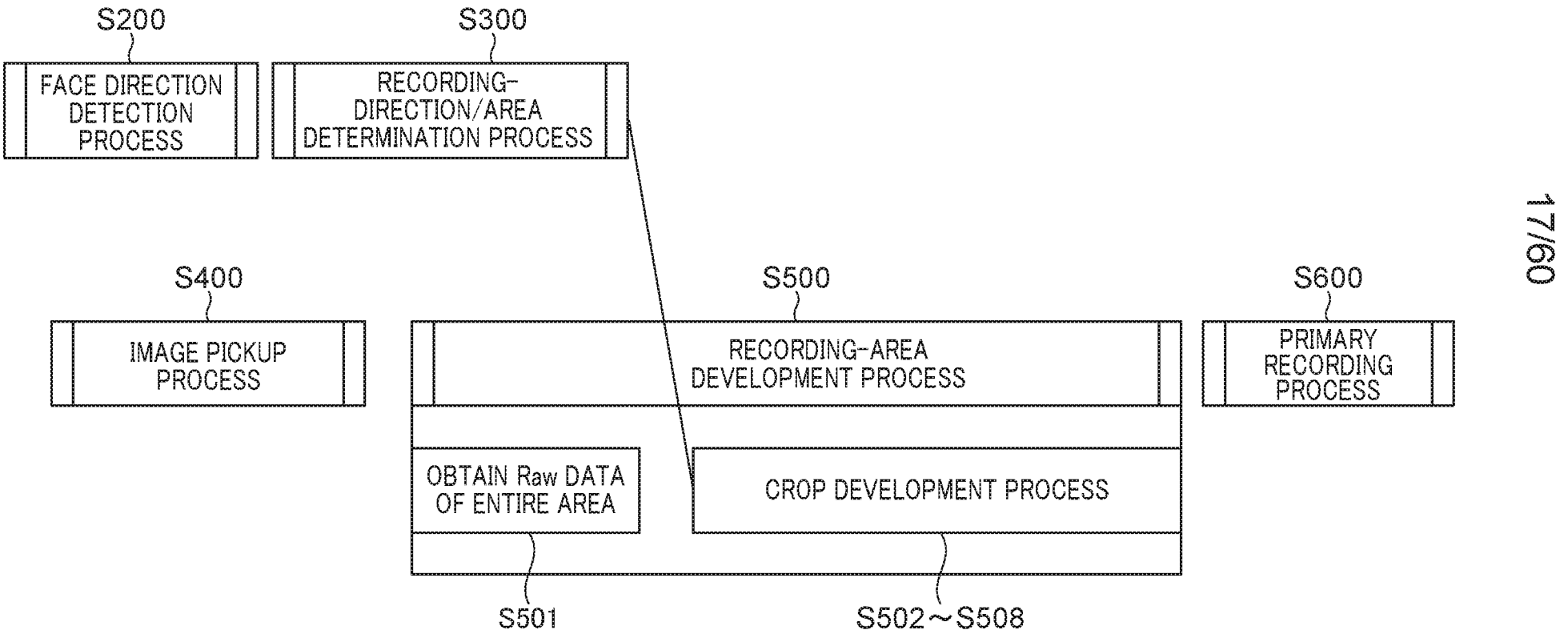
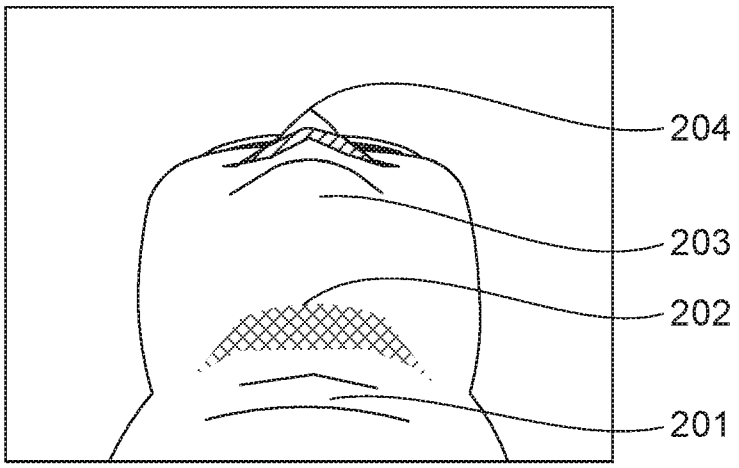

S200
FACE DIRECTION DETECTION PROCESS
S300
RECORDING-DIRECTION/AREA DETERMINATION PROCESS
S400
IMAGE PICKUP PROCESS
S500
RECORDING-AREA DEVELOPMENT PROCESS
OBTAIN Raw DATA OF ENTIRE AREA
CROP DEVELOPMENT PROCESS
S501
S502~S508
S600
PRIMARY RECORDING PROCESS

FIG. 8A



12 12 22

FIG. 8B

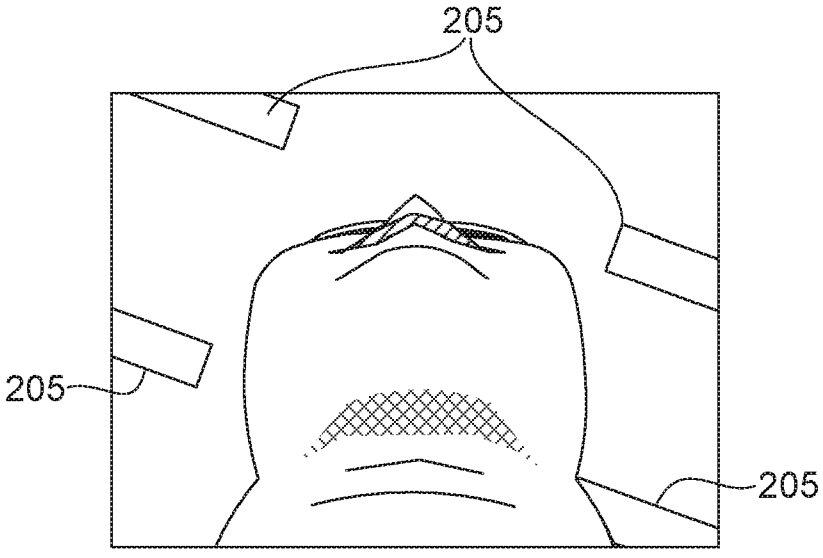
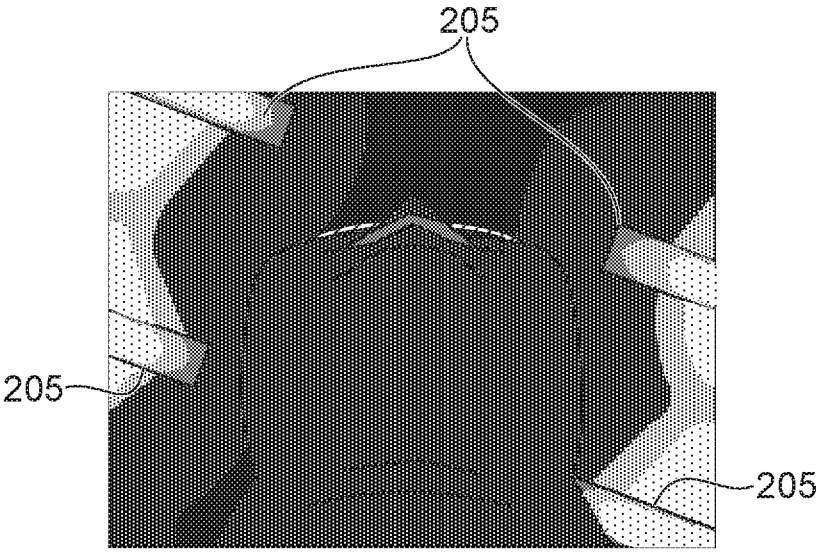


FIG. 8C



12 12 22

FIG. 8D

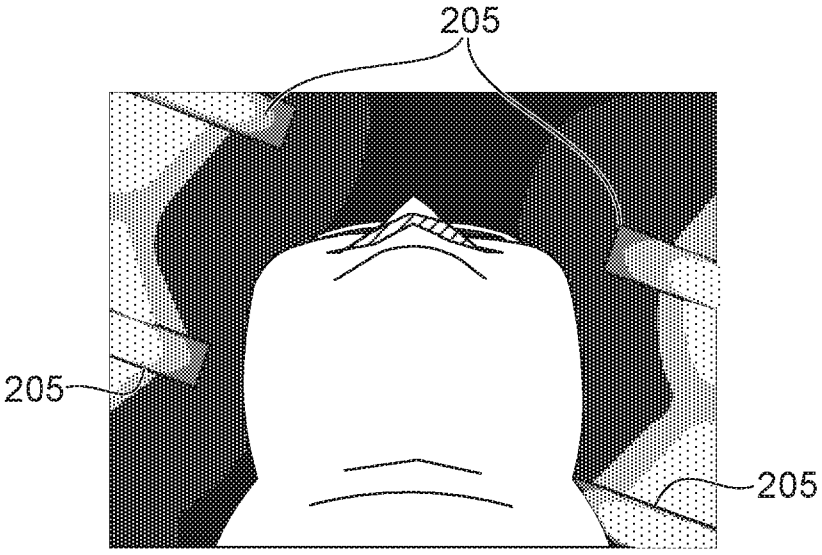
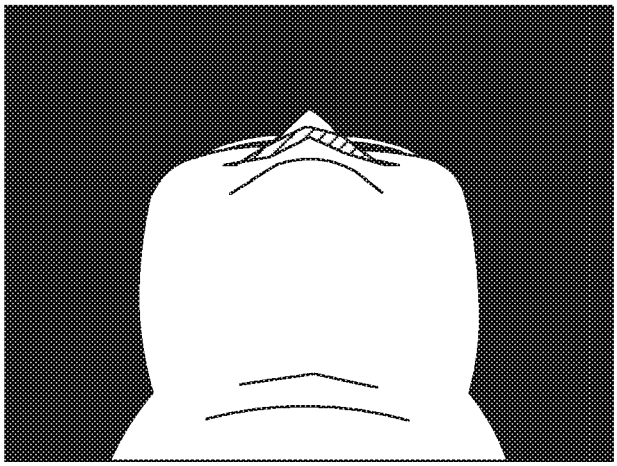


FIG. 8E



12 12 22

FIG. 8F

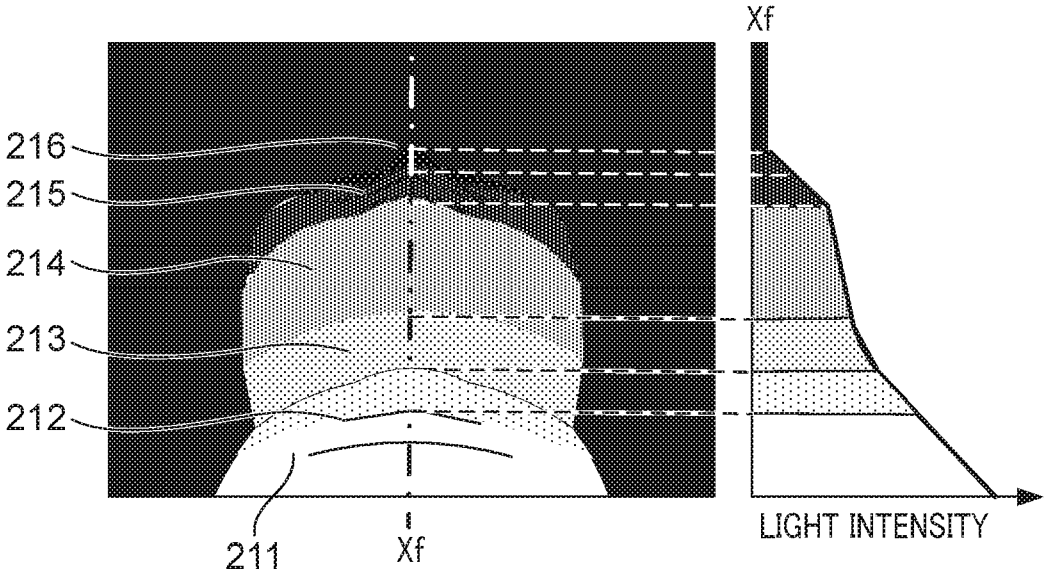
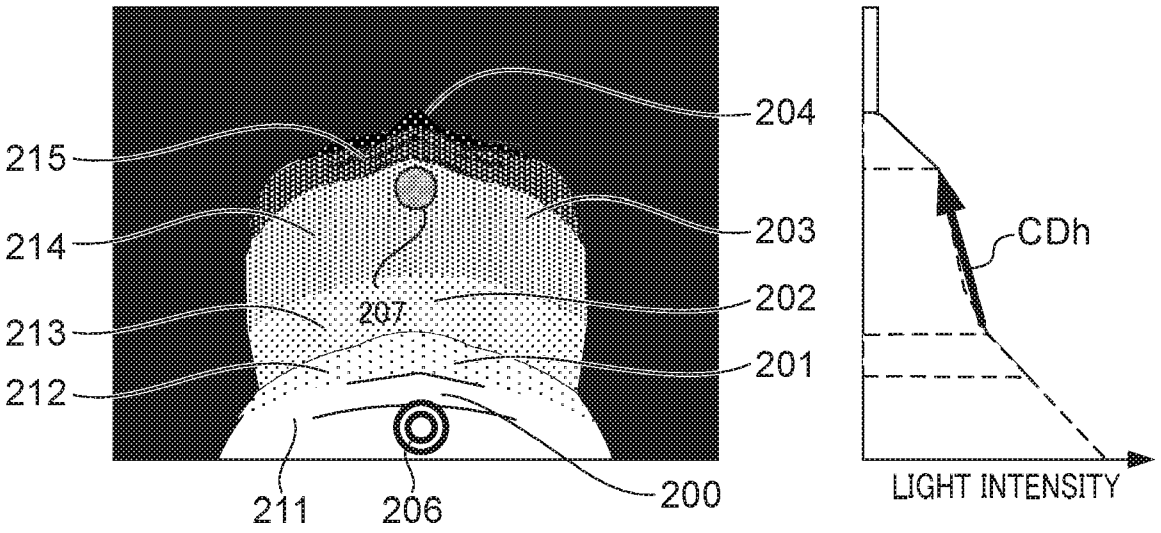


FIG. 8G



12 12 22

FIG. 8H

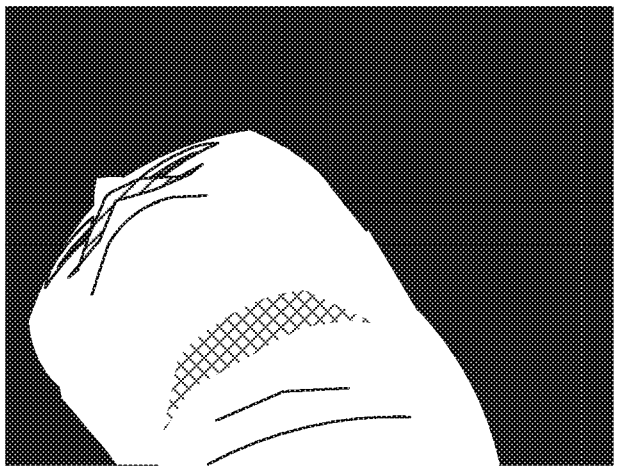
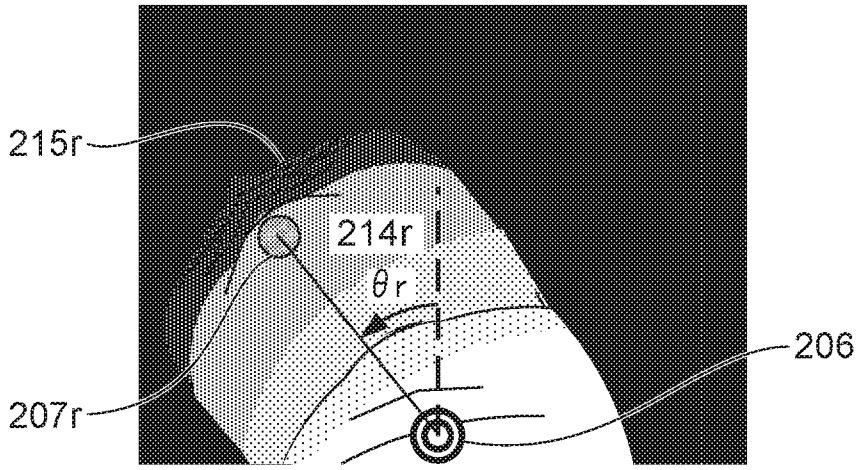


FIG. 8I



12 12 22

FIG. 8J

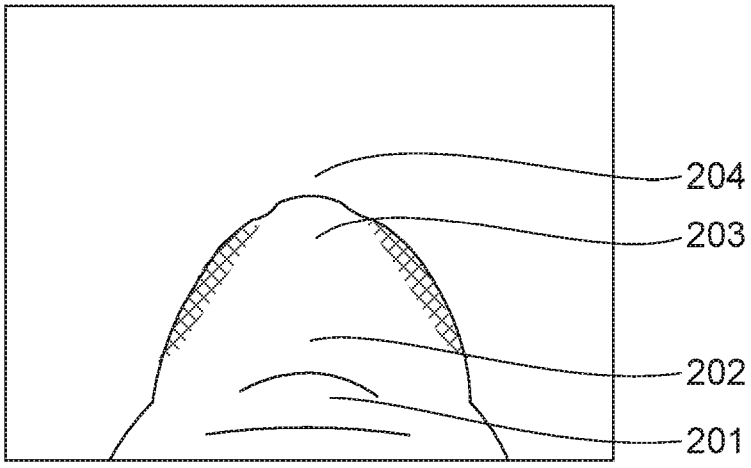


FIG. 8K

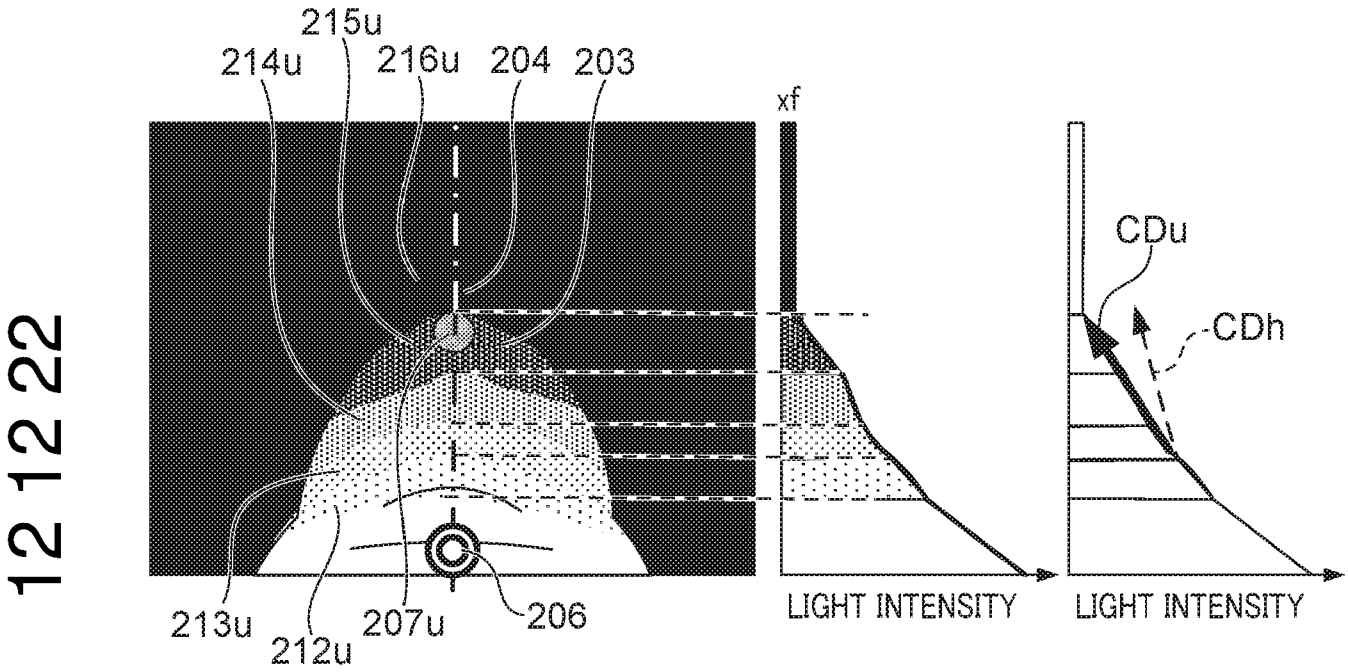
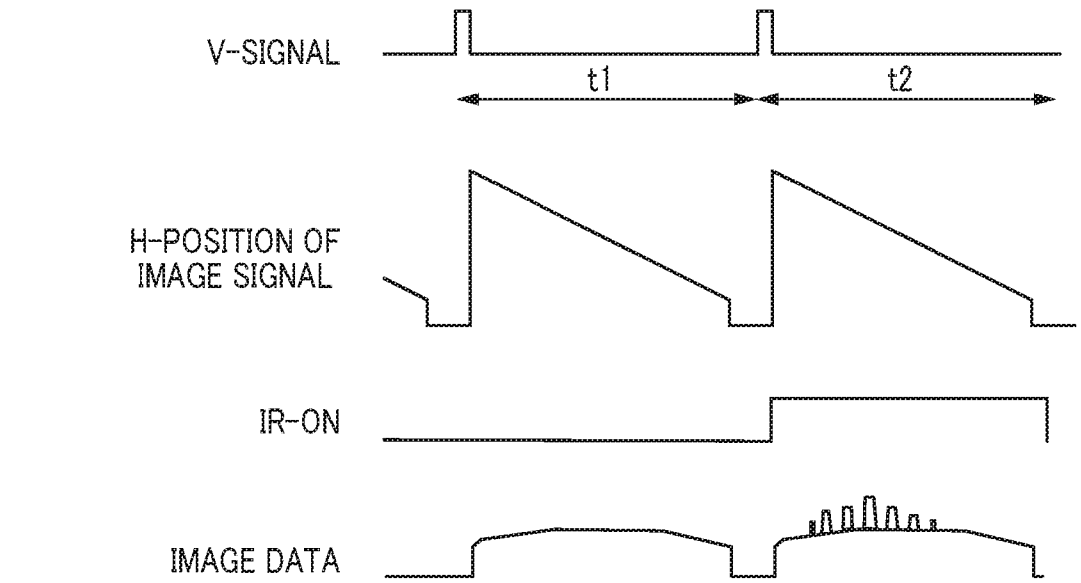
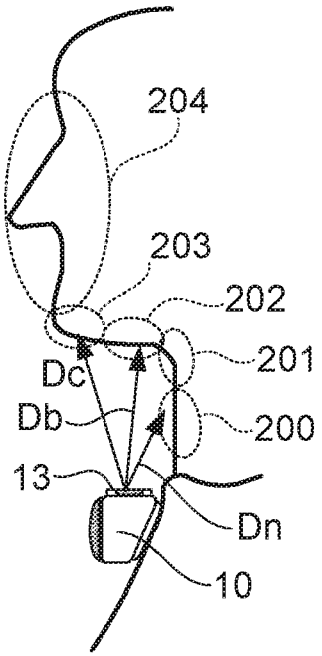

215u
214u
216u
204
203
xf
CDu
CDh
12 12 22
213u
212u
207u
206
LIGHT INTENSITY
LIGHT INTENSITY

FIG. 9


V-SIGNAL
t1
t2
H-POSITION OF IMAGE SIGNAL
IR-ON
IMAGE DATA
FACE IMAGE

12 12 22

FIG. 10A



12 12 22

FIG. 10B

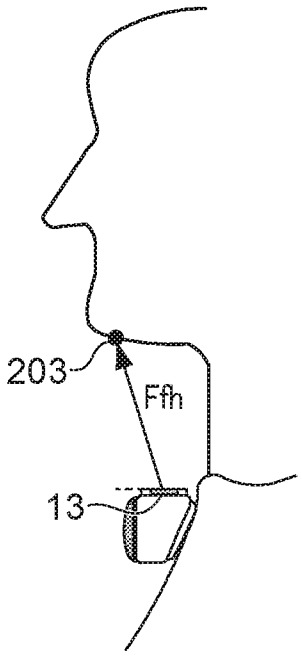


FIG. 10C

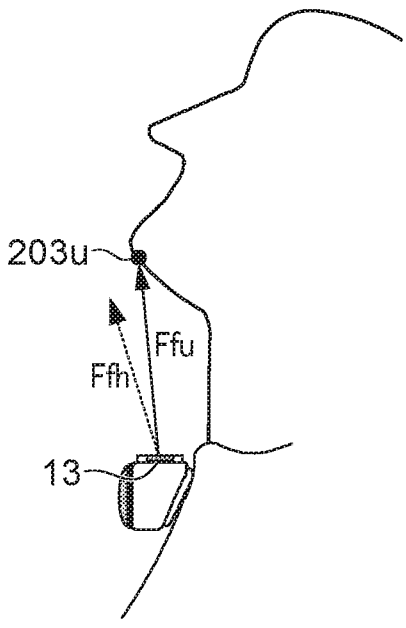


FIG. 10D

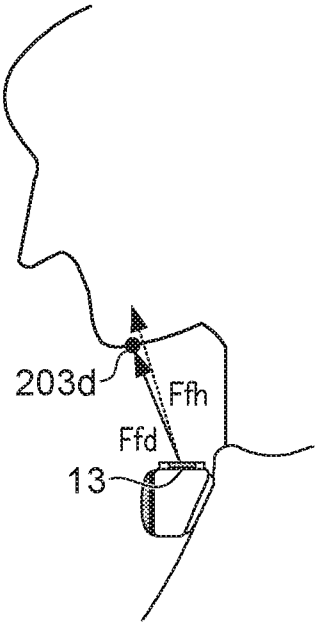
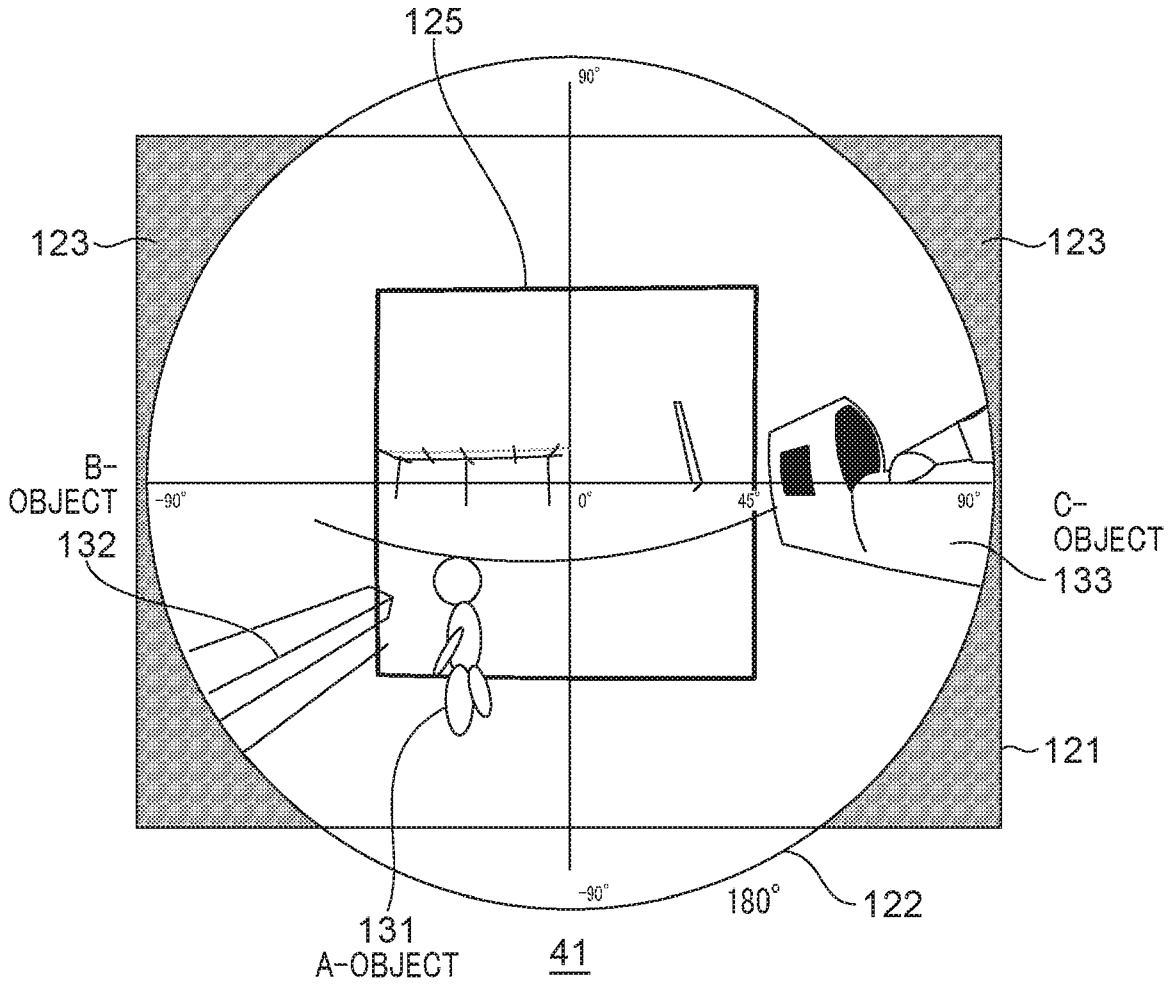


FIG. 11A



12 12 22

FIG. 11B

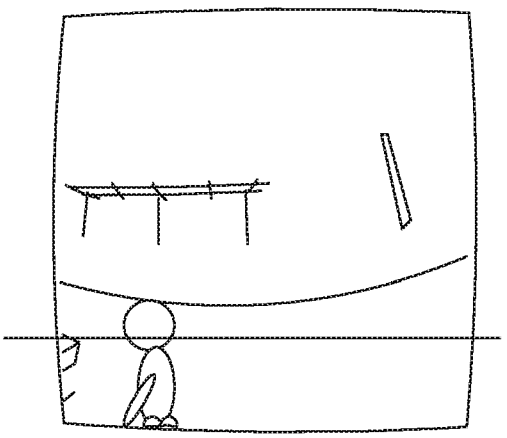
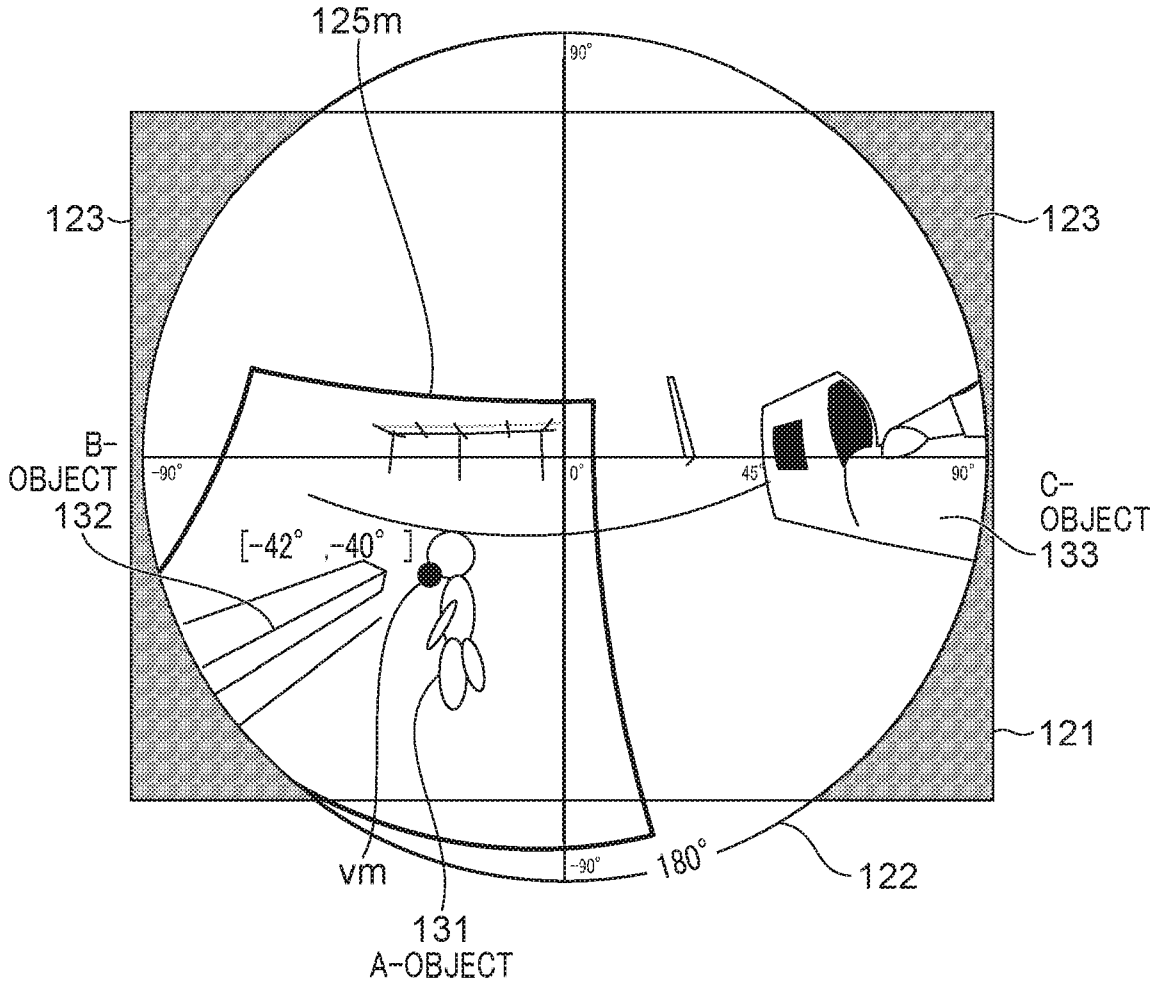


FIG. 11C



12 12 22

FIG. 11D

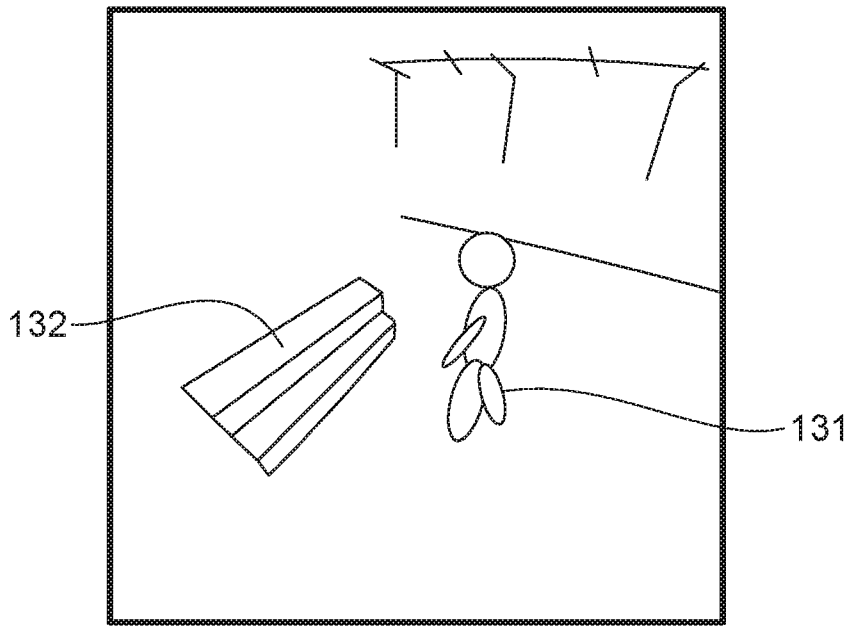
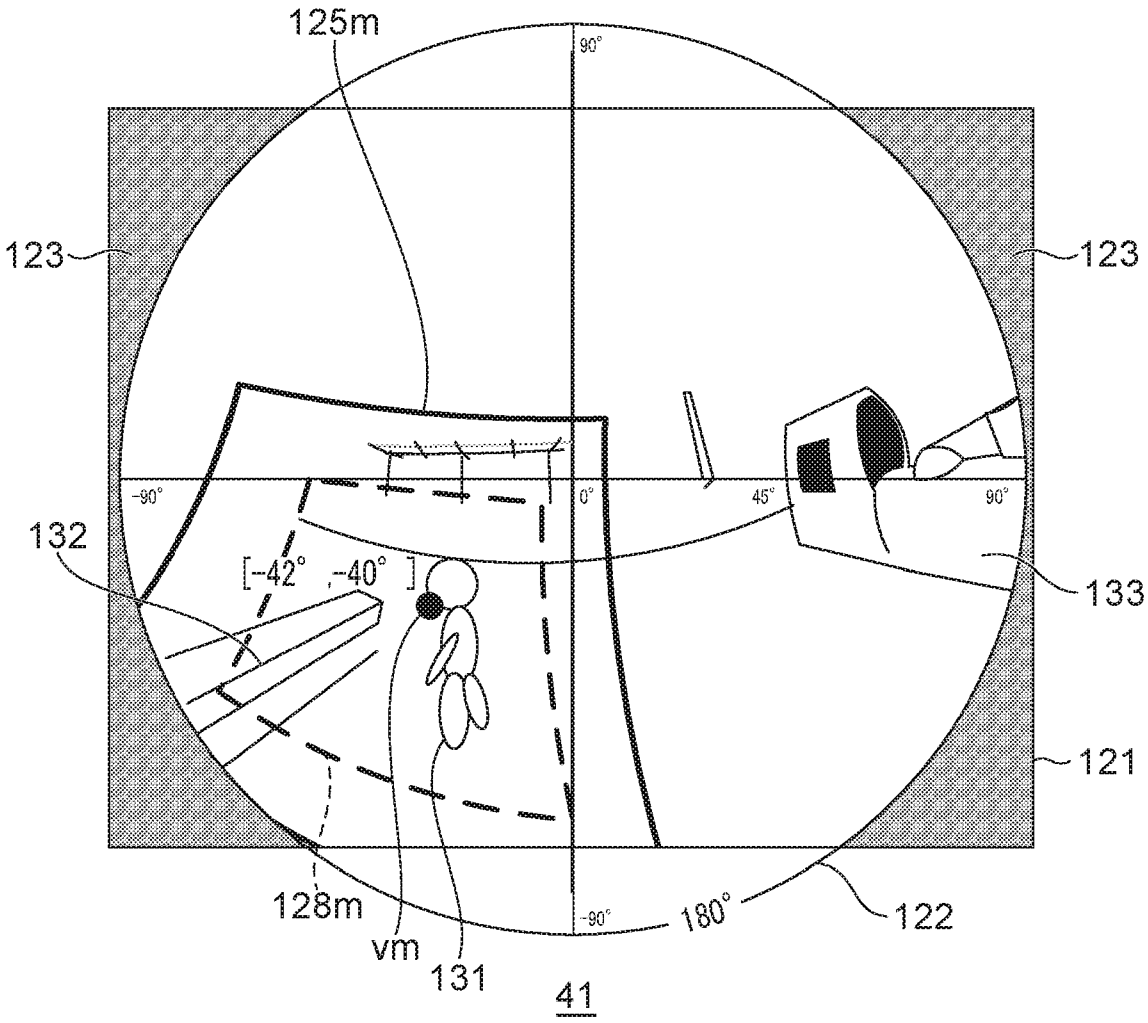


FIG. 11E



12 12 22

FIG. 11F

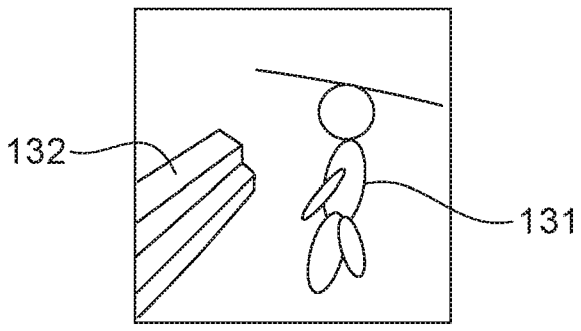
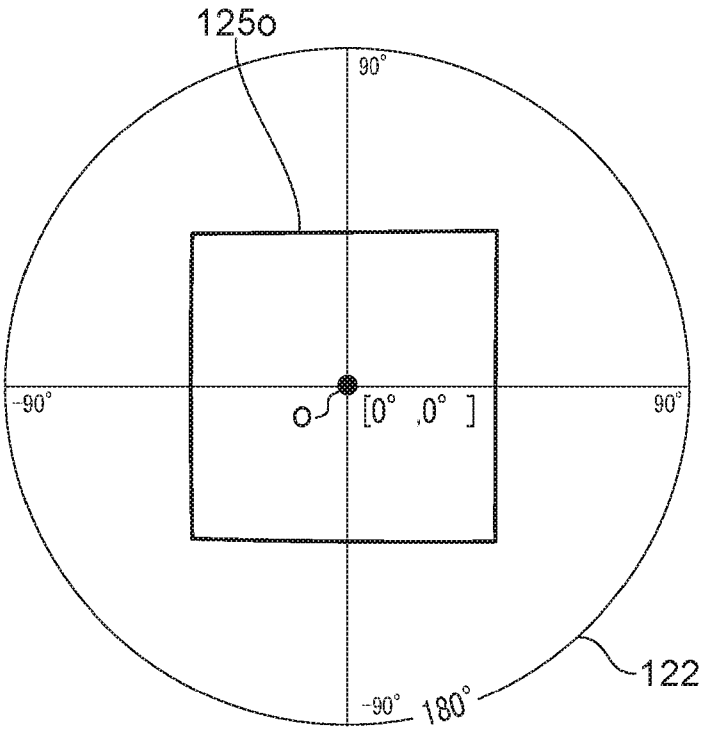


FIG. 12A



12 12 22

FIG. 12B

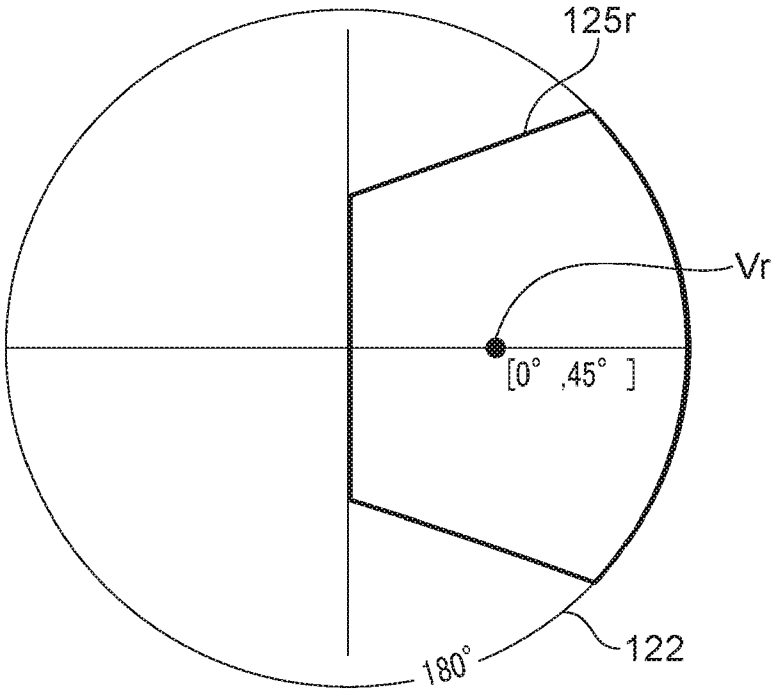
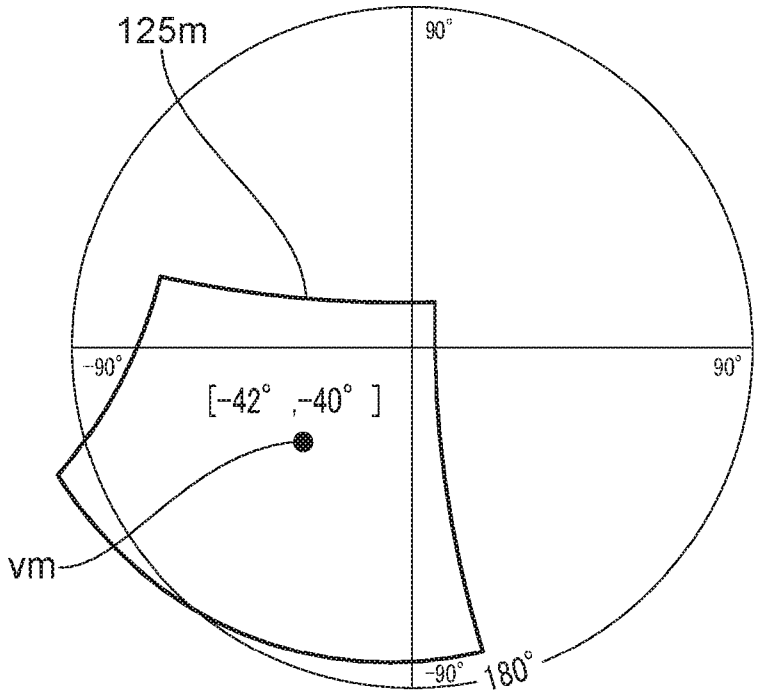


FIG. 12C



12 12 22

FIG. 12D

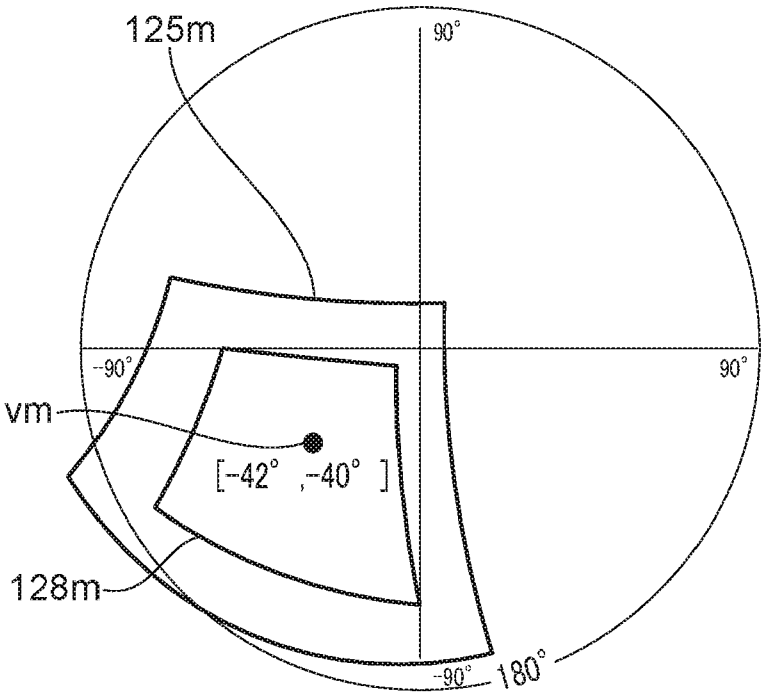
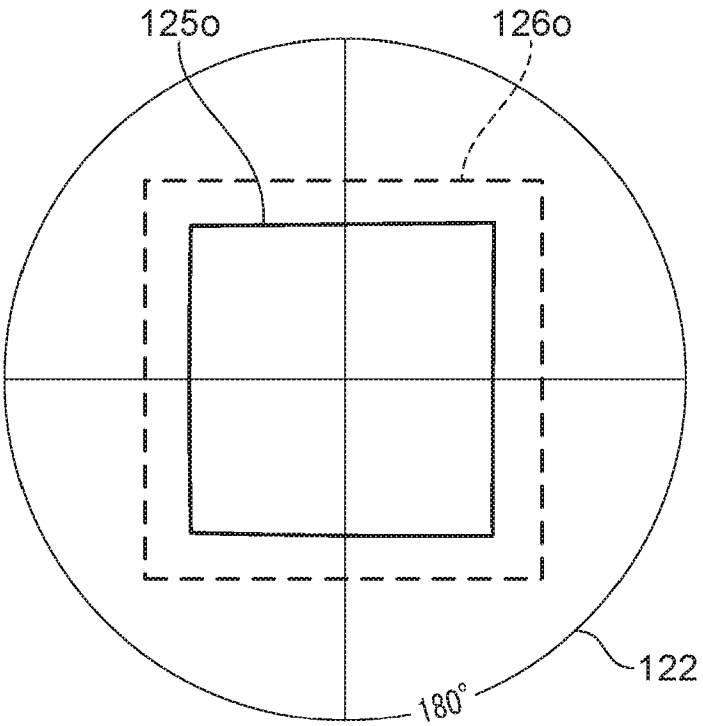


FIG. 12E



12 12 22

FIG. 12F

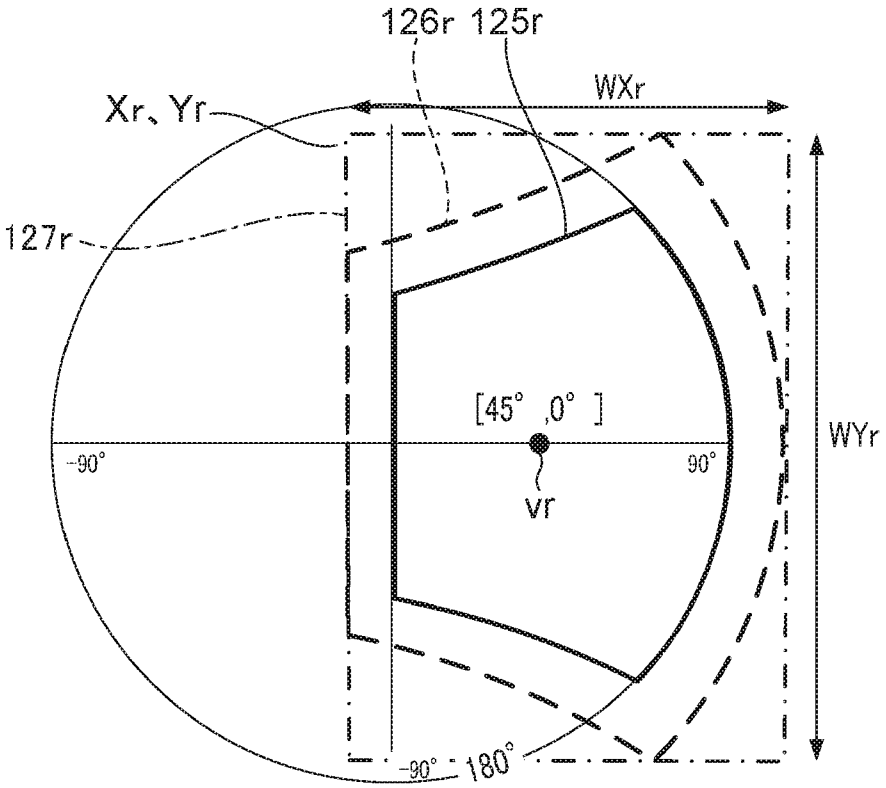


FIG. 12G

12 12 22

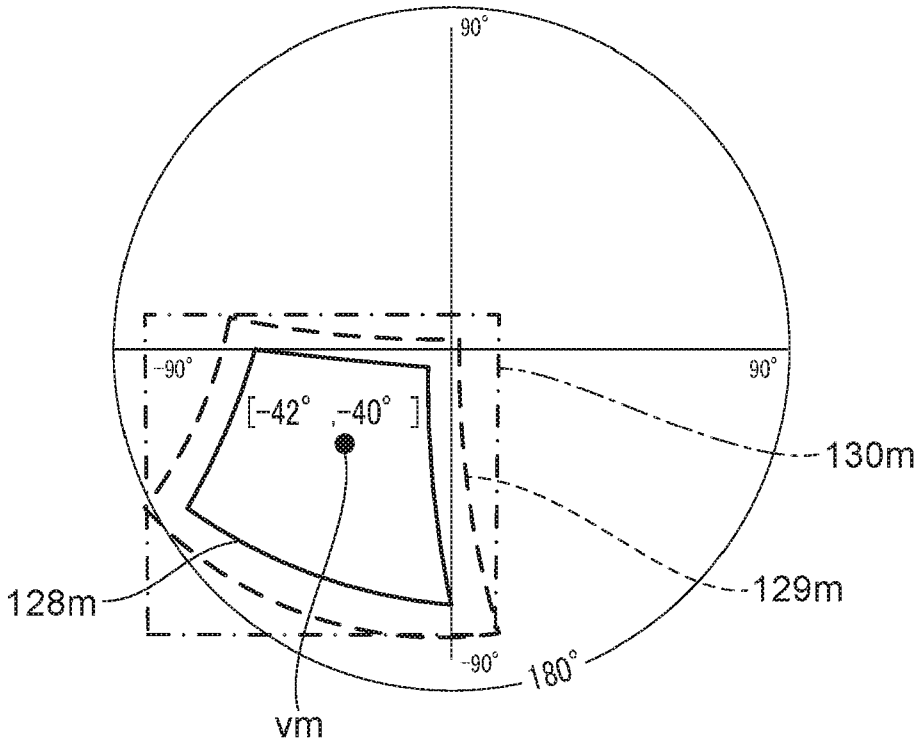
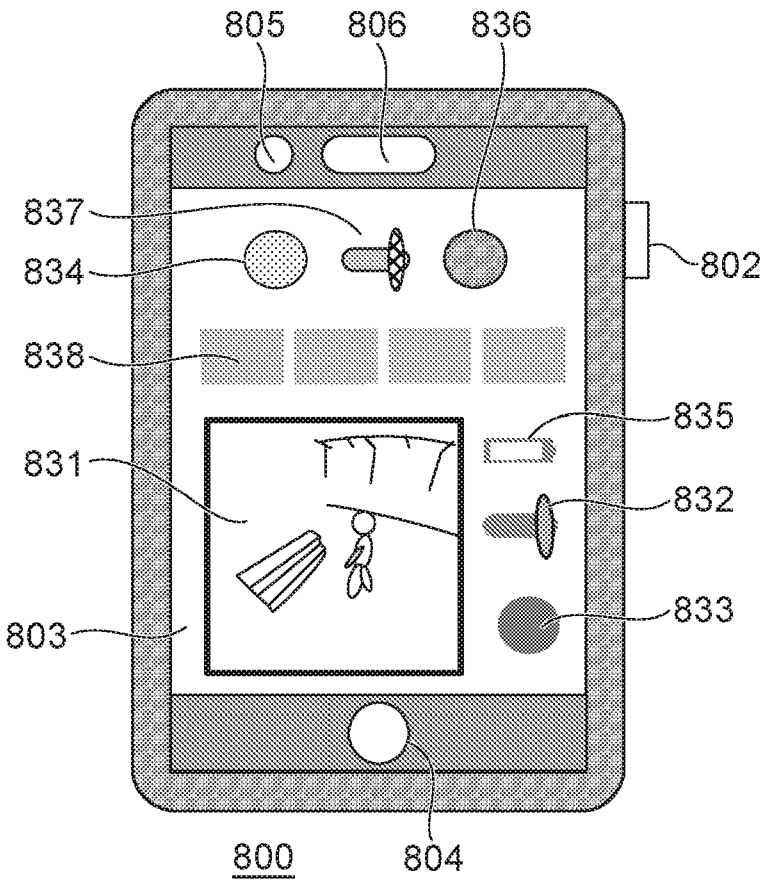
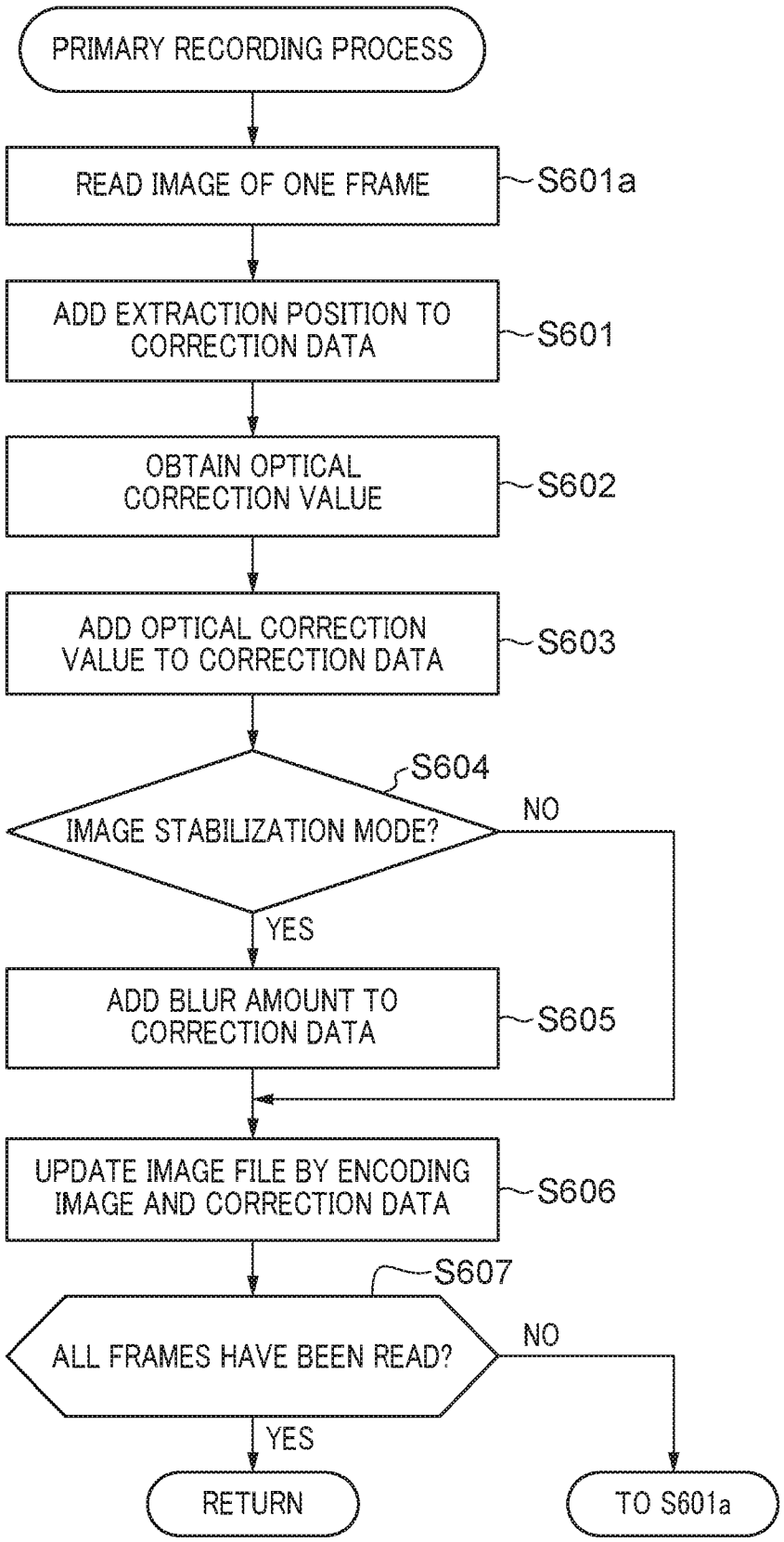


FIG. 13



12 12 22

FIG. 14



12 12 22

FIG. 15

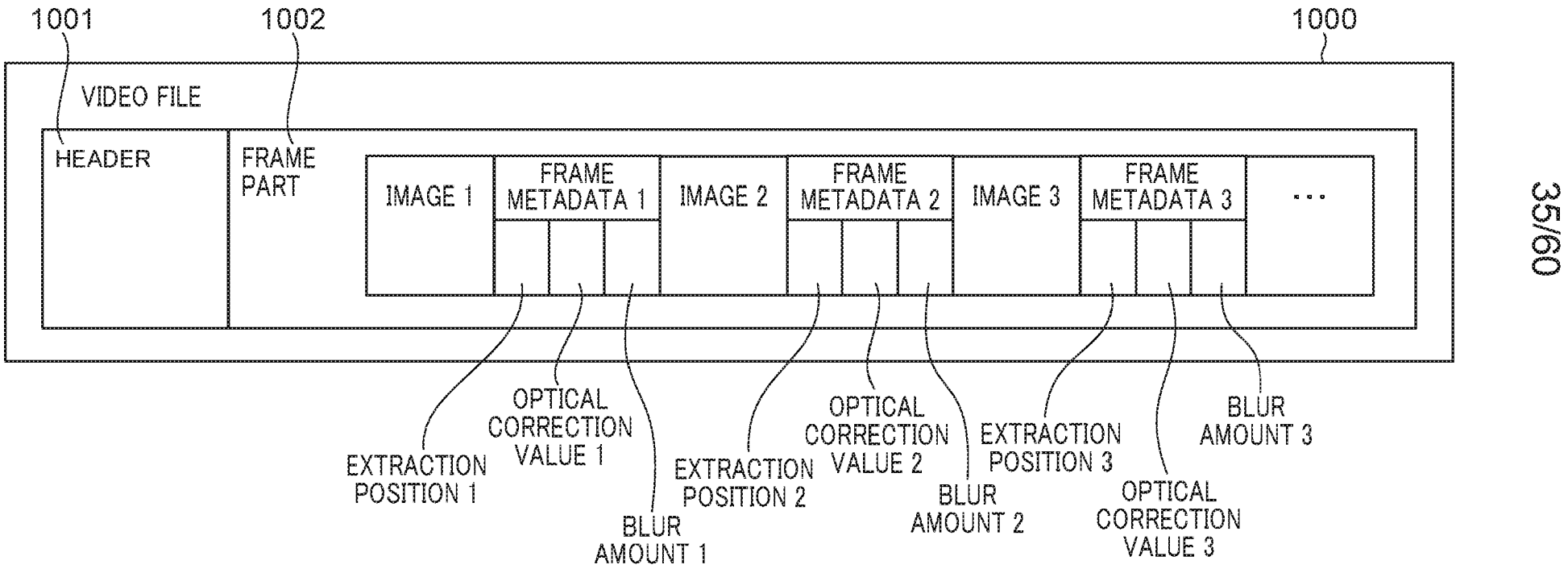
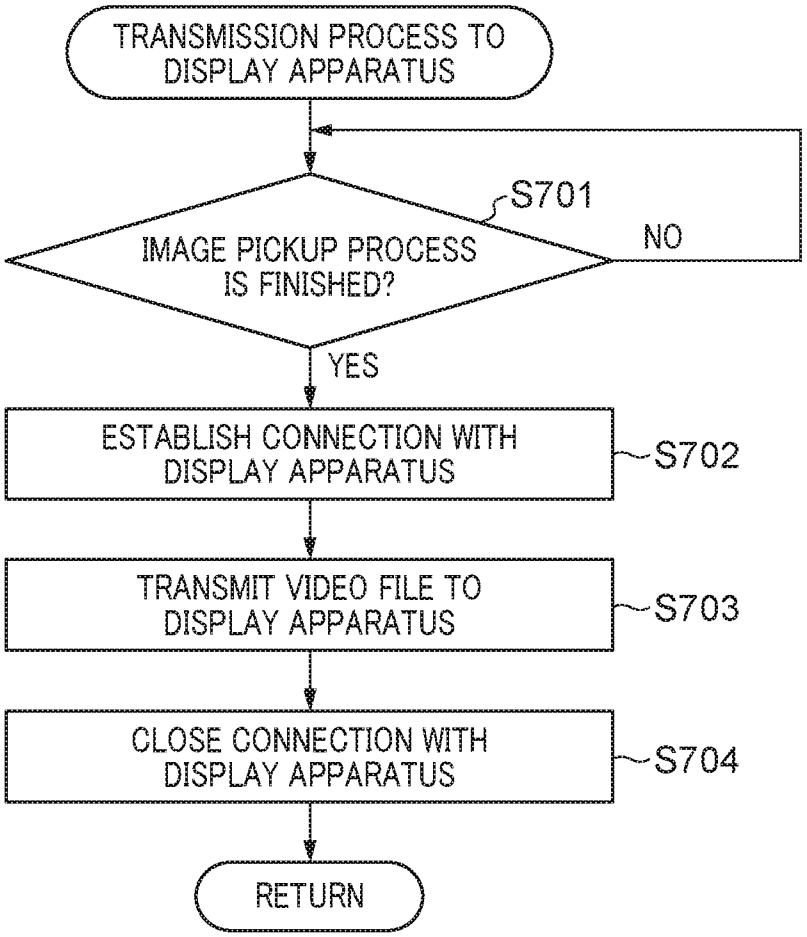
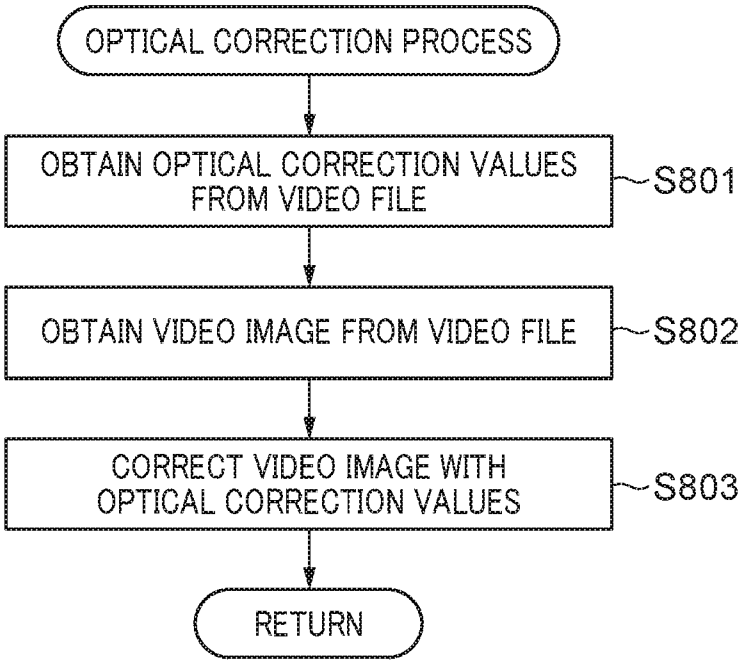

1001
1002
1000
VIDEO FILE
HEADER
FRAME PART
IMAGE 1
FRAME METADATA 1
IMAGE 2
FRAME METADATA 2
IMAGE 3
FRAME METADATA 3
...
EXTRACTION POSITION 1
OPTICAL CORRECTION VALUE 1
BLUR AMOUNT 1
EXTRACTION POSITION 2
OPTICAL CORRECTION VALUE 2
BLUR AMOUNT 2
EXTRACTION POSITION 3
OPTICAL CORRECTION VALUE 3
BLUR AMOUNT 3

FIG. 16



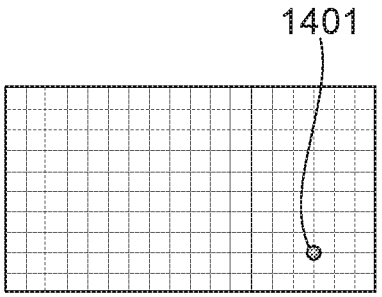
12 12 22

FIG. 17



12 12 22

FIG. 18A



OBJECT

FIG. 18B

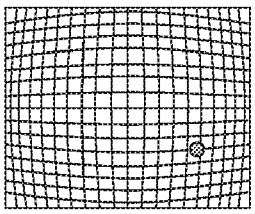
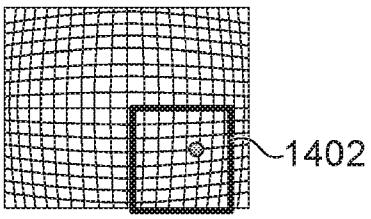


IMAGE ON IMAGE SENSOR

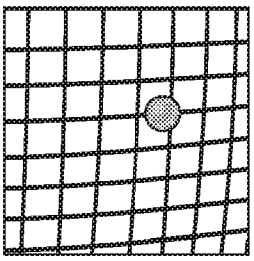
FIG. 18C



DEVELOPMENT AREA

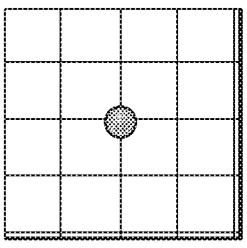
12 12 22

FIG. 18D



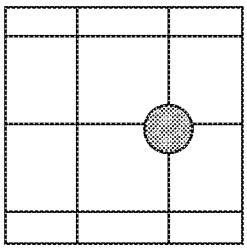
EXTRACTION AND DEVELOPMENT

FIG. 18E



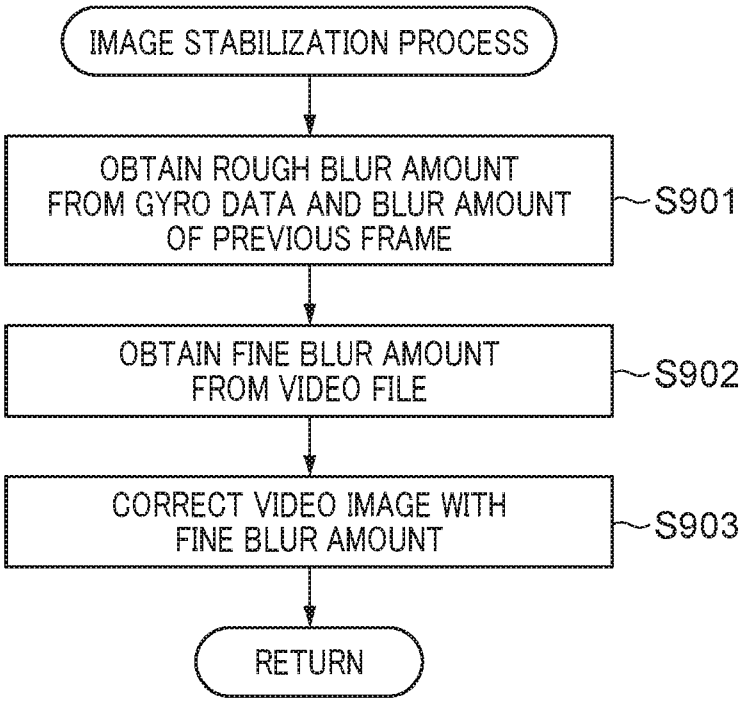
AFTER DISTORTION CORRECTION PROCESS

FIG. 18F



AFTER IMAGE STABILIZATION

FIG. 19



12 12 22

FIG. 20A

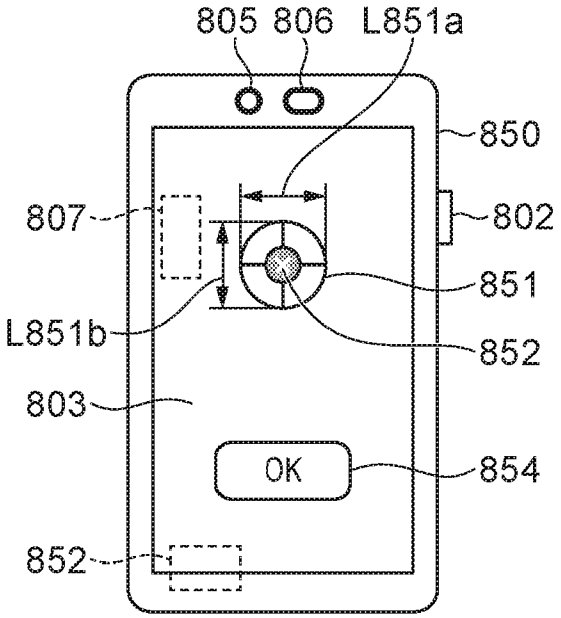
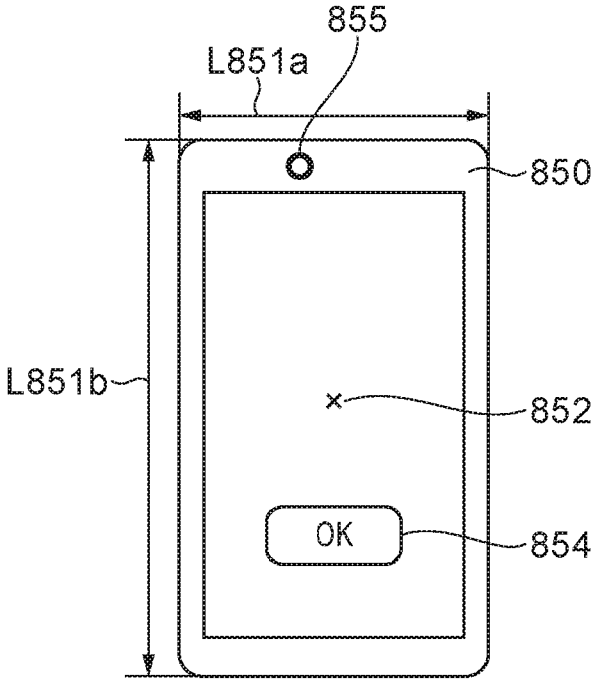
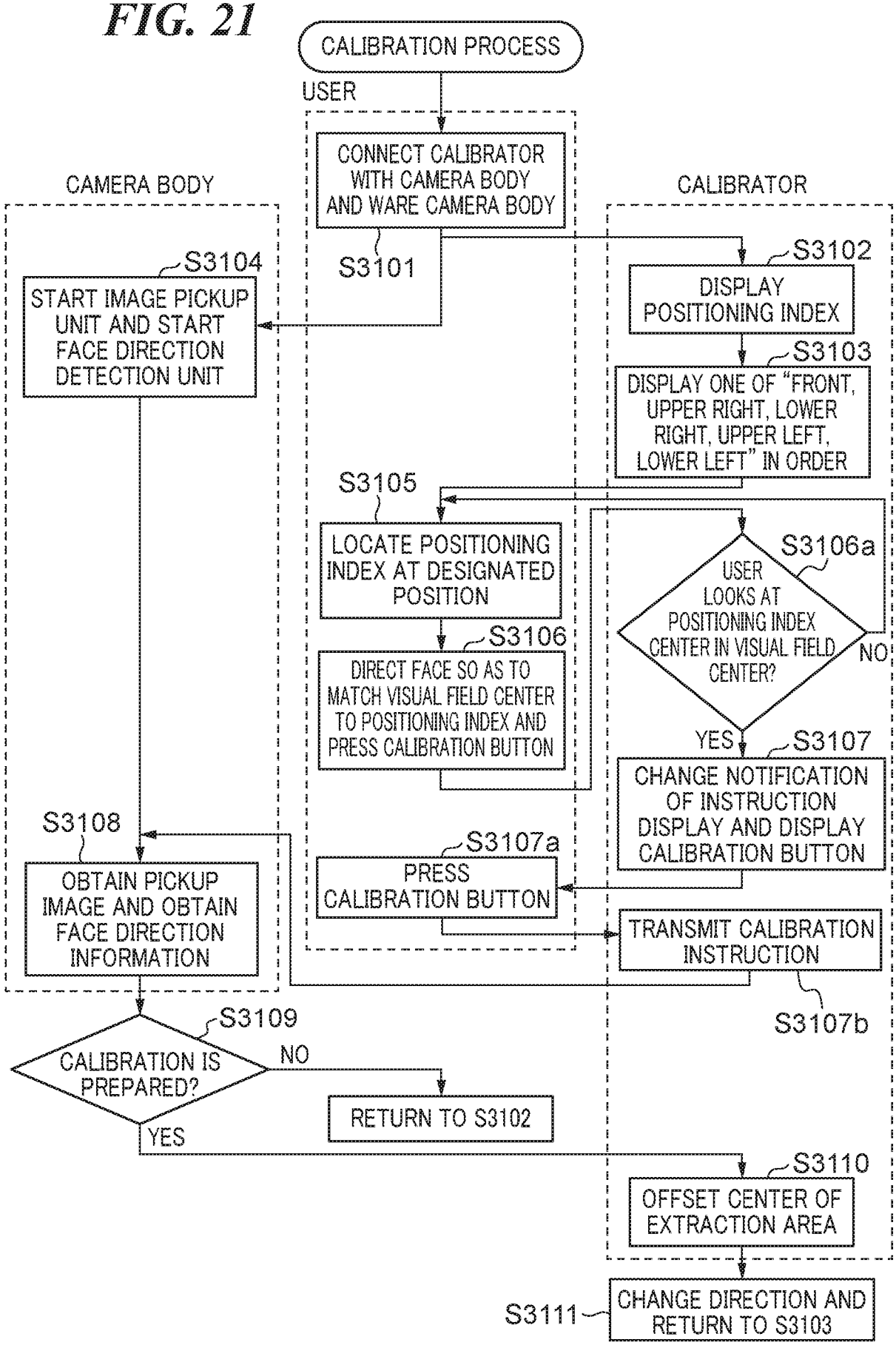


FIG. 20B



12 12 22

FIG. 21



12 12 22

FIG. 22A

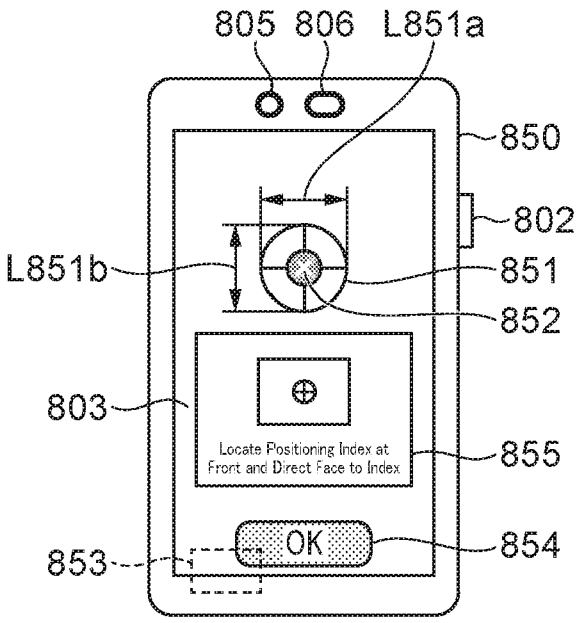
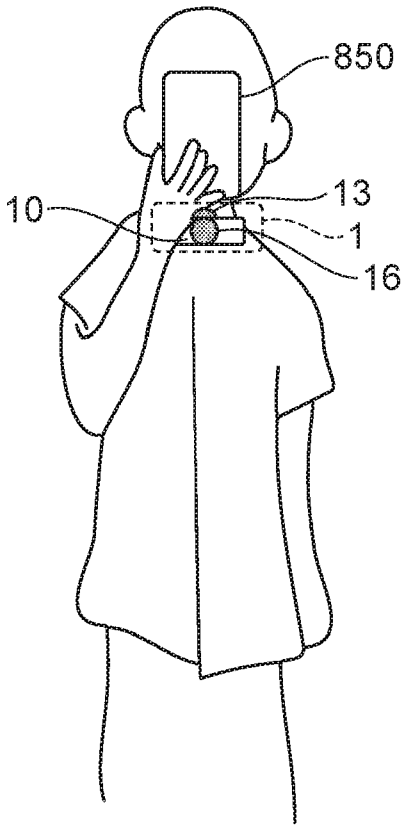
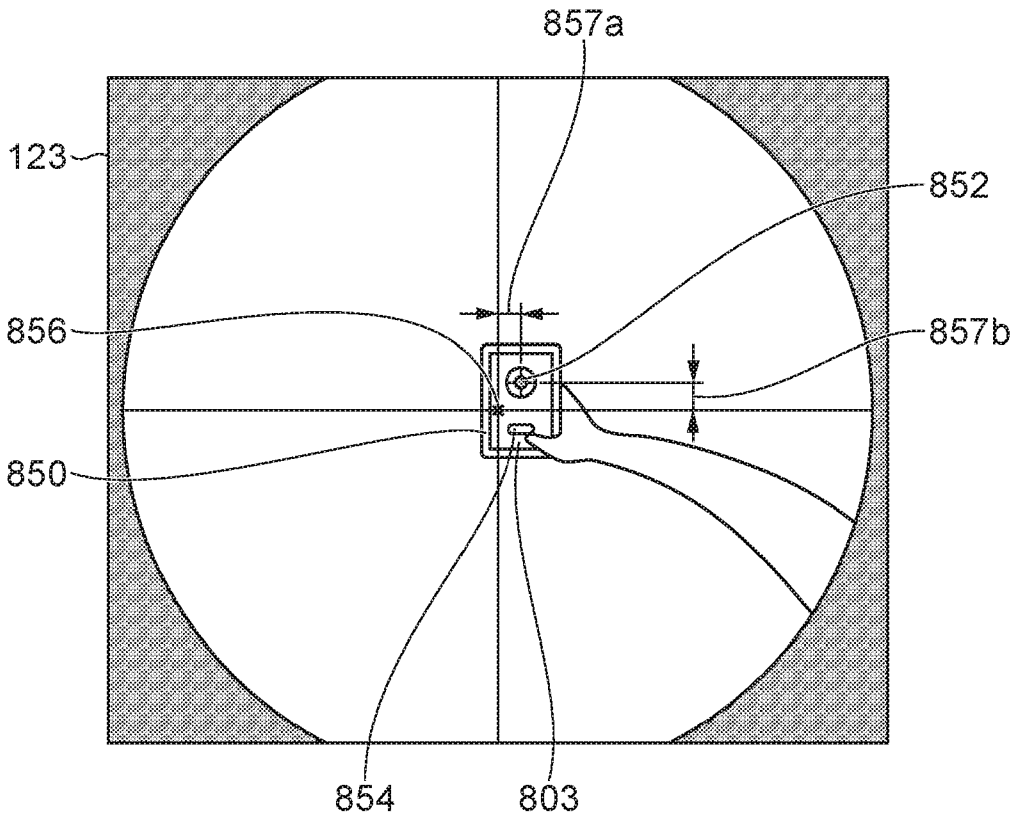


FIG. 22B



12 12 22

FIG. 22C



12 12 22

FIG. 22D

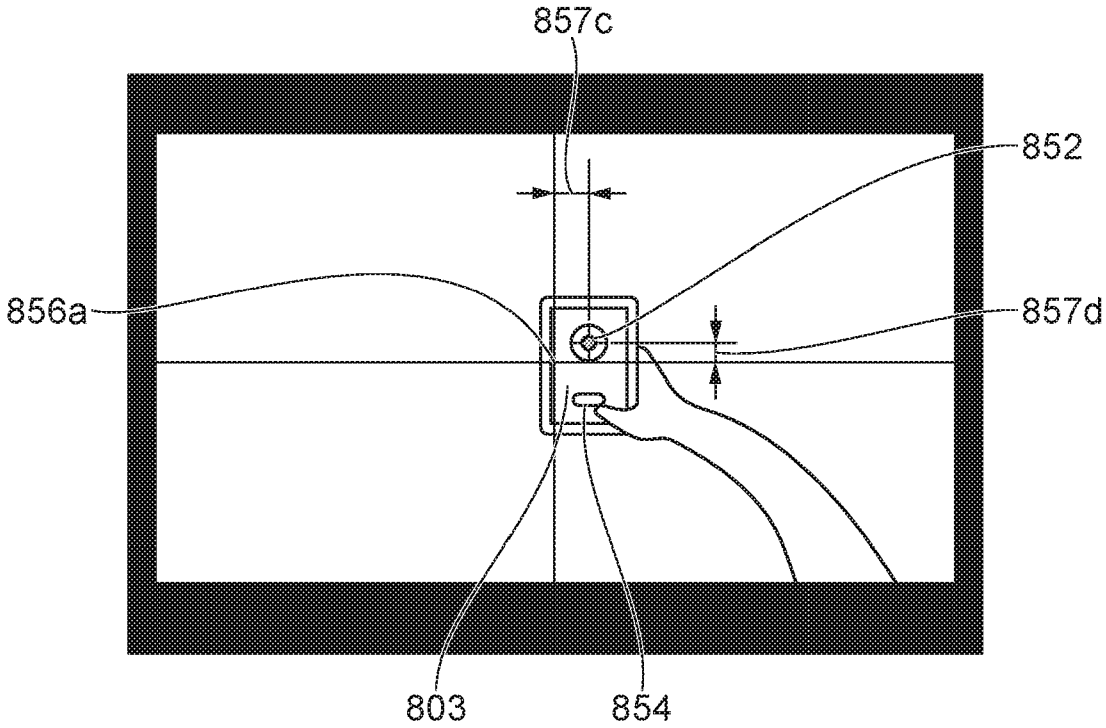
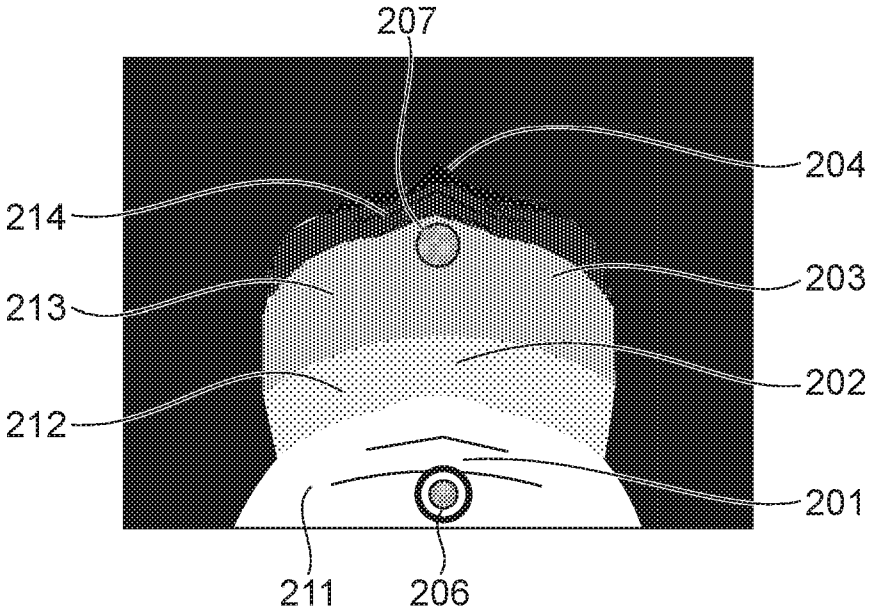


FIG. 22E



12 12 22

FIG. 22F

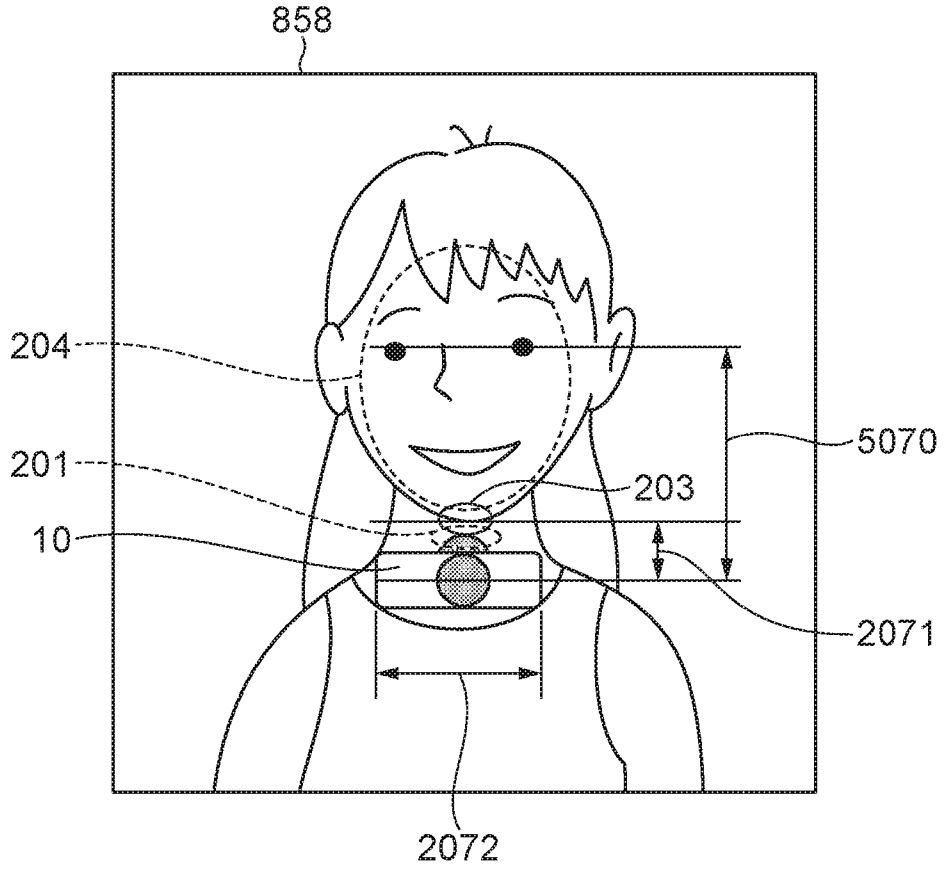
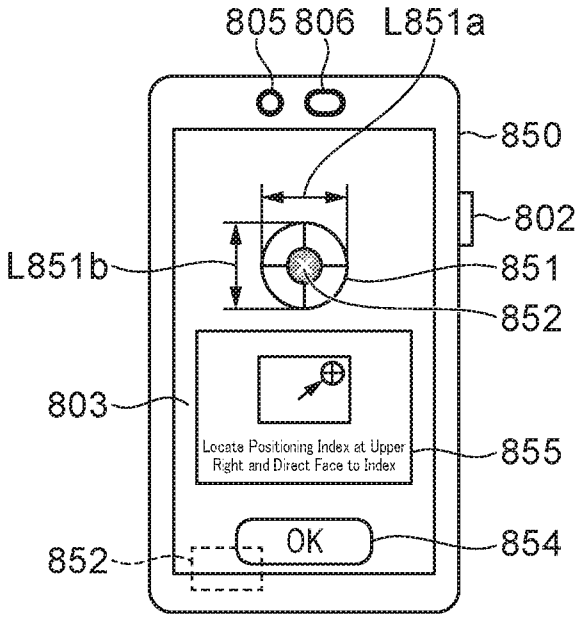


FIG. 23A



12 12 22

FIG. 23B

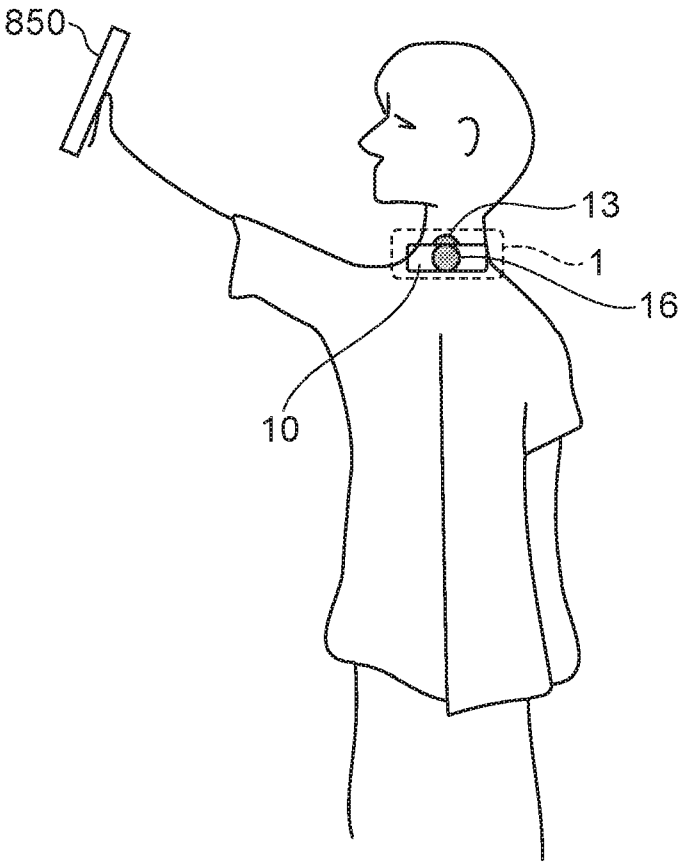
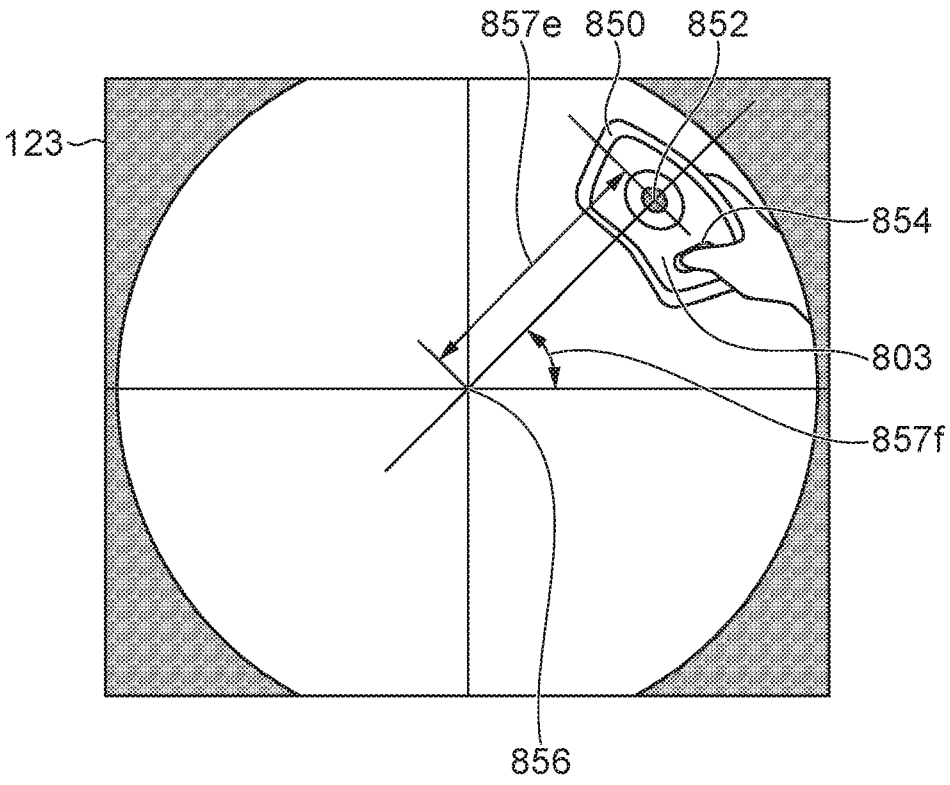


FIG. 23C



12 12 22

FIG. 23D

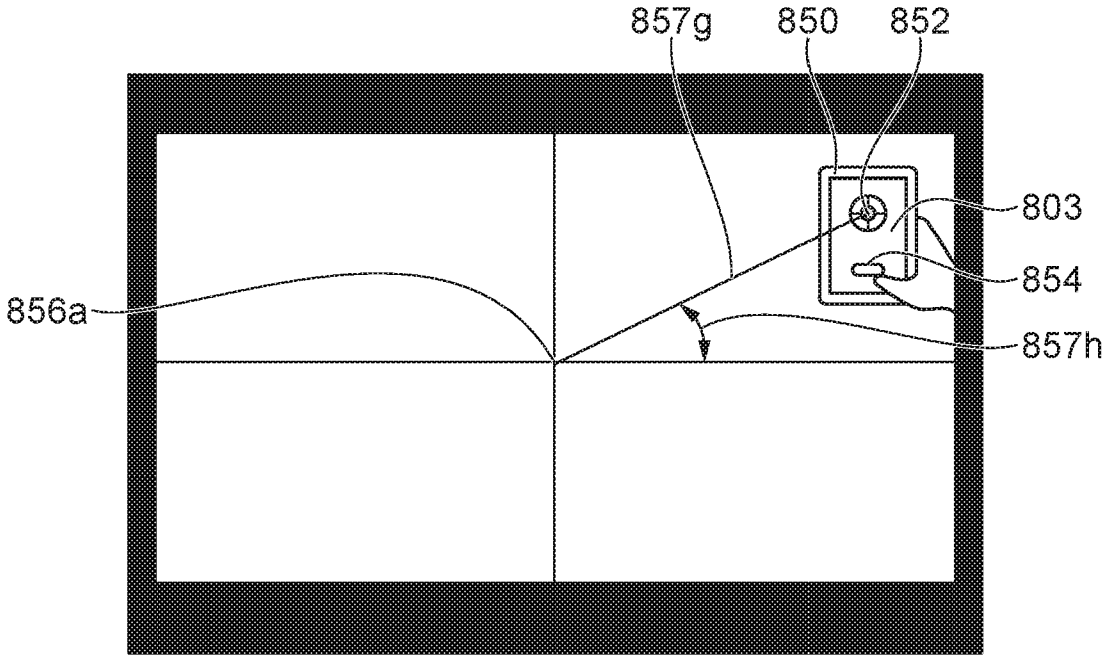
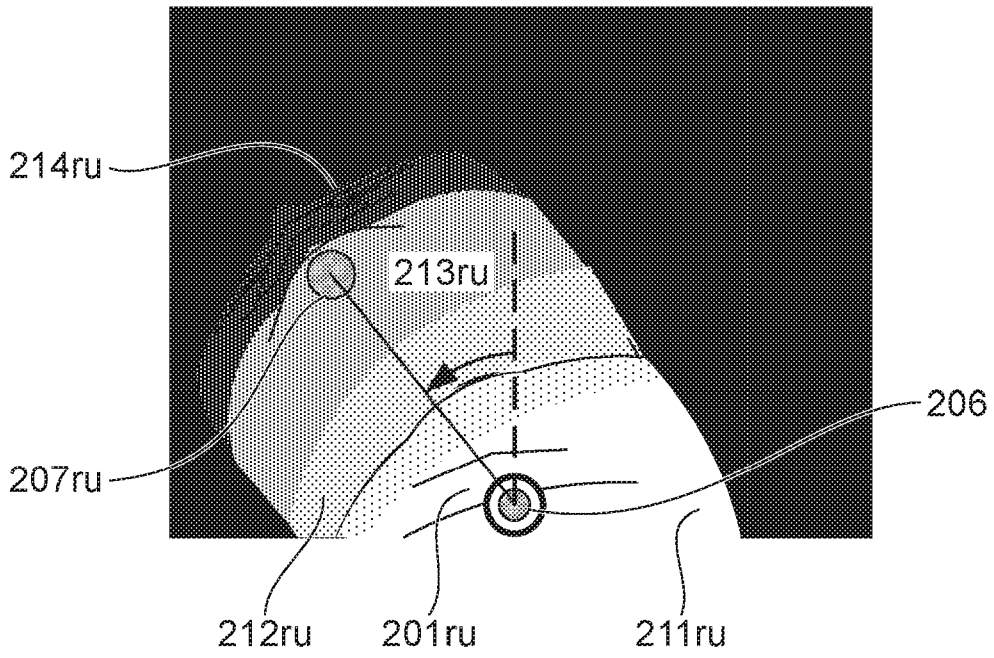


FIG. 23E



12 12 22

FIG. 24

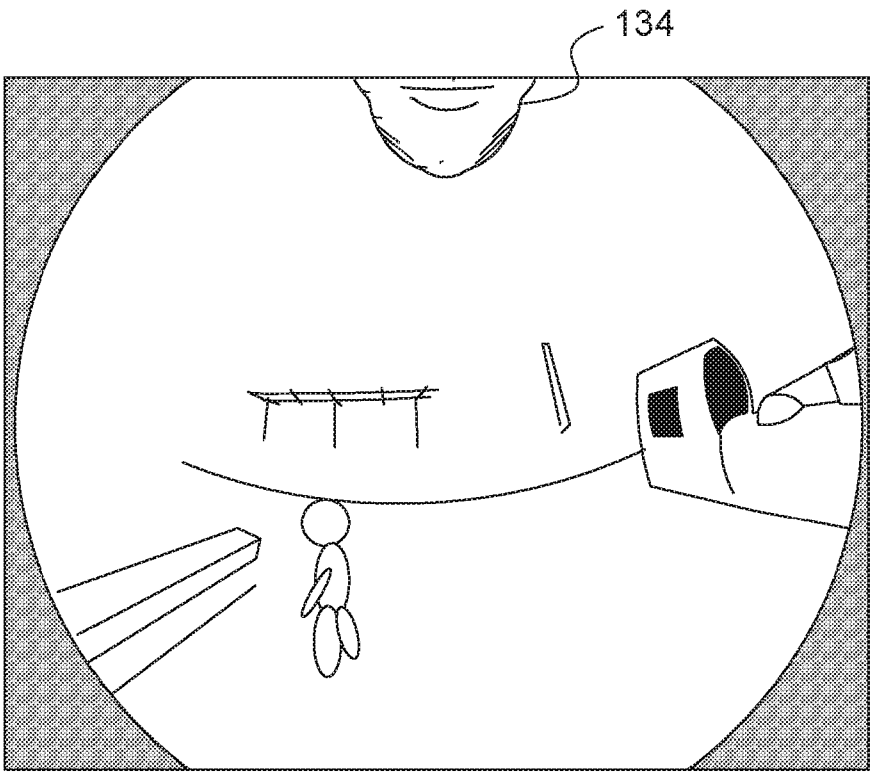


FIG. 25

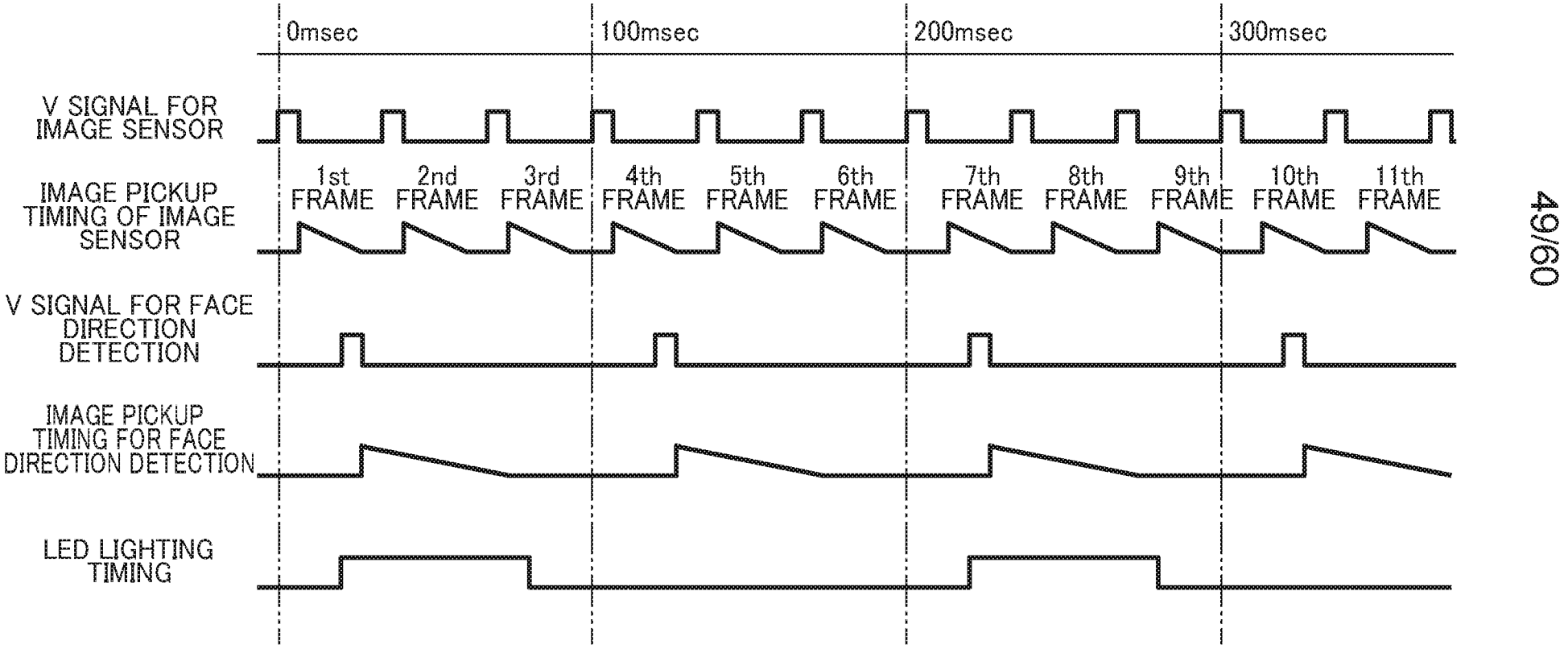
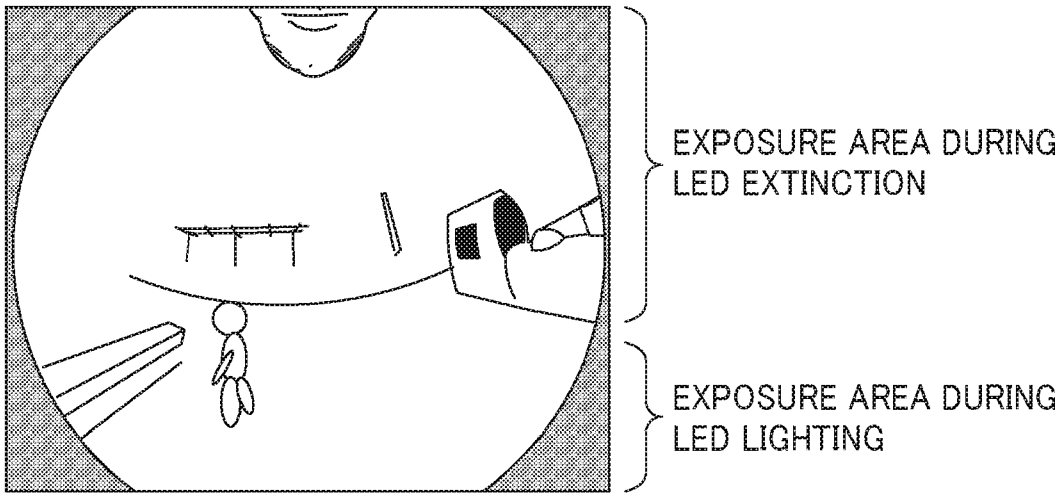

0msec
100msec
200msec
300msec
V SIGNAL FOR IMAGE SENSOR
IMAGE PICKUP TIMING OF IMAGE SENSOR
1st FRAME
2nd FRAME
3rd FRAME
4th FRAME
5th FRAME
6th FRAME
7th FRAME
8th FRAME
9th FRAME
10th FRAME
11th FRAME
V SIGNAL FOR FACE DIRECTION DETECTION
IMAGE PICKUP TIMING FOR FACE DIRECTION DETECTION
LED LIGHTING TIMING

FIG. 26A



12 12 22

FIG. 26B

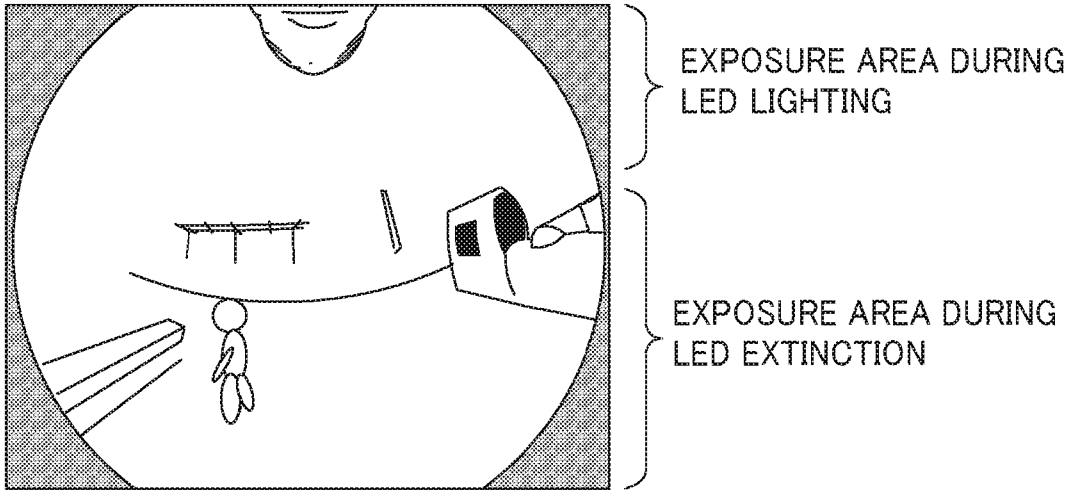


FIG. 27A

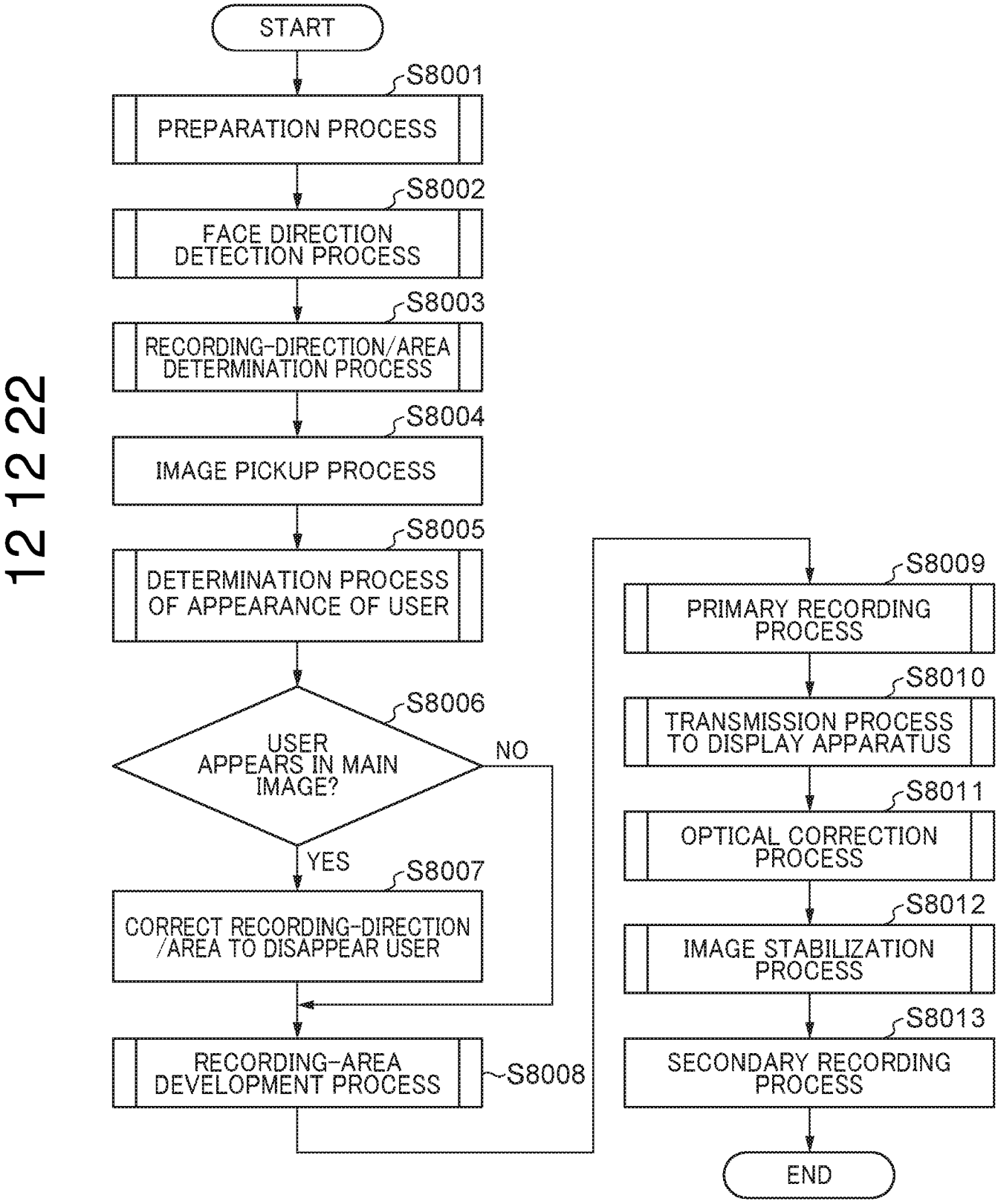
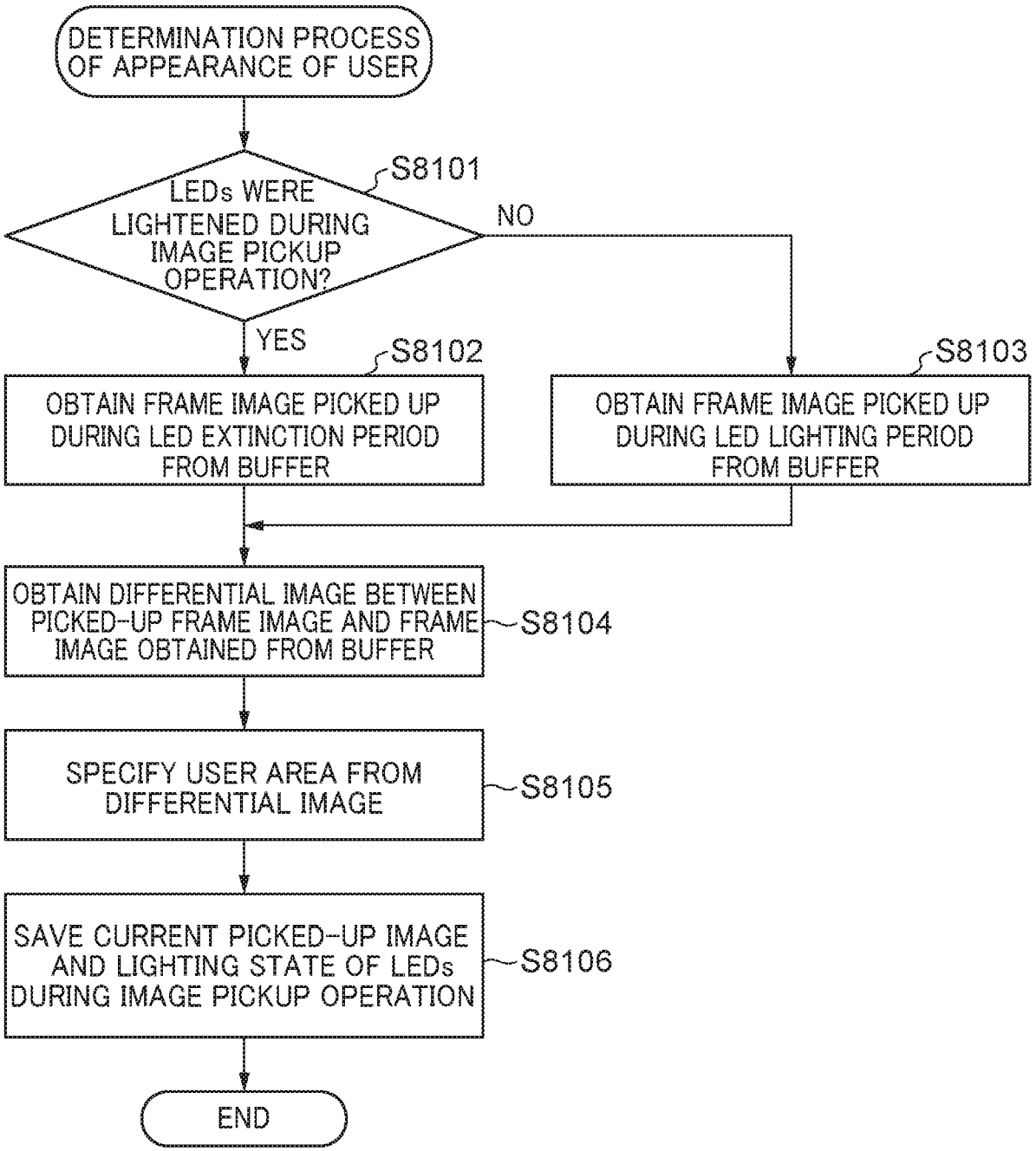

12 12 22
START
S8001
PREPARATION PROCESS
S8002
FACE DIRECTION DETECTION PROCESS
S8003
RECORDING-DIRECTION/AREA DETERMINATION PROCESS
S8004
IMAGE PICKUP PROCESS
S8005
DETERMINATION PROCESS OF APPEARANCE OF USER
S8006
USER APPEARS IN MAIN IMAGE?
NO
YES
S8007
CORRECT RECORDING-DIRECTION /AREA TO DISAPPEAR USER
RECORDING-AREA DEVELOPMENT PROCESS
S8008
S8009
PRIMARY RECORDING PROCESS
S8010
TRANSMISSION PROCESS TO DISPLAY APPARATUS
S8011
OPTICAL CORRECTION PROCESS
S8012
IMAGE STABILIZATION PROCESS
S8013
SECONDARY RECORDING PROCESS
END

FIG. 27B



12 12 22

FIG. 28A

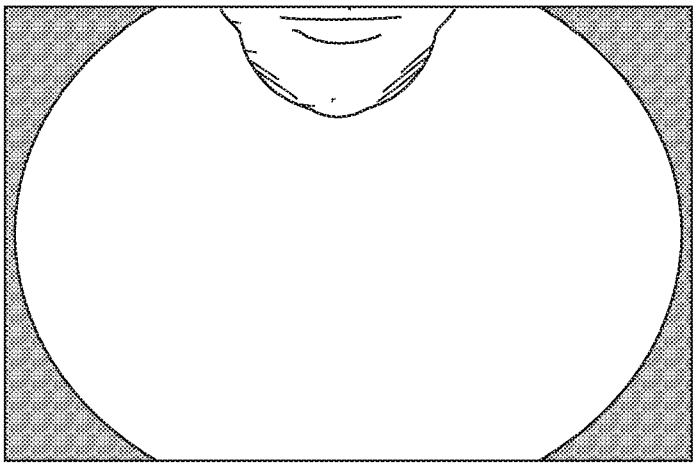


FIG. 28B

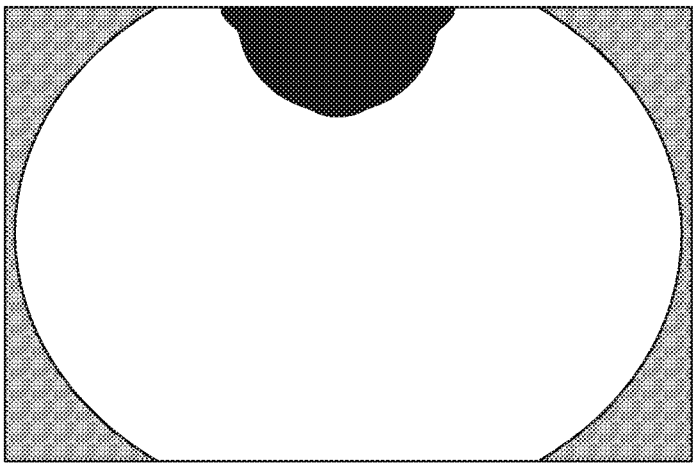
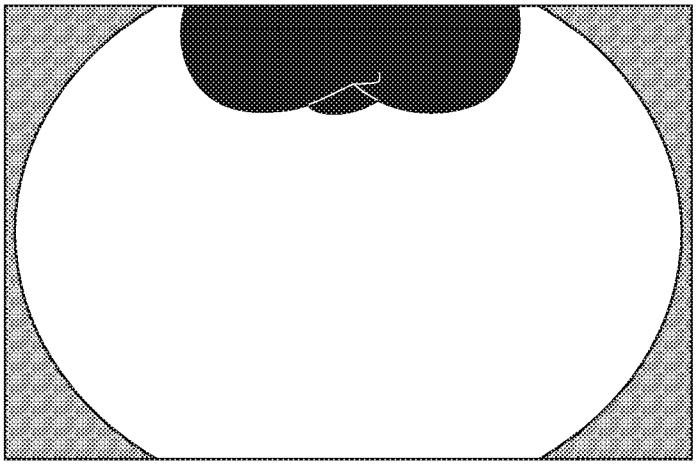
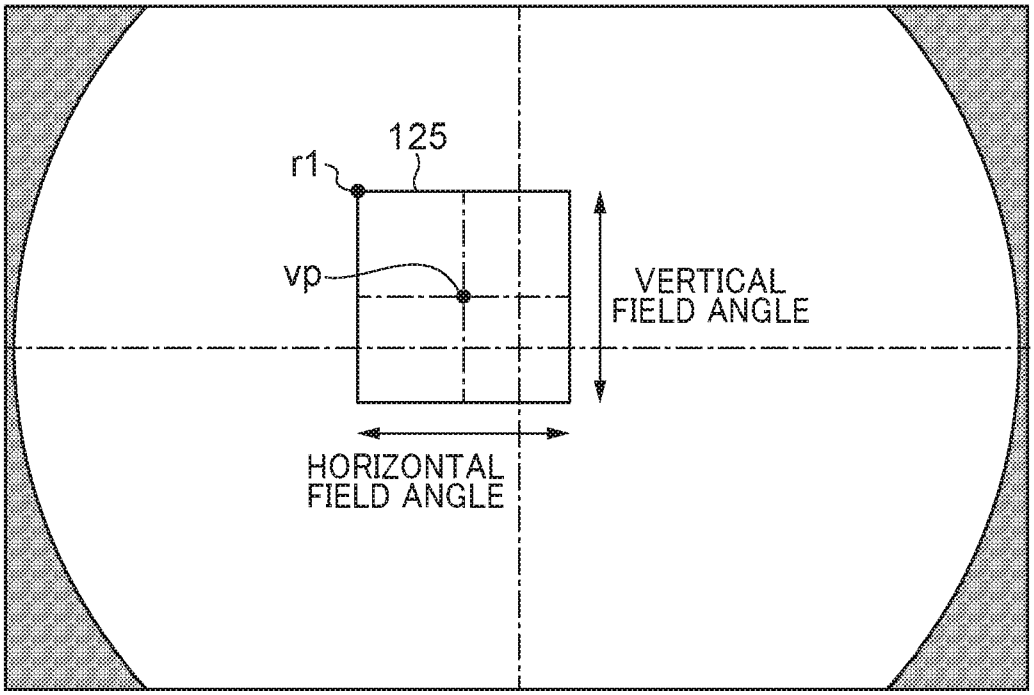


FIG. 28C



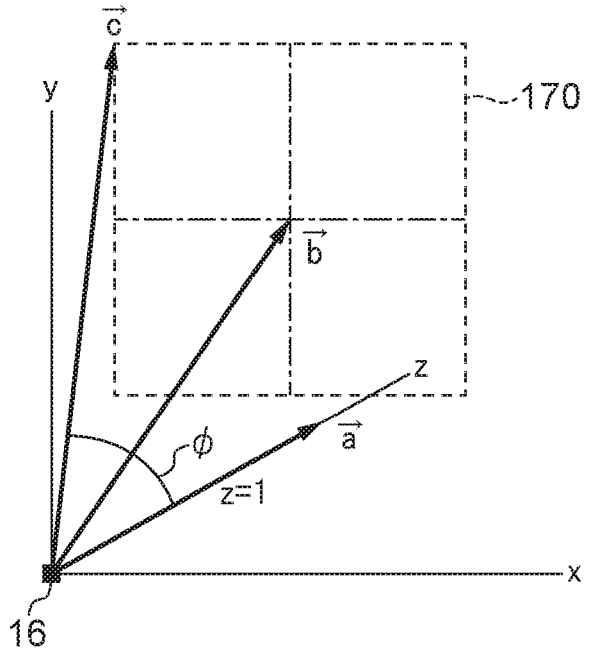
12 12 22

FIG. 29



12 12 22

FIG. 30



12 12 22

FIG. 31

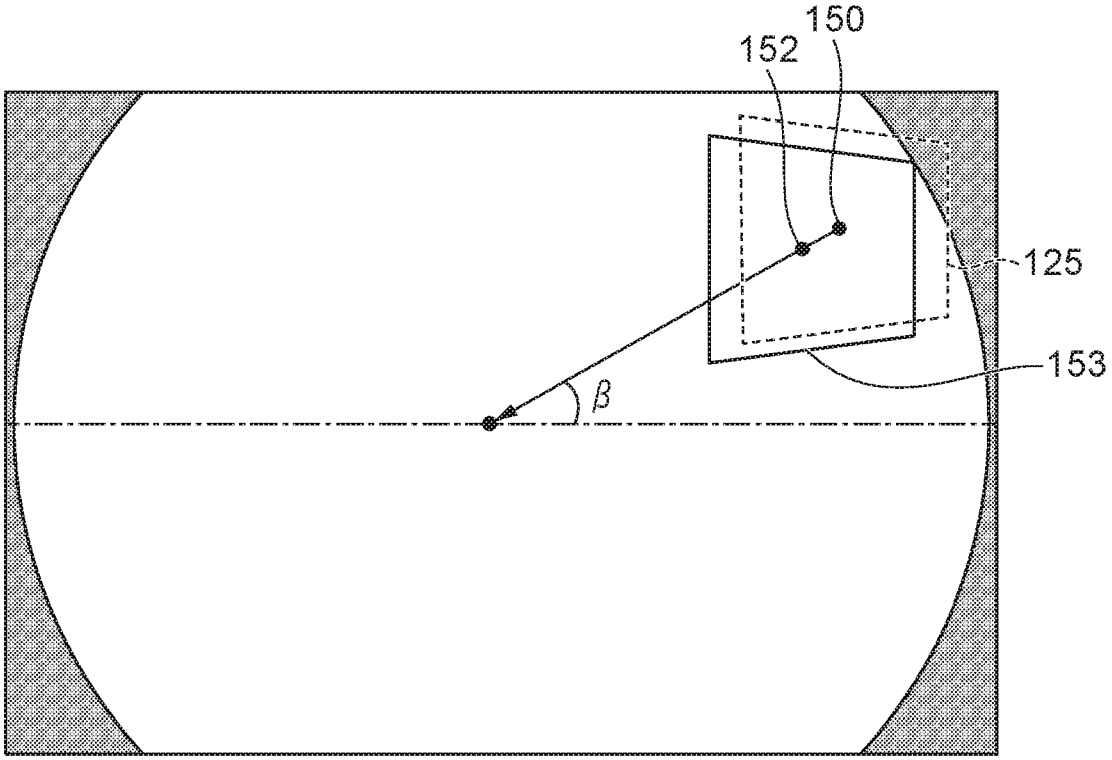
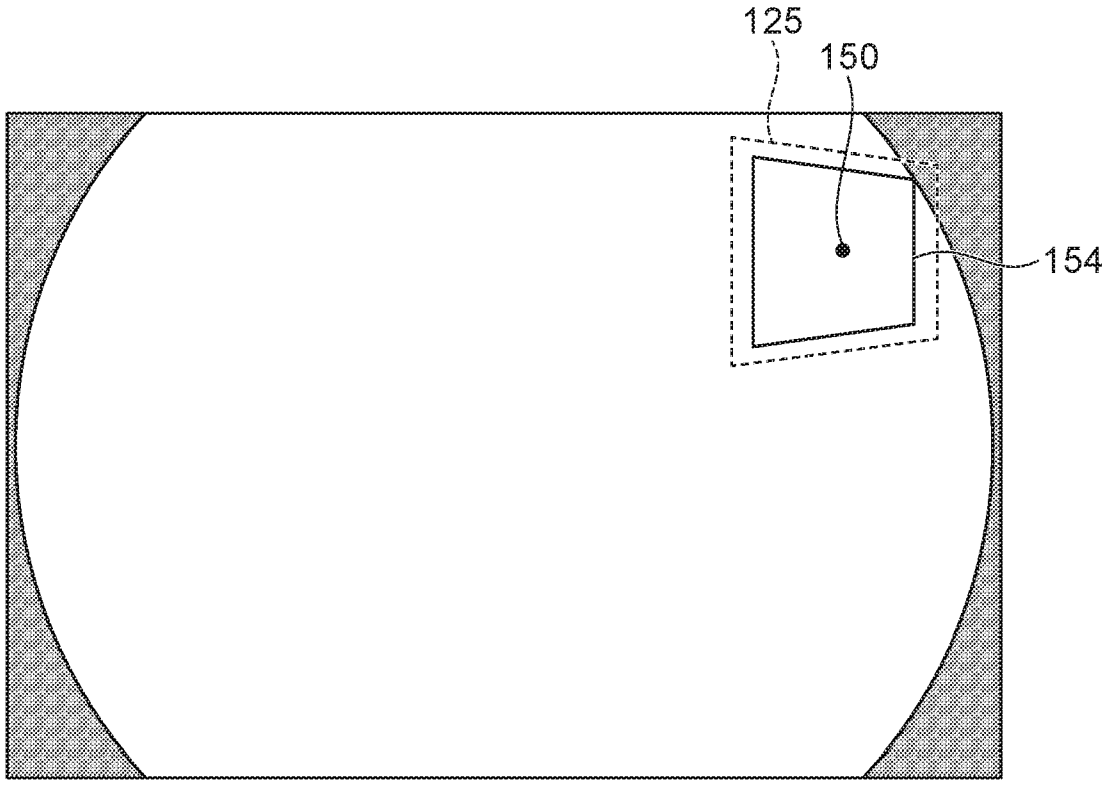
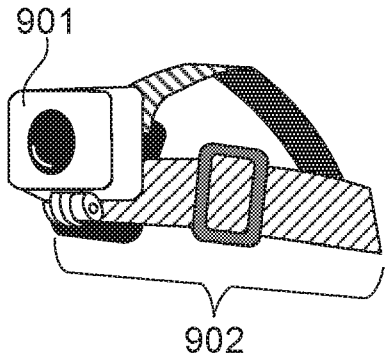


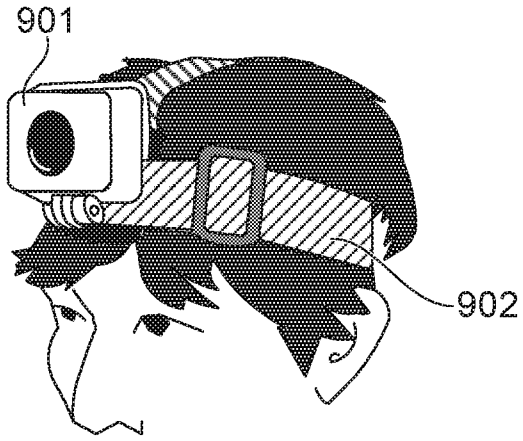
FIG. 32



PRIOR ART
FIG. 33A

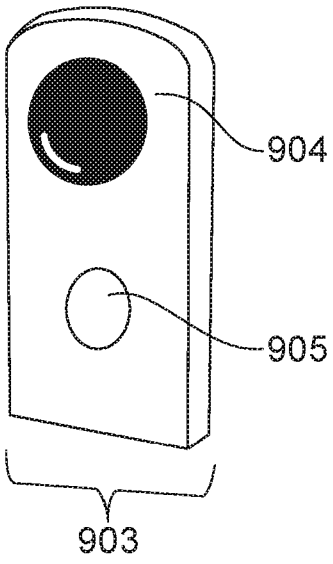


PRIOR ART
FIG. 33B



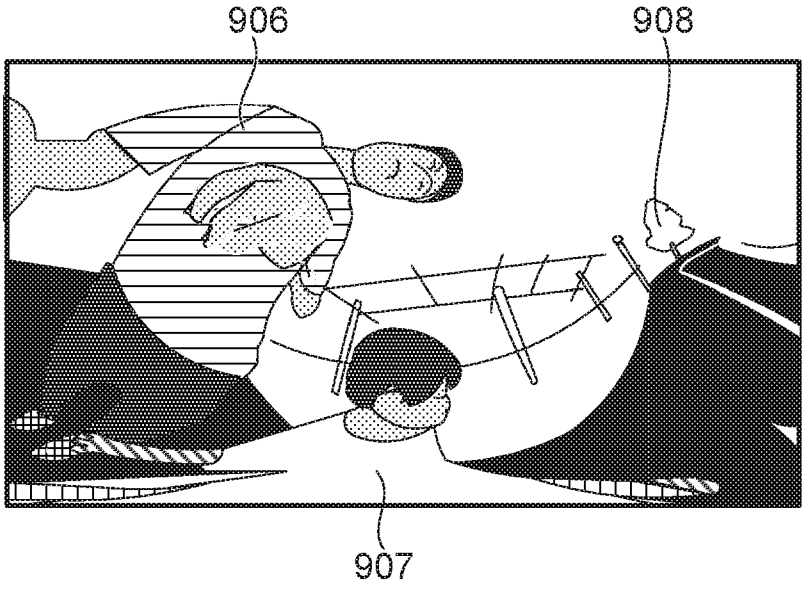
12 12 22

PRIOR ART
FIG. 34



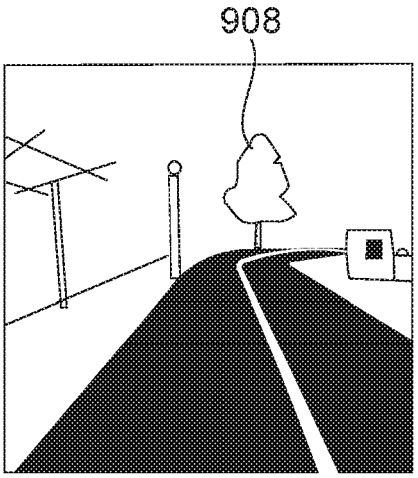
12 12 22

PRIOR ART
FIG. 35A

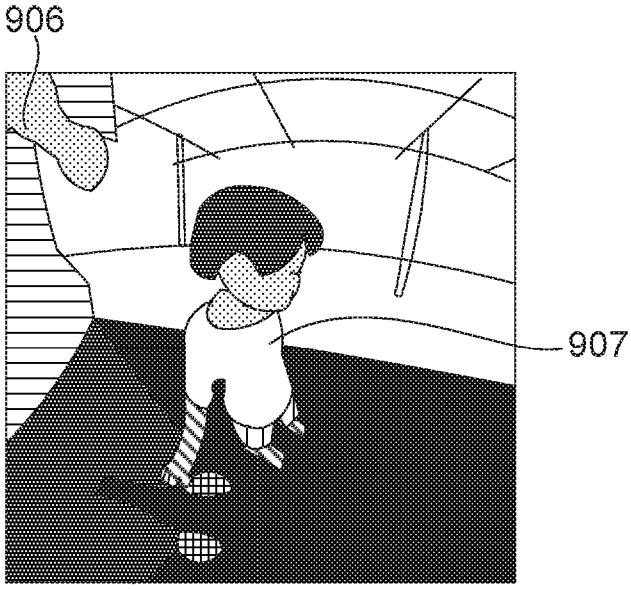


12 12 22

PRIOR ART
FIG. 35B



PRIOR ART
FIG. 35C



The following terms are registered trade marks and should be read as such wherever they occur in this document:

WiFi
Bluetooth
DVD
Blu-ray

TITLE OF THE INVENTION

IMAGE PICKUP APPARATUS USED AS ACTION CAMERA, CONTROL METHOD THEREFOR, AND STORAGE MEDIUM STORING CONTROL PROGRAM THEREFOR

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an image pickup apparatus used as an action camera, a control method therefor, and a storage medium storing a control program therefor.

Description of the Related Art

[0002] When a user picks up an image of an object with a camera, the user needs to continuously direct the camera toward the object. Accordingly, the user may find it difficult to manage actions other than an image pickup action because the user is busy in an image pickup operation. Further, the user may find it difficult to focus their attention on their immediate surroundings because the user must focus their attention on the image pickup operation.

[0003] For example, if the user is a parent, the user cannot play with a child while performing an image pickup operation with the child as the object, and the image pickup operation becomes impossible while playing with the child.

[0004] As a further example, if the user performs an image pickup operation while watching a sport game, the user cannot focus their attention on the game (e.g. cheer or remember game contents), and the image pickup operation becomes impossible while focusing attention to watch the sports game. Similarly, when a user performs an image pickup operation during group travel,

the user cannot focus their attention on the travel experience to the same extent as other group members, and when the user gives priority to their travel experience, the image pickup operation suffers as a result.

[0005] As a method for solving these matters, methods have been contemplated wherein a camera is fixed to the head of a user using a fixing-to-head accessory to pick up an image in an observing direction. This enables the user to perform an image pickup operation without being occupied with the image pickup operation. Further, there is also contemplated a method that picks up an image in a wide area with an entire-celestial-sphere camera during experience. This enables a user to focus attention on their experience during an image pickup operation. After the experience, the user may extract a desired image part from picked-up entire-celestial-sphere image and edit it to obtain an image of the experience.

[0006] However, these methods need a troublesome action that equips the head with the fixing-to-head accessory 902 to which a main body of an action camera 901 is fixed, as shown in FIG. 33A. Moreover, as shown in FIG. 33B, when the user equips the head with the action camera 901 with the fixing-to-head accessory 902, appearance is bad and also a hairstyle of the user is disheveled. Furthermore, the user may feel uneasy about the existence of the fixing-to-head accessory 902 and the action camera 901 because of their weights, and may worry about having a bad appearance to third persons. Accordingly, the user may find it difficult to perform an image pickup operation because the user cannot focus attention on their experience in the state shown in FIG. 33B, or because the user feels resistance to the style shown in FIG. 33B.

[0007] In the meantime, the latter method needs series of operations, such as image conversion and extraction position designation. For example, an entire-celestial-sphere camera 903 equipped with a lens 904 and an image pickup button

905 as shown in FIG. 34 is known. The lens 904 is one of a pair of fish-eye lenses for picking up half-celestial-sphere images provided in both sides of a housing of the entire celestial sphere camera 903. The entire-celestial-sphere camera 903 picks up an entire-celestial-sphere image using these fish-eye lenses. Then, the entire celestial sphere image is obtained by combining projection images of the pair of fish-eye lenses.

[0008] FIG. 35A, FIG. 35B, and FIG. 35C are views showing examples of conversion processes of the image picked up by the entire-celestial-sphere camera 903.

[0009] FIG. 35A shows an example of the entire-celestial-sphere image obtained by the entire celestial sphere camera 903, and a user 906, a child 907, and a tree 908 are included as objects. Since this image is an entire-celestial-sphere image obtained by combining projection images of the pair of fish-eye lenses, the user 906 is distorted greatly. Moreover, since a body part of the child 907 who is the object that the user 906 wants to pick up is located in a peripheral part of a pickup area of the lens 904, the body part distorts greatly in the right and left directions, and is extended. In the meantime, since the tree 908 is the object located in front of the lens 904, the tree 908 is picked up without great distortion.

[0010] In order to generate an image of a visual field at which people are usually looking from the image shown in FIG. 35A, it is necessary to extract a part of the image, to perform plane conversion, and to display the converted image.

[0011] FIG. 35B is an image located in front of the lens 904 that is extracted from the image shown in FIG. 35A. In the image in FIG. 35B, the tree 908 is shown in the center in the visual field at which people are usually looking. However, since the image in FIG. 35B does not include the child 907 who the user 906 wants to pick up, the user has to change an extraction position.

Specifically, in this case, it is necessary to move the extraction position leftward and downward by 30° from the tree 908 in FIG. 35A. FIG. 35C shows a displayed image that is obtained by extracting the moved position and by performing the plane conversion. In this way, in order to obtain the image in FIG. 35C that the user wants to pick up from the image in FIG. 35A, the user has to extract a necessary area and has to perform the plane conversion. Accordingly, although the user can focus attention on experience during the experience (during image pickup), there is a large subsequent workload for the user.

[0012] Japanese Laid-Open Patent Publication (Kokai) No. 2007-74033 (JP 2007-74033A) discloses a technique that uses a second camera that picks up a user in addition to a first camera that picks up an object. This technique calculates a moving direction and visual-line direction of a user from an image picked up by the second camera, determines an image pickup direction of the first camera, and picks up an image of an object estimated on the basis of user's viewpoint and state.

[0013] Japanese Laid-Open Patent Publication (Kokai) No. 2017-60078 (JP 2017-60078A) (Counterpart of US Patent Application 20170085841) discloses an image recording system including a sensor device that is attached to a user's head and an image pickup apparatus that is separately attached to a user's body or a bag. The sensor device consists of a gyro sensor or an acceleration sensor and detects a user's observation direction. The image pickup apparatus picks up an image in the observation direction detected by the sensor device.

[0014] However, since the second camera of JP 2007-74033A picks up an image of the user from a position distant from the user, the second camera needs high optical performance in order to calculate the moving direction and visual-line direction of the user from the image picked up by the second camera. Moreover,

since high arithmetic processing capability is needed for processing the image picked up by the second camera, a scale of an apparatus becomes large. Furthermore, even if the high optical performance and the high arithmetic processing capability are satisfied, the user's observation direction cannot be precisely calculated. Accordingly, since an object that the user wants to pick up cannot be estimated with sufficient accuracy on the basis of the user's viewpoint and state, an image other than what is wanted by the user may be picked up.

[0015] Moreover, since the sensor device of JP 2017-60078A directly detects a user's observation direction, the user needs to equip the head with the sensor device, which cannot solve troublesomeness in attaching any device to the head as mentioned above. Moreover, when the sensor device consists of a gyro sensor or an acceleration sensor, certain accuracy can be obtained in detection of a relative observation direction. However, since accuracy of detection of an absolute observation direction, especially in the horizontal rotation direction, cannot be obtained, there is an issue in a practical application.

SUMMARY OF THE INVENTION

[0016] The present invention provides an image pickup apparatus, a control method therefor, and a storage medium storing a control program therefor, which eliminate manual change of an image pickup direction during an image pickup operation, and which can easily obtain an image that records an experience while allowing a user to focus attention on the experience.

[0017] Accordingly, an aspect of the present invention provides an image pickup apparatus including an observation direction detection unit that is adapted to be worn on a body part other than a head of a user and that is configured to detect an observation direction of a user, an image pickup unit that is adapted to

be worn on a body of the user and that is configured to pick up an image, an image output unit configured to output an image in an image recording frame corresponding to the observation direction in the image picked up by the image pickup unit, and a determination unit configured to determine if a part of the body of the user appears in the image, and, in a case where a part of the body of the user appears in the image, restrict the image recording frame such that the part of the body of the user does not appear in an output image.

[0018] According to the present invention, manual change of an image pickup direction during an image pickup operation becomes unnecessary, and an image that records experience can be easily obtained while allowing a user to focus attention on the experience.

[0019] Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] FIG. 1A is an external view showing a camera body including an image-pickup/detection unit as an image pickup apparatus according to a first embodiment.

[0021] FIG. 1B is a view showing a state where a user wears the camera body.

[0022] FIG. 1C is a view showing a battery unit in the camera body viewed from a rear side in FIG. 1A.

[0023] FIG. 1D is an external view showing a display apparatus as a portable device according to the first embodiment that is separated from the camera body.

[0024] FIG. 2A is a front view showing the image-pickup/detection unit in the camera body.

[0025] FIG. 2B is a view showing a shape of a band part of a connection member in the camera body.

[0026] FIG. 2C is a rear view showing the image-pickup/detection unit.

[0027] FIG. 2D is a top view showing the image-pickup/detection unit.

[0028] FIG. 2E is a view showing a configuration of a face direction detection unit arranged inside the image-pickup/detection unit and under a face direction detection window in the camera body.

[0029] FIG. 2F is a view showing a state where a user wears the camera body viewed from a left side of the user.

[0030] FIG. 3A, FIG. 3B, and FIG. 3C are views showing details of the battery unit.

[0031] FIG. 4 is a functional block diagram showing the camera body according the first embodiment.

[0032] FIG. 5 is a block diagram showing a hardware configuration of the camera body according to the first embodiment.

[0033] FIG. 6 is a block diagram showing a hardware configuration of the display apparatus.

[0034] FIG. 7A is a flowchart schematically showing an image pickup/recording process according to the first embodiment executed by the camera body and display apparatus.

[0035] FIG. 7B is a flowchart showing a subroutine of a preparation process in a step S100 in FIG. 7A according to the first embodiment.

[0036] FIG. 7C is a flowchart showing a subroutine of a face direction detection process in a step S200 in FIG. 7A according to the first embodiment.

[0037] FIG. 7D is a flowchart showing a subroutine of a recording-

direction/area determination process in a step S300 in FIG. 7A according to the first embodiment.

[0038] FIG. 7E is a flowchart showing a subroutine of a recording-area development process in a step S500 in FIG. 7A according to the first embodiment.

[0039] FIG. 7F is a view for describing a process in the steps S200 through S500 in FIG. 7A in a video image mode.

[0040] FIG. 8A is a view showing an image of a user viewed from the face direction detection window.

[0041] FIG. 8B is a view showing a case where fluorescent lamps in a room appear as background in the image of the user viewed from the face direction detection window.

[0042] FIG. 8C is a view showing an image obtained by imaging the user and fluorescent lamps as background shown in FIG. 8B onto a sensor of the infrared detection device through the face direction detection window in a state where infrared LEDs of the infrared detection device are not lightened.

[0043] FIG. 8D is a view showing an image obtained by imaging the user and fluorescent lamps as background shown in FIG. 8B onto the sensor of the infrared detection device through the face direction detection window in a state where the infrared LEDs are lightened.

[0044] FIG. 8E is a view showing a difference image that is calculated by subtracting the image in FIG. 8C from the image in FIG. 8D.

[0045] FIG. 8F is a view showing a result obtained by adjusting shades of the difference image in FIG. 8E so as to fit with a scale of light intensities of reflected components of infrared light projected to a face and neck of the user.

[0046] FIG. 8G is a view obtained by superimposing reference numerals denoting parts of a user's body, a double circle showing a throat position, and a black circle showing a chin position on FIG. 8F.

[0047] FIG. 8H is a view showing a difference image calculated by the similar method as FIG. 8E in directing the user's face to the right.

[0048] FIG. 8I is a view showing a result obtained by adjusting shades of the difference image in FIG. 8H so as to fit with a scale of light intensities of reflected components of infrared light projected to a face and neck of the user and by superimposing the double circle showing the throat position and the black circle showing the chin position.

[0049] FIG. 8J is a view showing an image of the user who directs the face upward by 33° viewed from the face direction detection window.

[0050] FIG. 8K is a view showing a result obtained by adjusting shades of a difference image, which is calculated by the similar method as FIG. 8E in a case that the user directs the face upward by 33°, so as to fit with a scale of light intensities of reflected components of infrared light projected to a face and neck of the user and by superimposing the double circle showing the throat position and the black circle showing the chin position.

[0051] FIG. 9 is a timing chart showing a lighting timing of the infrared LEDs and related signals.

[0052] FIG. 10A through FIG. 10D are views describing movements of the user's face in a vertical direction.

[0053] FIG. 11A is a view showing a target visual field set in a superwide-angle image picked up by an image pickup unit of the camera body in a case where the user faces the front.

[0054] FIG. 11B is a view showing an image in the target visual field extracted from the superwide-angle image in FIG. 11A.

[0055] FIG. 11C is a view showing the target visual field set in the superwide-angle image in a case where the user is observing an A-object.

[0056] FIG. 11D is a view showing an image that is obtained by correcting

distortion and blur of an image in the target visual field in FIG. 11C extracted from the superwide-angle image.

[0057] FIG. 11E is a view showing a target visual field set in the superwide-angle image in a case where the user is observing the A-object at a field-angle set value smaller than that in FIG. 11C.

[0058] FIG. 11F is a view showing an image that is obtained by correcting distortion and blur of an image in the target visual field in FIG. 11E extracted from the superwide-angle image.

[0059] FIG. 12A is a view showing an example of the target visual field set in the superwide-angle image.

[0060] FIG. 12B is a view showing an example of the target visual field set in the superwide-angle image in a case where the field-angle set value is identical to that of the target visual field in FIG. 12A and where the observation direction differs.

[0061] FIG. 12C is a view showing another example of the target visual field set in the superwide-angle image in a case where the field-angle set value is identical to that of the target visual field in FIG. 12A and where the observation direction differs.

[0062] FIG. 12D is a view showing an example of the target visual field set in the superwide-angle image in a case where the observation direction is identical to that of the target visual field in FIG. 12C and where the field-angle set value is smaller.

[0063] FIG. 12E is a view showing an example that gives an image stabilization margin corresponding to a predetermined image stabilization level around the target visual field shown in FIG. 12A.

[0064] FIG. 12F is a view showing an example that gives an image stabilization margin corresponding to the same image stabilization level of the

image stabilization margin in FIG. 12E around the target visual field shown in FIG. 12B.

[0065] FIG. 12G is a view showing an example that gives an image stabilization margin corresponding to the same image stabilization level of the image stabilization margin in FIG. 12E around the target visual field shown in FIG. 12D.

[0066] FIG. 13 is a view showing a menu screen for setting various set values of the video image mode that is displayed on a display unit of the display apparatus before an image pickup operation of the camera body.

[0067] FIG. 14 is a flowchart showing a subroutine of a primary recording process in a step S600 in FIG. 7A.

[0068] FIG. 15 is a view showing a data structure of an image file generated by the primary recording process.

[0069] FIG. 16 is a flowchart of the subroutine of a transmission process to the display apparatus in a step S700 in FIG. 7A.

[0070] FIG. 17 is a flowchart showing a subroutine of an optical correction process in a step S800 in FIG. 7A.

[0071] FIG. 18A through FIG. 18F are views for describing a process of applying distortion correction in a step S803 in FIG. 17.

[0072] FIG. 19 is a flowchart showing a subroutine of an image stabilization process in a step S900 in FIG. 7A.

[0073] FIG. 20A and FIG. 20B are the views showing details of a calibrator used for a calibration process according to a second embodiment.

[0074] FIG. 21 is a flowchart showing the calibration process according to the second embodiment executed by the camera body and the calibrator.

[0075] FIG. 22A is a view showing a screen displayed on a display unit of the calibrator in a step S3103 in FIG. 21 during a calibration operation for a front

direction of the user.

[0076] FIG. 22B is a view showing a state where the user holds the calibrator in the front according to an instruction shown as an instruction display in FIG. 22A.

[0077] FIG. 22C is a schematic view showing an entire superwide-angle image that is caught by an image pickup lens in the state in FIG. 22B.

[0078] FIG. 22D is a schematic view showing an image that is obtained by correcting aberrations of the superwide-angle image shown in FIG. 22C.

[0079] FIG. 22E is a schematic view showing a face direction image that is obtained by a face direction detection unit in a step S3108 in FIG. 21 during the calibration operation for the front direction of the user.

[0080] FIG. 22F is a schematic view showing an in-camera image displayed in a step S3107 in FIG. 21.

[0081] FIG. 23A is a view showing a screen displayed on the display unit of the calibrator in the step S3103 in FIG. 21 during the calibration operation in an upper right direction of the user.

[0082] FIG. 23B is a view showing a state where the user holds the calibrator to upper right according to an instruction shown as the instruction display in FIG. 23A.

[0083] FIG. 23C is a schematic view showing the entire superwide-angle image that is caught by the image pickup lens in the state in FIG. 23B.

[0084] FIG. 23D is a schematic view showing an image that is obtained by correcting aberrations of the superwide-angle image shown in FIG. 23C.

[0085] FIG. 23E is a schematic view showing a face direction image that is obtained by the face direction detection unit in the step S3108 in FIG. 21 during the calibration operation for the upper right direction of the user.

[0086] FIG. 24 is a view describing a third embodiment and showing a

frame image in which a jaw of the user appears that is picked up by an image pickup unit of a camera body.

[0087] FIG. 25 is a timing chart showing a case where a V-signal for face direction detection and a V-signal for a solid state image sensor are asynchronous.

[0088] FIG. 26A is a view describing the third embodiment and showing one example of a frame image that has an exposure area during LED lighting and exposure area during LED extinction and that is picked up by the image pickup unit of the camera body.

[0089] FIG. 26B is a view showing another example of a frame image that has the exposure area during LED lighting and exposure area during LED extinction and that is picked up by the image pickup unit of the camera body for describing the third embodiment.

[0090] FIG. 27A is a flowchart showing a frame correction process for image recording according to the third embodiment.

[0091] FIG. 27B is a flowchart showing a determination process of appearance of a user in a step S8005 in FIG. 27A.

[0092] FIG. 28A is a view describing the third embodiment and showing an example of a difference image between an entire lighting image and an entire extinction image in a case where the user faces the front.

[0093] FIG. 28B is a view showing an example of a binary image converted from the difference image in FIG. 28A.

[0094] FIG. 28C is a view describing the third embodiment and showing an example of a logical sum image of five binary images converted from five difference images between entire lighting images and entire extinction images that are respectively obtained when the user faces five directions.

[0095] FIG. 29 is a schematic diagram describing a target visual field and image height in a fourth embodiment.

[0096] FIG. 30 is a schematic diagram describing an angle of an observation direction and a coordinate system in the fourth embodiment.

[0097] FIG. 31 is a schematic diagram describing the fourth embodiment.

[0098] FIG. 32 is a schematic diagram describing a fifth embodiment.

[0099] FIG. 33A and FIG. 33B are views showing a configuration example of a camera fixed to a head using a conventional fixing-to-head accessory.

[0100] FIG. 34 is a view showing a configuration example of a conventional entire-celestial-sphere camera.

[0101] FIG. 35A, FIG. 35B, and FIG. 35C are views showing examples of conversion processes of the image picked up by the entire-celestial-sphere camera in FIG. 35.

DESCRIPTION OF THE EMBODIMENTS

[0102] Hereafter, embodiments according to the present invention will be described in detail by referring to the drawings.

[0103] FIG. 1A through FIG. 1D are views for describing a camera system consisting of a camera body 1 and a display apparatus 800 that is separated from the camera body 1. The camera body 1 includes an image-pickup/detection unit 10 as a wearable image pickup apparatus according to a first embodiment. Although the camera body 1 and the display apparatus 800 are separated devices in this embodiment, they may be integrated.

[0104] FIG. 1A is an external view showing the camera body 1. The camera body 1 is provided with the image-pickup/detection unit 10, a battery unit (power source unit) 90, a right connection member 80R, and a left connection member 80L as shown in FIG. 1A. The right connection member 80R connects the image-pickup/detection unit 10 and the battery unit 90 on the right side of a

user's body (left side in FIG. 1A). The left connection member 80L connects the image-pickup/detection unit 10 and the battery unit 90 on the left side of the user's body (right side in FIG. 1A).

[0105] The image-pickup/detection unit 10 is provided with a face direction detection window 13, a start switch 14, a stop switch 15, an image pickup lens 16, an LED 17, and microphones 19L and 19R.

[0106] The face direction detection window 13 permits transmission of infrared light projected from infrared LEDs 22 (FIG. 5, an infrared radiation unit) built in the image-pickup/detection unit 10 to detect positions of face parts of the user. The face direction detection window 13 also permits transmission of reflected infrared light from the face.

[0107] The start switch 14 is used to start an image pickup operation. The stop switch 15 is used to stop the image pickup operation. The image pickup lens 16 guides light to be picked up to a solid state image sensor 42 (FIG. 5, an image sensor) inside the image-pickup/detection unit 10. The LED 17 indicates a state that the image pickup operation is on-going. Additionally or alternatively, the LED 17 can function as a warning light.

[0108] The microphones 19R and 19L take in peripheral sound. The microphone 19L takes in sound of the left side of user's periphery (right side in FIG. 1A). The microphone 19R takes in sound of the right side of the user's periphery (left side in FIG. 1A).

[0109] FIG. 1B is a view showing a state where the user wears the camera body 1.

[0110] When the user wears the camera body 1 so that the battery unit 90 is located proximate to a user's back side and the image-pickup/detection unit 10 is located proximate to the front side of the user's body, the image-pickup/detection unit 10 is supported while being energized in a direction toward a chest by the left

and right connection members 80L and 80R that are respectively connected to the left and right ends of the image-pickup/detection unit 10. Thereby, the image-pickup/detection unit 10 is positioned in front of clavicles of the user. At this time, the face direction detection window 13 is located under a jaw of the user. An infrared condenser lens 26 shown in FIG. 2E mentioned later is arranged inside the face direction detection window 13. An optical axis (detection optical axis) of the infrared condenser lens 26 is directed to the user's face and is directed to a different direction from an optical axis (image pickup optical axis) of the image pickup lens 16. A face direction detection unit 20 (see FIG. 5) including the infrared condenser lens 26 detects a user's observation direction on the basis of the positions of face parts. This enables an image pickup unit 40 mentioned later to pick up an image of an object in the observation direction. Adjustment of the setting position due to individual difference of a body shape and difference in clothes will be mentioned later.

[0111] Moreover, since the image-pickup/detection unit 10 is arranged in the front side of the body and the battery unit 90 is arranged in the back face in this way, weight of the camera body 1 is distributed, which reduces user's fatigue and reduces displacement of the camera body 1 due to forces on the camera body 1 caused by movement of the user.

[0112] Although the example in which the user wears the camera body 1 so that the image-pickup/detection unit 10 will be located in front of the clavicles of the user is described in this embodiment, this example is not imperative. That is, the user may wear the camera body 1 in any position of the user's body part other than the head as long as the camera body 1 can detect the user's observation direction and the image pickup unit 40 can pick up an image of an object in the observation direction.

[0113] FIG. 1C is a view showing the battery unit 90 viewed from a rear

side in FIG. 1A. The battery unit 90 is provided with a charge cable inserting slot 91, adjustment buttons 92L and 92R, and a backbone escape cutout 93 as shown in FIG. 1C.

[0114] A charge cable (not shown) can be connected to the charge cable inserting slot 91. An external power source charges internal batteries 94L and 94R (see FIG. 3A) and supplies electric power to the image-pickup/detection unit 10 through the charge cable.

[0115] Adjustment buttons 92L and 92R are used to adjust the respective lengths of the band parts 82L and 82R of the left and right connection members 80L and 80R. The adjustment button 92L is used to adjust the left band part 82L, and the adjustment button 92R is used to adjust the right band part 82R. Although the lengths of the band parts 82L and 82R are independently adjusted with the adjustment buttons 92L and 92R in the embodiment, the lengths of the band parts 82L and 82R may be simultaneously adjusted with one button.

[0116] The backbone escape cutout 93 is formed by shaping the battery unit 90 so that the battery unit 90 will not touch the backbone. Since the backbone escape cutout 93 avoids a convex part of the backbone of the body, displeasure of wearing is reduced and lateral displacement of the battery unit 90 is prevented.

[0117] FIG. 1D is an external view showing the display apparatus 800 as a portable device according to the first embodiment that is separated from the camera body 1. As shown in FIG. 1D, the display apparatus 800 is provided with an A-button 802, a display unit 803, a B-button 804, an in-camera 805, a face sensor 806, an angular speed sensor 807, and an acceleration sensor 808. Moreover, the display apparatus 800 is provided with a wireless LAN unit (not shown in FIG. 1D) that enables high-speed connection with the camera body 1.

[0118] The A-button 802 has a function of a power button of the display apparatus 800. The display apparatus 800 receives an ON/OFF operation by a

long press of the A-button 802 and receives a designation of another process timing by a short press of the A-button 802.

[0119] The display unit 803 is used to check an image picked up by the camera body 1 and can display a menu screen required for setting. In this embodiment, a transparent touch sensor that is provided on the surface of the display unit 803 receives a touch operation to a screen (for example, a menu screen) that is displaying.

[0120] The B-button 804 functions as a calibration button 854 used for a calibration process mentioned later. The in-camera 805 can pick up an image of a person who is observing the display apparatus 800.

[0121] The face sensor 806 detects a face shape and an observation direction of the person who is observing the display apparatus 800. A concrete configuration of the face sensor 806 is not limited. For example, a structural optical sensor, a ToF (Time of Flight) sensor, and a millimeter wave radar may be employed.

[0122] Since the angular speed sensor 807 is built in the display apparatus 800, it is shown by a dotted line as a meaning of a perspective view. Since the display apparatus 800 of this embodiment is also provided with a function of the calibrator mentioned later, a triaxial gyro sensor that enables detection in X, Y, and Z directions is mounted. The acceleration sensor 808 detects a posture of the display apparatus 800.

[0123] It should be noted that a general smart phone is employed as the display apparatus 800 according to this embodiment. The camera system of the embodiment is achieved by matching firmware in the smart phone to firmware of the camera body 1. In the meantime, the camera system of the embodiment can be achieved by matching the firmware of the camera body 1 to an application and OS of the smart phone as the display apparatus 800.

[0124] FIG. 2A through FIG. 2F are views describing the image-pickup/detection unit 10 in detail. In views from FIG. 2A, a component that has the same function of a part that has been already described is indicated by the same reference numeral and its description in this specification is omitted.

[0125] FIG. 2A is a front view showing the image-pickup/detection unit 10.

[0126] The right connection member 80R has the band part 82R and an angle-holding member 81R of hard material that holds an angle with respect to the image-pickup/detection unit 10. The left connection member 80L has the band part 82L and an angle-holding member 81L similarly.

[0127] FIG. 2B is a view showing the shapes of the band parts 82L and 82R of the left and right connection members 80L and 80R. In FIG. 2B, the angle holding members 81L and 81R are shown as transparent members in order to show the shapes of the band parts 82L and 82R.

[0128] The band part 82L is provided with a left connecting surface 83L and an electric cable 84 that are arranged at the left side of the user's body (right side in FIG. 2B) when the user wears the camera body 1. The band part 82R is provided with a right connecting surface 83R arranged at the right side of the user's body (left side in FIG. 2B) when the user wears the camera body 1.

[0129] The left connecting surface 83L is connected with the angle holding member 81L, and its sectional shape is an ellipse but is not a perfect circle. The right connecting surface 83R also has a similar elliptical shape. The right connecting surface 83R and left connecting surface 83L are arranged bisymmetrically in a reverse V-shape. That is, the distance between the right connecting surface 83R and the left connecting surface 83L becomes shorter toward the upper side from the lower side in FIG. 2B. Thereby, since the long axis directions of the left and right connecting surfaces 83L and 83R match the user's body when the user hangs the camera body 1, the band parts 82L and 82R

touch the user's body comfortably and movement of the image-pickup/detection unit 10 in the left-and-right direction and front-and-back direction can be prevented.

[0130] The electric cable (a power supply member) 84 is wired inside the band part 82L and electrically connects the battery unit 90 and the image-pickup/detection unit 10. The electric cable 84 connects the power source of the battery unit 90 to the image-pickup/detection unit 10 or transfers an electrical signal with an external apparatus.

[0131] FIG. 2C is a rear view showing the image-pickup/detection unit 10. FIG. 2C shows the side that contacts to the user's body. That is, FIG. 2C is a view viewed from the opposite side of FIG. 2A. Accordingly, the positional relationship between the right connection member 80R and the left connection member 80L is reverse to FIG. 2A.

[0132] The image-pickup/detection unit 10 is provided with a power switch 11, an image pickup mode switch 12, and chest contact pads 18a and 18b at the back side. The power switch 11 is used to switch ON/OFF of the power of the camera body 1. Although the power switch 11 of this embodiment is a slide lever type, it is not limited to this. For example, the power switch 11 may be a push type switch or may be a switch that is integrally constituted with a slide cover (not shown) of the image pickup lens 16.

[0133] The image pickup mode switch (a change member) 12 is used to change an image pickup mode, i.e., is used to change a mode in connection with an image pickup operation. In this embodiment, the image pickup mode switch 12 can select the image pickup mode from among a still image mode, a video image mode, and a below-mentioned preset mode that is set using the display apparatus 800. In this embodiment, the image pickup mode switch 12 is a slide lever switch that can select one of "Photo", "Normal", and "Pre" shown in FIG.

2C. The image pickup mode shifts to the still image mode by sliding to "Photo", shifts to the video image mode by sliding to "Normal", and shifts to the preset mode by sliding to "Pre". It should be noted that the configuration of the image pickup mode switch 12 is not limited to the embodiment as long as the switch can change the image pickup mode. For example, the image pickup mode switch 12 may consist of three buttons of "Photo", "Normal", and "Pre".

[0134] The chest contact pads (fixing members) 18a and 18b touch the user's body when the image-pickup/detection unit 10 is energized. As shown in FIG. 2A, the image-pickup/detection unit 10 is formed so that a lateral (left-and-right) overall length will become longer than a vertical (up-and-down) overall length in wearing the camera body 1. The chest contact pads 18a and 18b are respectively arranged in vicinities of right and left ends of the image-pickup/detection unit 10. This arrangement reduces rotational blur in the left-and-right direction during the image pickup operation of the camera body 1. Moreover, the chest contact pads 18a and 18b prevent the power switch 11 and the image pickup mode switch 12 from touching the user's body. Furthermore, the chest contact pads 18a and 18b prevent heat transmission to the user's body even if the image-pickup/detection unit 10 heats up due to a long-time image pickup operation and are used for the adjustment of the angle of the image-pickup/detection unit 10.

[0135] FIG. 2D is a top view showing the image-pickup/detection unit 10. As shown in FIG. 2D, the face direction detection window 13 is provided in the central part of the top surface of the image-pickup/detection unit 10, and the chest contact pads 18a and 18b are projected from the image-pickup/detection unit 10.

[0136] FIG. 2E is a view showing a configuration of the face direction detection unit 20 arranged inside the image-pickup/detection unit 10 and under the face direction detection window 13. The face direction detection unit 20 is

provided with the infrared LEDs 22 and the infrared condenser lens 26. The face direction detection unit 20 is also provided with an infrared LED lighting circuit 21 and an infrared detection device 27 shown in FIG. 5 mentioned later.

[0137] The infrared LEDs 22 project infrared light 23 (FIG. 5) toward the user. The infrared condenser lens 26 images reflected light 25 (FIG. 5) from the user in projecting the infrared light 23 from the infrared LEDs 22 onto a sensor (not shown) of the infrared detection device 27.

[0138] FIG. 2F is a view showing a state where a user wears the camera body 1 viewed from the left side of the user.

[0139] An angle adjustment button 85L is provided in the angle holding member 81L and is used in adjusting the angle of the image-pickup/detection unit 10. An angle adjustment button (not shown in FIG. 2F) is provided in the opposite angle holding member 81R in the symmetrical position of the angle adjustment button 85L. Although the angle adjustment buttons are actually visible in FIG. 2A, FIG. 2C, and FIG. 2D, they are omitted to simplify the description.

[0140] When moving the angle holding member 81L upwardly or downwardly in FIG. 2F while pressing the angle adjustment button 85L, the user can change the angle between the image-pickup/detection unit 10 and the angle holding member 81L. The right side is the same as the left side. Moreover, projection angles of the chest contact pads 18a and 18b can be changed. The functions of these two kinds of angle change members (the angle adjustment buttons and chest contact pads) can adjust the image-pickup/detection unit 10 so as to keep the optical axis of the image pickup lens 16 horizontally irrespective of individual difference of a chest position shape.

[0141] FIG. 3A, FIG. 3B, and FIG. 3C are views showing details of the battery unit 90. FIG. 3A is a partially transparent back view showing the battery

unit 90.

[0142] As shown in FIG. 3A, the left battery 94L and right battery 94R are symmetrically mounted inside the battery unit 90 in order to keep weight balance. In this way, since the left and right batteries 94L and 94R are arranged symmetrically with the central part of the battery unit 90, the weight balance in the left-and-right direction is achieved and the position displacement of the camera body 1 is prevented. It should be noted that the battery unit 90 may mount a single battery.

[0143] FIG. 3B is a top view showing the battery unit 90. The batteries 94L and 94R are shown as the transparent members also in FIG. 3B. As shown in FIG. 3B, since the batteries 94L and 94R are symmetrically arranged at both the sides of the backbone escape cutout 93, the user can wear the battery unit 90 that is relatively heavy without any burden.

[0144] FIG. 3C is a rear view showing the battery unit 90. FIG. 3C is the view viewed from the side touched to the user's body, i.e., is the view viewed from the opposite side of FIG. 3A. As shown in FIG. 3C, the backbone escape cutout 93 is provided in the center along the backbone of the user.

[0145] FIG. 4 is a functional block diagram showing the camera body 1. Hereinafter, the process executed by the camera body 1 will be described roughly using FIG. 4. Details will be mentioned later.

[0146] As shown in FIG. 4, the camera body 1 is provided with the face direction detection unit 20, a recording-direction/field-angle determination unit 30, the image pickup unit 40, an image extraction/development unit 50, a primary recording unit 60, a transmission unit 70, and a second controller 111. These functional blocks are achieved by control of an overall control CPU 101 (FIG. 5) that controls the entire camera body 1.

[0147] The face direction detection unit 20 (an observation direction

detection unit) is a functional block executed by the above-mentioned infrared LEDs 22, the infrared detection device 27, etc. The face direction detection unit 20 estimates an observation direction by detecting the face direction and passes the observation direction to the recording-direction/field-angle determination unit 30.

[0148] The recording-direction/field-angle determination unit (a recording direction determination unit) 30 determines information about a position and an area that will be extracted from an image picked up by the image pickup unit 40 by performing various calculations on the basis of the observation direction estimated by the face direction detection unit 20. And then, the information is passed to the image extraction/development unit 50. The image pickup unit 40 converts light from an object to a wide-angle image and passes the image to the image extraction/development unit 50.

[0149] The image extraction/development unit (a development unit) 50 extracts an image that the user looks at from the image passed from the image pickup unit 40 by using the information passed from the recording-direction/field-angle determination unit 30. Then, the image extraction/development unit 50 develops the extracted image and passes the developed image to the primary recording unit 60.

[0150] The primary recording unit 60 is a functional block constituted by a primary memory 103 (FIG. 5) etc., records image information, and passes the image information to the transmission unit 70 at a required timing.

[0151] The transmission unit 70 is wirelessly connected with predetermined communication parties, such as the display apparatus 800 (FIG. 1D), a calibrator 850, and a simplified display apparatus 900, and communicates with these parties. Although the display apparatus 800 and the calibrator 850 are wirelessly connected in this embodiment, they may be wiredly connected.

[0152] The display apparatus 800 is connectable to the transmission unit 70 through a high-speed wireless LAN (hereinafter referred to as a "high-speed wireless network"). In this embodiment, the high-speed wireless network employs wireless communication corresponding to the IEEE802.11ax (WiFi 6) standard. In the meantime, wireless communication corresponding to other standards, such as the WiFi 4 standard and the WiFi 5 standard, may be employed. Moreover, the display apparatus 800 may be a dedicated apparatus developed for the camera body 1 or may be a general smart phone, a tablet terminal, etc.

[0153] In addition, the display apparatus 800 may be connected to the transmission unit 70 through a small-power wireless network, may be connected through both the high-speed wireless network and small-power wireless network, or may be connected while switching the networks. In this embodiment, large amount data like an image file of a video image mentioned later is transmitted through the high-speed wireless network, and small amount data and data that does not need quick transmission are transmitted through the small-power wireless network. Although the Bluetooth is used for the small-power wireless network in this embodiment, other short-distance wireless communications, such as the NFC (Near Field Communication), may be employed.

[0154] The calibrator 850 performs initial setting and individual setting of the camera body 1, and is connectable to the transmission unit 70 through the high-speed wireless network in the same manner as the display apparatus 800. Details of the calibrator 850 are mentioned later. Moreover, the display apparatus 800 may have the function of the calibrator 850.

[0155] The simplified display apparatus 900 is connectable to the transmission unit 70 only through the small-power wireless network, for example. Although the simplified display apparatus 900 cannot perform communication of

a video image with the transmission unit 70 due to time restriction, it can transmit an image pickup start/stop timing and can be used for an image check of a composition check level. Moreover, the simplified display apparatus 900 may be a dedicated apparatus developed for the camera body 1 as well as the display apparatus 800 or may be a smart watch etc.

[0156] FIG. 5 is a block diagram showing a hardware configuration of the camera body 1. Moreover, the configurations and functions described using FIG. 1A through FIG. 1C are indicated by the same reference numerals and their detailed descriptions will be omitted.

[0157] As shown in FIG. 5, the camera body 1 is provided with the overall control CPU 101, power switch 11, image pickup mode switch 12, face direction detection window 13, start switch 14, stop switch 15, image pickup lens 16, and LED 17.

[0158] The camera body 1 is further provided with the infrared LED lighting circuit 21, infrared LEDs 22, infrared condenser lens 26, and infrared detection device 27 that constitute the face direction detection unit 20 (FIG. 4).

[0159] Moreover, the camera body 1 is provided with the image pickup unit 40 (FIG. 4), which consists of an image pickup driver 41, a solid state image sensor 42, and an image signal processing circuit 43, and the transmission unit 70 (FIG. 4), which consists of a small-power wireless communication unit 71 and high-speed wireless communication unit 72.

[0160] Although the camera body 1 has the single image pickup unit 40 in this embodiment, it may have two or more image pickup units in order to pick up a 3D image or to pick up images of different directions.

[0161] The camera body 1 is provided with various memories, such as a large-capacity nonvolatile memory 51, an internal nonvolatile memory 102, the primary memory 103, etc.

[0162] Furthermore, the camera body 1 is provided with an audio processor 104, a speaker 105, a vibrator 106, an angular speed sensor 107, an acceleration sensor 108, and various switches 110.

[0163] The switches like the power switch 11, which are described above using FIG. 2C, are connected to the overall control CPU 101. The overall control CPU 101 controls the entire camera body 1. The recording-direction/field-angle determination unit 30, image extraction/development unit 50, and second controller 111 in FIG. 4 are achieved by the overall control CPU 101.

[0164] The infrared LED lighting circuit 21 controls lighting of the infrared LEDs 22 described above using FIG. 2E to control projection of the infrared light 23 directed to the user from the infrared LEDs 22.

[0165] The face direction detection window 13 is constituted by a visible light cut filter that hardly permits transmission of visible light and sufficiently permits transmission of the infrared light 23 and its reflected light 25 that belong to infrared region. The infrared condenser lens 26 condenses the reflected light 25.

[0166] The infrared detection device (an infrared detection unit) 27 has a sensor that detects the reflected light 25 condensed by the infrared condenser lens 26. The sensor converts an image formed by the condensed reflected light 25 into sensor data and passes the sensor data to the overall control CPU 101.

[0167] As shown in FIG. 1B, when the user wears the camera body 1, the face direction detection window 13 is located under a user's jaw. Accordingly, as shown in FIG. 5, the infrared light 23 projected from the infrared LEDs 22 transmits the face direction detection window 13 and irradiates an infrared irradiation surface 24 near the user's jaw. Moreover, the reflected light 25 reflected from the infrared irradiation surface 24 transmits the face direction detection window 13 and is condensed by the infrared condenser lens 26 onto the

sensor in the infrared detection device 27.

[0168] The various switches 110 are not shown in FIG. 1A through FIG. 1C. The various switches 110 are used to execute functions that are unrelated to this embodiment.

[0169] The image pickup driver 41 includes a timing generator etc., generates various timing signals, outputs the timing signals to sections related to the image pickup operation, and drives the solid state image sensor 42.

[0170] The solid state image sensor 42 outputs the signal obtained by photoelectric conversion of the object image formed through the image pickup lens 16 described using FIG. 1A to the image signal processing circuit 43.

[0171] The image signal processing circuit 43 outputs picked-up image data, which is generated by applying a clamp process and an A/D conversion process, etc. to the signal from the solid state image sensor 42, to the overall control CPU 101.

[0172] The internal nonvolatile memory 102 is constituted by a flash memory etc. and stores a boot program of the overall control CPU 101 and set values of various program modes. In this embodiment, a set value of an observation visual field (field angle) and a set value of an effect level of an image stabilization process are recorded.

[0173] The primary memory 103 is constituted by a RAM etc. and temporarily stores processing image data and a calculation result of the overall control CPU 101.

[0174] The large-capacity nonvolatile memory 51 stores image data. In this embodiment, the large-capacity nonvolatile memory 51 is a semiconductor memory that is not detachable. However, the large-capacity nonvolatile memory 51 may be constituted by a detachable storage medium like an SD card, and may be used together with the internal nonvolatile memory 102.

[0175] The small-power wireless communication unit 71 exchanges data with the display apparatus 800, the calibrator 850, and the simplified display apparatus 900 through the small-power wireless network. The high-speed wireless communication unit 72 exchanges data with the display apparatus 800 and the calibrator 850 through the high-speed wireless network.

[0176] The audio processor 104 processes outside sound (analog signals) collected by the microphones 19L and 19R and generates an audio signal.

[0177] In order to notify the user of a state of the camera body 1 and to warn the user, the LED 17 emits light, the speaker 105 outputs sound, and the vibrator 106 vibrates.

[0178] The angular speed sensor 107 uses a gyro etc. and detects movement of the camera body 1 itself as gyro data. The acceleration sensor 108 detects the posture of the image-pickup/detection unit 10.

[0179] FIG. 6 is a block diagram showing a hardware configuration of the display apparatus 800. The components that have been described using FIG. 1D are indicated by the same reference numerals and their descriptions will be omitted to simplify the description.

[0180] As shown in FIG. 6, the display apparatus 800 is provided with a display-apparatus controller 801, the A-button 802, the display unit 803, the B-button 804, the face sensor 806, the angular speed sensor 807, the acceleration sensor 808, an image signal processing circuit 809, and various switches 811.

[0181] Moreover, the display apparatus 800 is provided with an internal nonvolatile memory 812, a primary memory 813, a large-capacity nonvolatile memory 814, a speaker 815, a vibrator 816, an LED 817, an audio processor 820, a small-power wireless communication unit 871, and a high-speed wireless communication unit 872. The above-mentioned components are connected to the display-apparatus controller 801. The display-apparatus controller 801 is

constituted by a CPU and controls the display apparatus 800.

[0182] The image signal processing circuit 809 bears equivalent functions with the image pickup driver 41, solid state image sensor 42, and image signal processing circuit 43 inside the camera body 1. The image signal processing circuit 809 constitutes the in-camera 805 in FIG. 1D together with an in-camera lens 805a. The display-apparatus controller 801 processes the data output from the image signal processing circuit 809. The contents of the process of the data will be mentioned later.

[0183] The various switches 811 are used to execute functions that are unrelated to this embodiment. The angular speed sensor 807 uses a gyro etc. and detects movement of the display apparatus 800.

[0184] The acceleration sensor 808 detects a posture of the display apparatus 800 itself. The angular speed sensor 807 and the acceleration sensor 808 are built in the display apparatus 800, and respectively have the functions equivalent to that of the above-mentioned angular speed sensor 107 and acceleration sensor 108 of the camera body 1.

[0185] The internal nonvolatile memory 812 is constituted by a flash memory etc. and stores a boot program of the display-apparatus controller 801 and set values of various program modes.

[0186] The primary memory 813 is constituted by a RAM etc. and temporarily stores processing image data and a calculation result of the image signal processing circuit 809. In this embodiment, when a video image is recording, gyro data detected with the angular speed sensor 107 at pickup time of each frame is stored into the primary memory 813 in association with the frame.

[0187] The large-capacity nonvolatile memory 814 stores image data of the display apparatus 800. In this embodiment, the large-capacity nonvolatile memory 814 is constituted by a detachable memory like an SD card. It should

be noted that the large-capacity nonvolatile memory 814 may be constituted by a fixed memory as with the large-capacity nonvolatile memory 51 in the camera body 1.

[0188] In order to notify the user of a state of the display apparatus 800 and to warn the user, the speaker 815 outputs sound, the vibrator 816 vibrates, and the LED 817 emits light.

[0189] The audio processor 820 processes outside sound (analog signals) collected by the left microphone 819L and right microphone 819R and generates an audio signal.

[0190] The small-power wireless communication unit 871 exchanges data with the camera body 1 through the small-power wireless network. The high-speed wireless communication unit 872 exchanges data with the camera body 1 through the high-speed wireless network.

[0191] The face sensor (a face detection unit) 806 is provided with an infrared LED lighting circuit 821 and infrared LEDs 822, an infrared condenser lens 826, and an infrared detection device 827.

[0192] The infrared LED lighting circuit 821 has the function equivalent to that of the infrared LED lighting circuit 21 in FIG. 5 and controls lighting of the infrared LEDs 822 to control projection of the infrared light 823 directed to the user from the infrared LEDs 822. The infrared condenser lens 826 condenses the reflected light 825 of the infrared light 823.

[0193] The infrared detection device 827 has a sensor that detects the reflected light 825 condensed by the infrared condenser lens 826. The sensor converts the condensed reflected light 825 into sensor data and passes the sensor data to the display-apparatus controller 801.

[0194] When the face sensor 806 shown in FIG. 1D is directed to the user, an infrared irradiation surface 824 that is the entire face of the user is irradiated

with the infrared light 823 projected from the infrared LEDs 822 as shown in FIG. 6. Moreover, the reflected light 825 reflected from the infrared irradiation surface 824 is condensed by the infrared condenser lens 826 onto the sensor in the detection device 827.

[0195] Other functions 830 are functions of a smart phone, such as a telephone function, that are not related to the embodiment.

[0196] Hereinafter, how to use the camera body 1 and display apparatus 800 will be described. FIG. 7A is a flowchart schematically showing an image pickup/recording process according to the first embodiment executed by the camera body 1 and display apparatus 800.

[0197] In order to assist the description, a reference numeral shown in FIG. 4 and FIG. 5 of a unit that executes a process in each step is shown on a right side of each step in FIG. 7A. That is, steps S100 through S700 in FIG. 7A are executed by the camera body 1, and steps S800 through S1000 in FIG. 7A are executed by the display apparatus 800.

[0198] When the power switch 11 is set to ON and power of the camera body 1 turns ON, the overall control CPU 101 is activated and reads the boot program from the internal nonvolatile memory 102. After that, in the step S100, the overall control CPU 101 executes a preparation process that performs setting of the camera body 1 before an image pickup operation. Details of the preparation process will be mentioned later using FIG. 7B.

[0199] In a step S200, the face direction detection process that estimates an observation direction based on a face direction detected by the face direction detection unit 20 is executed. Details of the face direction detection process will be mentioned later using FIG. 7C. This process is executed at a predetermined frame rate. In a step S300, the recording-direction/field-angle determination unit 30 executes a recording-direction/area determination process. Details of the

recording-direction/area determination process will be mentioned later using FIG. 7D.

[0200] In a step S400, the image pickup unit 40 picks up an image and generates pickup image data. In a step S500, the image extraction/development unit 50 extracts an image from the pickup image data generated in the step S400 according to recording-direction/field-angle information determined in the step S300 and performs a recording area development process that develops the extracted area. Details of the recording area development process will be mentioned later using FIG. 7E.

[0201] In a step S600, the primary recording unit (an image recording unit) 60 executes a primary recording process that stores the image developed in the step S500 into the primary memory 103 as image data. Details of the primary recording process will be mentioned later using FIG. 14.

[0202] In the step S700, the transmission unit (an image output unit) 70 executes a transmission process to the display apparatus 800 that wirelessly transmits (outputs) the image primarily recorded in the step S600 to the display apparatus 800 at a designated timing. Details of the transmission process to the display apparatus 800 will be mentioned later using FIG. 16.

[0203] The steps from the step S800 are executed by the display apparatus 800. In the step S800, the display-apparatus controller 801 executes an optical correction process that corrects optical aberration of the image transferred from the camera body 1 in the step S700. Details of the optical correction process will be mentioned later using FIG. 17.

[0204] In a step S900, the display-apparatus controller 801 applies the image stabilization process to the image of which the optical aberration has been corrected in the step S800. Details of the image stabilization process will be mentioned later using FIG. 19. It should be noted that the order of the step S800

and the step S900 may be inverted. That is, the image stabilization process may be executed in advance and the optical correction process may be executed after that.

[0205] In a step S1000, the display-apparatus controller (video recording unit) 801 executes a secondary recording process that records the image to which the optical correction process in the step S800 and the image stabilization process in the step S900 have been applied into the large-capacity nonvolatile memory 814. And then, the display-apparatus controller 801 finishes this process.

[0206] Next, the subroutines in the respective steps in FIG. 7A will be described in detail using FIG. 7B through FIG. 7F and other drawings in the order of the processes. FIG. 7B is a flowchart showing the subroutine of the preparation process in the step S100 in FIG. 7A. Hereinafter, this process is described using the components shown in FIG. 2A through FIG. 2F and FIG. 5.

[0207] It is determined whether the power switch 11 is ON in a step S101. The process waits when the power is OFF. When the power becomes ON, the process proceeds to a step S102.

[0208] In the step S102, the mode selected by the image pickup mode switch 12 is determined. As a result of the determination, when the mode selected by the image pickup mode switch 12 is the video image mode, the process proceeds to a step S103.

[0209] In the step S103, various set values of the video image mode are read from the internal nonvolatile memory 102 and are stored into the primary memory 103. Then, the process proceeds to a step S104. The various set values of the video image mode include a field-angle set value V_{ang} and an image stabilization level. The field-angle set value V_{ang} is preset to 90° in this embodiment. The image stabilization level is selected from among "Strong", "Middle", and "OFF". In the step S104, an operation of the image pickup driver 41 for the video image

mode is started. And then, the process exits from this subroutine.

[0210] As a result of the determination in the step S102, when the mode selected by the image pickup mode switch 12 is the still image mode, the process proceeds to a step S106. In the step S106, various set values of the still image mode are read from the internal nonvolatile memory 102 and are stored into the primary memory 103. Then, the process proceeds to a step S107. The various set values of the still image mode include the field-angle set value V_{ang} and the image stabilization level. The field-angle set value V_{ang} is preset to 45° in this embodiment. The image stabilization level is selected from among "Strong", "Middle", and "OFF". In the step S107, an operation of the image pickup driver 41 for the still image mode is started. And then, the process exits from this subroutine.

[0211] As the result of the determination in the step S102, when the mode selected by the image pickup mode switch 12 is the preset mode, the process proceeds to a step S108. The preset mode is one of the three image pickup modes that can be changed by the image pickup mode switch 12. In the preset mode, the image pickup mode of the camera body 1 can be changed by an external device like the display apparatus 800. That is, the preset mode is a mode for a custom image pickup operation. Since the camera body 1 is a compact wearable device, operation switches, a setting screen, etc. for changing advanced set values are not mounted on the camera body 1. The advanced set values are changed by an external device like the display apparatus 800.

[0212] For example, a case where the user would like to pick up a video image at the field angle 90° and the field angle 110° continuously is considered. In such a case, the following operations are needed. Since the field angle is set to 90° in a regular video image mode, the user first performs the video image pickup operation in the regular video image mode, once finishes the video image

pickup operation, displays the setting screen on the display apparatus 800, and changes the field angle to 110° on the setting screen. However, the operations to the display apparatus 800 during a certain event are troublesome.

[0213] In the meantime, when the preset mode is preset to a video image pickup operation at the field angle 110°, the user can change the field angle in the video image pickup operation to 110° immediately by only sliding the image pickup mode switch 12 to "Pre" after finishing the video image pickup operation at the field angle 90°. That is, the user is not required to suspend the current operation and to perform the above-mentioned troublesome operations.

[0214] It should be noted that contents of the preset mode may include the image stabilization level, which is selected from among "Strong", "Middle", and "OFF", and a set value of voice recognition that is not described in this embodiment in addition to the field angle.

[0215] In the step S108, various set values of the preset mode are read from the internal nonvolatile memory 102 and are stored into the primary memory 103. Then, the process proceeds to a step S109. The various set values of the preset mode include the field-angle set value V_{ang} and the image stabilization level that is selected from among "Strong", "Middle", and "OFF".

[0216] In the step S109, an operation of the image pickup driver 41 for the preset mode is started. And then, the process exits from this subroutine.

[0217] Hereinafter, the various set values of the video image mode read in the step S103 will be described using FIG. 13. FIG. 13 is a view showing a menu screen for setting the various set values of the video image mode that is displayed on the display unit 803 of the display apparatus 800 before an image pickup operation of the camera body 1. The components that have been described using FIG. 1D are indicated by the same reference numerals and their descriptions will be omitted. The display unit 803 has a touch panel function

and will be described under the presumption that it functions by touch operations, such as a swipe operation.

[0218] As shown in FIG. 13, the menu screen includes a preview screen 831, a zoom lever 832, a recording start/stop button 833, a switch 834, a battery level indicator 835, a button 836, a lever 837, and an icon display area 838. The user can check the image picked up by the camera body 1, a zoom amount, and a field angle on the preview screen 831.

[0219] The user can change a zoom setting (a field angle) by shifting the zoom lever 832 rightward or leftward. This embodiment describes a case where the field-angle set value V_{ang} can be selected from among 45°, 90°, 110°, and 130°. In the meantime, the field-angle set value V_{ang} may be set to a value other than the four values by operating the zoom lever 832.

[0220] The recording start/stop button 833 is a toggle switch that has both of the functions of the start switch 14 and the stop switch 15. The switch 834 is used to switch "OFF" and "ON" of the image stabilization process. The battery level indicator 835 displays battery level of the camera body 1. The button 836 is used to change a mode.

[0221] The lever 837 is used to set the image stabilization level. Although the image stabilization level can be set to "Strong" or "Middle" in this embodiment, another image stabilization level, for example "Weak", may be set. Moreover, the image stabilization level may be set steplessly. A plurality of thumbnail icons for preview are displayed in the icon display area 838.

[0222] FIG. 7C is a flowchart showing a subroutine of the face direction detection process in the step S200 in FIG. 7A. Before describing the details of this process, a face direction detection method using infrared light will be described using FIG. 8A through FIG. 8K.

[0223] FIG. 8A is a view showing a visible light image of a user's face

looked at from the position of the face direction detection window 13. The image in FIG. 8A is identical to an image picked up by a visible-light image sensor on the assumption that the face direction detection window 13 permits transmission of visible light and that the visible-light image sensor is mounted as a sensor of the infrared detection device 27.

[0224] The image in FIG. 8A includes a neck front part 201 above clavicles of the user, a root 202 of a jaw, a chin 203, and a face 204 including a nose. FIG. 8B is a view showing a case where fluorescent lamps 205 in a room appear as background in the visible-light image of the user shown in FIG. 8A.

[0225] The fluorescent lamps 205 around the user appear in the visible-light image in FIG. 8B. In this way, since various backgrounds appear in a user's image according to a use condition, it becomes difficult that the face direction detection unit 20 or the overall control CPU 101 cuts out a face image from a visible-light image. In the meantime, although there is a technique that cuts such an image by using an AI etc., the technique is not suitable for the camera body 1 as a portable device because the overall control CPU 101 is required to have high performance.

[0226] Accordingly, the camera body 1 of the first embodiment detects a user's face using an infrared image. Since the face direction detection window 13 is constituted by a visible light cut filter, visible light is not transmitted mostly. Accordingly, an image obtained by the infrared detection device 27 is different from the images in FIG. 8A and FIG. 8B.

[0227] FIG. 8C is a view showing an infrared image obtained by imaging the user and the fluorescent lamps as the background shown in FIG. 8B onto the sensor of the infrared detection device 27 through the face direction detection window 13 in a state where the infrared LEDs 22 are not lightened.

[0228] In the infrared image in FIG. 8C, the user's neck and jaw are dark.

In the meantime, since the fluorescent lamps 205 emit an infrared component in addition to the visible light, they are slightly bright.

[0229] FIG. 8D is a view showing an image obtained by imaging the user and the fluorescent lamps as the background shown in FIG. 8B onto the sensor of the infrared detection device 27 through the face direction detection window 13 in a state where the infrared LEDs 22 are lightened.

[0230] In the image in FIG. 8D, the user's neck and jaw are bright. In the meantime, unlike FIG. 8C, the brightness around the fluorescent lamps 205 has not changed.

[0231] FIG. 8E is a view showing a difference image that is calculated by subtracting the image in FIG. 8C from the image in FIG. 8D. The user's face emerges.

[0232] In this way, the overall control CPU (an image obtainment unit) 101 obtains the difference image (hereinafter referred to as a face image) by calculating the difference between the image formed on the sensor of the infrared detection device 27 in the state where the infrared LEDs 22 are lightened and the image formed on the sensor in the state where the infrared LEDs 22 are not lightened.

[0233] The face direction detection unit 20 of this embodiment employs a method that obtains a face image by extracting infrared reflection intensity as a two-dimensional image by the infrared detection device 27. The sensor of the infrared detection device 27 employs a configuration similar to a general image sensor and obtains a face image frame-by-frame. A vertical synchronization signal (hereinafter referred to as a V-signal) that obtains frame synchronization is generated by the infrared detection device 27 and is output to the overall control CPU 101.

[0234] FIG. 9 is a timing chart showing timings of lighting and extinction of

the infrared LEDs 22 and related signals.

[0235] A V-signal output from the infrared detection device 27, an H-position of the image signal output from the sensor of the infrared detection device 27, an IR-ON signal output to the infrared LED lighting circuit 21 from the overall control CPU 101, and pickup image data output to the overall control CPU 101 from the sensor of the infrared detection device 27 are shown in FIG. 9 in the order from the top. The horizontal time axes of these four signals are identical. When the V-signal becomes High, timings of the frame synchronization and timings of lighting and extinction of the infrared LEDs 22 are obtained.

[0236] FIG. 9 shows a first face image obtainment period t1 and a second face image obtainment period t2.

[0237] The infrared detection device 27 controls the operation of the sensor so that the H-position of the image signal will synchronize with the V-signal as shown in FIG. 9. Since the sensor of the infrared detection device 27 employs the configuration similar to a general image sensor as mentioned above and its operation is well-known, a detailed description of the control method is omitted.

[0238] The overall control CPU 101 controls switching of the IR-ON signal between High and Low in synchronization with the V-signal. Specifically, the overall control CPU 101 outputs the IR-ON signal of Low to the infrared LED lighting circuit 21 during the period t1 and outputs the IR-ON signal of High to the infrared LED lighting circuit 21 during the second period t2.

[0239] The infrared LED lighting circuit 21 lightens the infrared LEDs 22 to project the infrared light 23 to the user during the High period of the IR-ON signal. In the meantime, the infrared LED lighting circuit 21 extinguishes the infrared LEDs 22 during the Low period of the IR-ON signal.

[0240] A vertical axis of the pickup image data indicates a signal intensity that is a light receiving amount of the reflected light 25. Since the infrared LEDs

22 are extinguished during the first period t1, no reflected light comes from the user's face and pickup image data as shown in FIG. 8C is obtained. In the meantime, since the infrared LEDs 22 are lightened during the second period t2, the reflected light 25 comes from the user's face and pickup image data as shown in FIG. 8D is obtained. Accordingly, the signal intensity in the period t2 increases from the signal intensity in the period t1 by the reflected light 25 from the user's face.

[0241] A face image indicated in the bottom in FIG. 9 is obtained by subtracting the image data picked up during the first period t1 from the image data picked up during the second period t2. As a result of the subtraction, face image data in which only the component of the reflected light 25 from the user's face is extracted is obtained.

[0242] FIG. 7C shows the face direction detection process in the step S200 that includes the operations described using FIG. 8C through FIG. 8E and FIG. 9.

[0243] In a step S201, a timing V1 at which the first period t1 starts is obtained when the V-signal output from the infrared detection device 27 becomes High. When the timing V1 is obtained, the process proceeds to a step S202.

[0244] In a step S202, the IR-ON signal is set to Low and is output to the infrared LED lighting circuit 21. Thereby, the infrared LEDs 22 are extinguished.

[0245] In a step S203, one frame of pickup image data output from the infrared detection device 27 during the first period t1 is read. The image data is temporarily stored into the primary memory 103 as Frame1.

[0246] In a step S204, a timing V2 at which the second period t2 starts is obtained when the V-signal output from the infrared detection device 27 becomes High. When the timing V2 is obtained, the process proceeds to a step S205.

[0247] In the step S205, the IR-ON signal is set to High and is output to the

infrared LED lighting circuit 21. Thereby, the infrared LEDs 22 are lightened.

[0248] In a step S206, one frame of pickup image data output from the infrared detection device 27 during the second period t2 is read. The image data is temporarily stored into the primary memory 103 as Frame2.

[0249] In a step S207, the IR-ON signal is set to Low and is output to the infrared LED lighting circuit 21. Thereby, the infrared LEDs 22 are extinguished.

[0250] In a step S208, Frame1 and Frame2 are read from the primary memory 103, and light intensity Fn of the reflected light 25 from the user corresponding to the face image shown in FIG. 9 is calculated by subtracting Frame1 from Frame2. This process is generally called black subtraction.

[0251] In a step S209, a throat position (a neck rotation center) is extracted from the light intensity Fn. First, the overall control CPU (a division unit) 101 divides the face image into a plurality of distance areas that will be described using FIG. 8F on the basis of the light intensity Fn.

[0252] FIG. 8F is a view showing a result obtained by adjusting shades of the difference image shown in FIG. 8E so as to fit with a scale of light intensity of the reflected light 25 of the infrared light 23 projected to the face and neck of the user. FIG. 8F shows light intensity distribution about sections of the face and neck of the user.

[0253] The face image on the left side in FIG. 8F shows the light intensity distribution of the reflected light 25 in the face image shown in FIG. 8E by gray steps applied to the respective divided areas. An Xf axis is oriented in a direction from the central part of the user's neck toward the chin.

[0254] In a graph on the right side in FIG. 8F, a horizontal axis shows the light intensity on the Xf axis of the face image and a vertical axis shows the Xf axis. The light intensity shown by the horizontal axis increases as going

rightward.

[0255] The face image in FIG. 8F is divided into six areas (distance areas) 211 through 216 according to the light intensity. The area 211 is an area where the light intensity is the strongest and is shown by white among the gray steps. The area 212 is an area where the light intensity falls slightly than the area 211 and is shown by quite bright gray among the gray steps. The area 213 is an area where the light intensity falls still more than the area 212 and is shown by bright gray among the gray steps. The area 214 is an area where the light intensity falls still more than the area 213 and is shown by middle gray among the gray steps. The area 215 is an area where the light intensity falls still more than the area 214 and is shown by slightly dark gray among the gray steps. The area 216 is an area where the light intensity is the weakest and is shown by the darkest gray among the gray steps. The area above the area 216 is shown by black showing no light intensity.

[0256] The light intensity will be described in detail using FIG. 10A through FIG. 10D. FIG. 10A through FIG. 10D are views describing movement of the user's face in the vertical direction and show states observed from the left side of the user.

[0257] FIG. 10A is a view showing a state where the user faces the front. There is the image-pickup/detection unit 10 in front of the clavicles of the user. Moreover, the infrared light 23 of the infrared LEDs 22 irradiates the lower part of the user's head from the face direction detection window 13 mounted in the upper portion of the image-pickup/detection unit 10. A distance Dn from the face direction detection window 13 to the throat 200 above the clavicles of the user, a distance Db from the face direction detection window 13 to the root 202 of the jaw, and a distance Dc from the face direction detection window 13 to the chin 203 satisfy a relation of $Dn < Db < Dc$. Since light intensity is in inverse

proportion to the square of distance, the light intensity in the image formed by the reflected light 25 from the infrared irradiation surface 24 on the sensor becomes gradually weaker in the order of the throat 200, the root 202 of the jaw, and the chin 203. Moreover, since the distance from the face direction detection window 13 to the face 204 including the nose is still longer than the distance Dc, the light intensity in the image corresponding to the face 204 becomes still weaker. That is, in the case as shown in FIG. 10A, the image having the light intensity distribution shown in FIG. 8F is obtained.

[0258] It should be noted that the configuration of the face direction detection unit 20 is not limited to the configuration shown in this embodiment as long as the face direction of the user can be detected. For example, the infrared LEDs 22 may be an infrared pattern radiation unit that projects an infrared pattern, and the sensor of the infrared detection device 27 may be an infrared pattern detection unit that detects the infrared pattern reflected from an irradiation target. In this case, it is preferable that the sensor of the infrared detection device 27 is constituted by a structural optical sensor. Moreover, the sensor of the infrared detection device 27 may be an infrared pattern phase comparison unit that compares the phase of the infrared light 23 and the phase of the reflected light 25. For example, a ToF (Time of Flight) sensor may be employed.

[0259] Next, the extraction of the throat position in the step S209 in FIG. 7C will be described using FIG. 8G. A left image in FIG. 8G is obtained by superimposing the reference numerals denoting the parts of the user's body shown in FIG. 10A, a double circle showing the throat position, and a black circle showing the chin position on FIG. 8F.

[0260] The white area 211 corresponds to the throat 200 (FIG. 10A), the quite bright gray area 212 corresponds to the neck front part 201 (FIG. 10A), and the bright gray area 213 corresponds to the root 202 of the jaw (FIG. 10A).

Moreover, the middle gray area 214 corresponds to the chin 203 (FIG. 10A), and the slightly dark gray area 215 corresponds to a lip located in the lower part of the face 204 (FIG. 10A) and a face lower part around the lip. Furthermore, the darkest gray area 216 corresponds to the nose located in the center of the face 204 (FIG. 10A) and a face upper part around the nose.

[0261] Since the difference between the distances Db and Dc is relatively small as compared with the differences between the other distances from the face direction detection window 13 to other parts of the user as shown in FIG. 10A, the difference between the reflected light intensities in the bright gray area 213 and the middle gray area 214 is also small.

[0262] In the meantime, since the distance Dn is the shortest distance among the distances from the face direction detection window 13 to the parts of the user as shown in FIG. 10A, the reflection light intensity in the white area 211 corresponding to the throat 200 becomes the strongest.

[0263] Accordingly, the overall control CPU (a setting unit) 101 determines that the area 211 corresponds to the throat 200 and its periphery, and then, sets the position 206 (indicated by the double circle in FIG. 8G), which is located at the center in the lateral direction and is the nearest to the image-pickup/detection unit 10, as the position of the head rotation center (hereinafter referred to as a throat position 206). The processes up to the moment are the contents performed in the step S209 in FIG. 7C.

[0264] Next, the extraction of the chin position in the step S210 in FIG. 7C will be described using FIG. 8G. In the image in FIG. 8G, the middle gray area 214 that is brighter than the area 215 corresponding to the face lower part including the lip of the face 204 includes the chin. A graph on the right side in FIG. 8G shows that the light intensity falls sharply in the area 215 adjacent to the area 214 because the change rate of the distance from the face direction detection

window 13 becomes large.

[0265] The overall control CPU 101 determines that the brighter area 214 adjacent to the area 215 in which the light intensity falls sharply is a chin area. Furthermore, the overall control CPU 101 calculates (extracts) the position (indicated by the black circle shown in FIG. 8G), which is located at the center in the lateral direction in the area 214 and is the farthest from the throat position 206, as a chin position 207.

[0266] For example, FIG. 8H and FIG. 8I show changes in directing the face to the right. FIG. 8H is a view showing a difference image calculated by the similar method as FIG. 8E in directing the user's face to the right. FIG. 8I is a view showing a result obtained by adjusting shades of the difference image in FIG. 8H so as to fit with a scale of light intensities of reflected components of the infrared light projected to the face and neck of the user and by superimposing the double circle showing the throat position 206 as the position of the neck rotation center and the black circle showing a chin position 207r.

[0267] Since the user's face is directed to the right, the area 214 moves to an area 214r shown in FIG. 8I that is located in the left side when it is looked up from the image-pickup/detection unit 10. The area 215 corresponding to the face lower part including the lip in the face 204 also moves to an area 215r that is located in the left side when it is looked up from the image-pickup/detection unit 10.

[0268] Accordingly, the overall control CPU 101 determines that the brighter area 214r adjacent to the area 215r in which the light intensity falls sharply is the chin area. Furthermore, the overall control CPU 101 calculates (extracts) the position (indicated by the black circle shown in FIG. 8I), which is located at the center in the lateral direction in the area 214r and is the farthest from the throat position 206, as the chin position 207r.

[0269] After that, the overall control CPU 101 finds a moving angle θr that shows the rotational movement to the right from the chin position 207 in the image in FIG. 8G to the chin position 207r in FIG. 8I around the throat position 206. As shown in FIG. 8I, the moving angle θr is an angle of movement of the user's face in the lateral direction.

[0270] According to the above-mentioned method, the angle of face (hereinafter, referred to as a face angle) of the user in the lateral direction is calculated in the step S210 from the chin position detected by the infrared detection device 27 of the face direction detection unit (a three-dimensional detection sensor) 20.

[0271] Next, detection of the face directed upward will be described. FIG. 10B is a view showing a state where the user directs the face horizontally. FIG. 10C is a view showing a state where the user directs the face upward by 33° from the horizontal direction.

[0272] The distance from the face direction detection window 13 to the chin 203 is Ffh in FIG. 10B, and the distance from the face direction detection window 13 to a chin 203u is Ffu in FIG. 10C. Since the chin 203u moves upwardly together with the face, the distance Ffu becomes longer than the distance Ffh as shown in FIG. 10C.

[0273] FIG. 8J is a view showing an image of the user who directs the face upward by 33° from the horizontal direction viewed from the face direction detection window 13. Since the user directs the face upward as shown in FIG. 10C, the face 204 including the lip and nose cannot be seen from the face direction detection window 13 located under the user's jaw. The chin 203 and its neck side are seen. FIG. 8K shows distribution of the light intensity of the reflected light 25 in irradiating the user in the state shown in FIG. 10C with the infrared light 23. An image on the left side in FIG. 8K is a view showing a result

obtained by adjusting shades of the difference image calculated by the same method as FIG. 8E so as to fit with a scale of light intensities of reflected components of the infrared light projected to the face and neck of the user and by superimposing the double circle showing the throat position 206 and the black circle showing a chin position 207u. Two graphs in FIG. 8K show density changes of the left image. The left graph is equivalent to the graph in FIG. 8F and the right graph is equivalent to the graph in FIG. 8G.

[0274] Six areas 211u, 212u, 213u, 214u, 215u, and 216u corresponding to the light intensities in FIG. 8K are indicated by adding "u" to the reference numerals of the same light intensity areas shown in FIG. 8F. Although the light intensity of the user's chin 203 is included in the middle gray area 214 in FIG. 8F, it shifts to the black side and is included in the slightly dark gray area 215u in FIG. 8K. In this way, since the distance Ffu is longer than the distance Ffh as shown in FIG. 10C, the infrared detection device 27 can detect that the light intensity of the reflected light 25 from the chin 203 is weakened in inverse proportion to the square of distance.

[0275] Next, detection of the face directed downward will be described. FIG. 10D is a view showing a state that the user directs the face downward by 22° from the horizontal direction. In FIG. 10D, a distance from the face direction detection window 13 to a chin 203d is Ffd.

[0276] Since the chin 203d moves downwardly together with the face, the distance Ffd becomes shorter than the distance Ffh as shown in FIG. 10D and the light intensity of the reflected light 25 from the chin 203 becomes stronger.

[0277] Returning back to FIG. 7C, in a step S211, the overall control CPU (a distance calculation unit) 101 calculates the distance from the chin position to the face direction detection window 13 on the basis of the light intensity of the chin position detected by the infrared detection device 27 of the face direction

detection unit (a three-dimensional detection sensor) 20. A face angle in the vertical direction is also calculated on the basis of this.

[0278] In a step S212, the overall control CPU 101 stores the face angle in the lateral direction (a first detection direction) obtained in the step S210 and the face angle in the vertical direction (a second detection direction) obtained in the step S211 into the primary memory 103 as a three-dimensional observation direction vi ("i" is arbitrary reference numeral) of the user. For example, when the user is observing the front center, the face angle θh in the lateral direction is 0° and the face angle θv in the vertical direction is 0°. Accordingly, an observation direction vo in this case is represented by vector information [0°, 0°]. Moreover, when the user is observing a right 45° direction, an observation direction vr is represented by vector information [45°, 0°].

[0279] Although the face angle in the vertical direction is calculated by detecting the distance from the face direction detection window 13 in the step S211, the face angle may be calculated by another method. For example, change of the face angle may be calculated by comparing change levels of the light intensity of the chin 203. That is, the change of the face angle may be calculated by comparing a gradient CDh of the reflected light intensity from the root 202 of the jaw to the chin 203 in the graph in FIG. 8G with a gradient CDu of the reflected light intensity from the root 202 of the jaw to the chin 203 in the graph in FIG. 8K.

[0280] FIG. 7D is a flowchart showing a subroutine of the recording-direction/area determination process in the step S300 in FIG. 7A. Before describing details of this process, a superwide-angle image that is subjected to determine a recording direction and a recording area in this embodiment will be described first using FIG. 11A.

[0281] In the camera body 1 of this embodiment, the image pickup unit 40

picks up a superwide-angle image of the periphery of the image-pickup/detection unit 10 using the superwide-angle image pickup lens 16. An image of an observation direction can be obtained by extracting a part of the superwide-angle image.

[0282] FIG. 11A is a view showing a target visual field 125 set in a superwide-angle image picked up by the image pickup unit 40 in a case where the user faces the front.

[0283] As shown in FIG. 11A, a pixel area 121 that can be picked up by the solid state image sensor 42 is a rectangular area. Moreover, an effective projection area (a predetermined area) 122 is an area of a circular half-celestial sphere image that is a fish-eye image projected onto the solid state image sensor 42 by the image pickup lens 16. The image pickup lens 16 is adjusted so that the center of the pixel area 121 will match the center of the effective projection area 122.

[0284] The outermost periphery of the circular effective projection area 122 shows a position where an FOV (field of view) angle is 180°. When the user is looking at the center in both the vertical and horizontal directions, an angular range of the target visual field 125 that is picked up and recorded becomes 90° (a half of the FOV angle) centered on the center of the effective projection area 122. It should be noted that the image pickup lens 16 of this embodiment can also introduce light outside the effective projection area 122 and can project light within the maximal FOV angle 192° onto the solid state image sensor 42 as a fish-eye image. However, the optical performance falls greatly in the area outside the effective projection area 122. For example, resolution falls extremely, light amount falls, and distortion increases. Accordingly, in this embodiment, an image of an observation direction is extracted as a recording area only from the inside of the image (hereinafter referred to as a superwide-angle image, simply)

projected in the pixel area 121 within the half-celestial sphere image displayed on the effective projection area 122.

[0285] Since the size of the effective projection area 122 in the vertical direction is larger than the size of the short side of the pixel area 121, the upper and lower ends of the image in the effective projection area 122 are out of the pixel area 121 in this embodiment. However, the relationship between the areas is not limited to this. For example, the optical system may be designed so that the entire effective projection area 122 will be included in the pixel area 121 by changing the configuration of the image pickup lens 16. Invalid pixel areas 123 are parts of the pixel area 121 that are not included in the effective projection area 122.

[0286] The target visual field 125 shows an area of an image of a user's observation direction that will be extracted from the superwide-angle image. The target visual field 125 is prescribed by left, right, upper, and lower field angles (45° in this case, the FOV angle 90°) centering on the observation direction. In the example of FIG. 11A, since the user faces the front, the center of the target visual field 125 becomes the observation direction vo that matches the center of the effective projection area 122.

[0287] The superwide-angle image shown in FIG. 11A includes an A-object 131 that is a child, a B-object 132 that shows steps that the child who is the A-object is trying to climb, and a C-object 133 that is locomotive-type playground equipment.

[0288] Next, the recording-direction/area determination process in the step S300 in FIG. 7A that is executed to obtain an image of an observation direction from the superwide-angle image described using FIG. 11A is shown in FIG. 7D. Hereinafter, this process is described using FIG. 12A through FIG. 12G that show concrete examples of the target visual field 125.

[0289] In a step S301, a field-angle set value V_{ang} that is set in advance is obtained by reading from the primary memory 103.

[0290] In this embodiment, the internal nonvolatile memory 102 stores all the available field angles (45°, 90°, 110°, and 130°) as field-angle set values V_{ang}. The image extraction/development unit 50 extracts an image of an observation direction in an area defined by the field-angle set value V_{ang} from the superwide-angle image. Moreover, the field-angle set value V_{ang} included in the various set values read from the internal nonvolatile memory 102 in one of the steps S103, S106, and S108 in FIG. 7B is established and is being stored in the primary memory 103.

[0291] Moreover, in the step S301, the observation direction vi determined in the step S212 is determined as the recording direction, an image in the target visual field 125 of which the center is designated by the observation direction vi and of which an area is defined by the obtained field-angle set value V_{ang} is extracted from the superwide-angle image, and the extracted image is stored into the primary memory 103.

[0292] For example, when the field-angle set value V_{ang} is 90° and the observation direction vo (vector information [0°, 0°]) is detected through the face direction detection process (FIG. 7C), the target visual field 125 of which the angular widths are 45° in left and right and are 45° in up and down (FIG. 11A) is established centering on the center O of the effective projection area 122. FIG. 11B is a view showing the image in the target visual field 125 extracted from the superwide-angle image in FIG. 11A. That is, the overall control CPU (a relative position setting unit) 101 sets the angle of the face direction detected by the face direction detection unit 20 to the observation direction vi that is the vector information showing the relative position of the target visual field 125 with respect to the superwide-angle image.

[0293] In the case of the observation direction vo, since the influence of the optical distortion caused by the image pickup lens 16 can be disregarded mostly, the shape of the established target visual field 125 is almost identical to the shape of a target visual field 125o (FIG. 12A) after converting the distortion in a step S303 mentions later. Hereinafter, a target visual field after converting the distortion in the case of the observation direction vi is called a target visual field 125i.

[0294] Next, an image stabilization level that is set in advance is obtained by reading from the primary memory 103 in a step S302.

[0295] In this embodiment, as mentioned above, the image stabilization level included in the various setting values read from the internal nonvolatile memory 102 in one of the steps S103, S106, and S108 is established and is being stored in the primary memory 103.

[0296] Moreover, in the step S302, an image-stabilization-margin pixel number Pis is set on the basis of the obtained image stabilization level.

[0297] In the image stabilization process, an image following in a direction opposite to a blur direction is obtained according to a blur amount of the image-pickup/detection unit 10. Accordingly, in this embodiment, an image stabilization margin required for the image stabilization is established around the target visual field 125i.

[0298] Moreover, in this embodiment, a table that keeps values of the image-stabilization-margin pixel number Pis in association with respective image stabilization levels is stored in the internal nonvolatile memory 102. For example, when the image stabilization level is "middle", an image stabilization margin of which width is "100 pixels" that is the image-stabilization-margin pixel number Pis read from the above-mentioned table is established around the target visual field.

[0299] FIG. 12E is a view showing an example that gives an image stabilization margin corresponding to a predetermined image stabilization level around the target visual field 125o shown in FIG. 12A. Hereinto, a case where the image stabilization level is "middle", i.e., where the image-stabilization-margin pixel number Pis is "100 pixels" will be described.

[0300] As shown by a dotted line in FIG. 12E, an image stabilization margin 126o of which the width is "100 pixels" that is the image-stabilization-margin pixel number Pis is established at the left, right, upper, and lower sides of the target visual field 125o.

[0301] FIG. 12A and FIG. 12E show the case where the observation direction vi matches the center O (the optical axis center of the image pickup lens 16) of the effective projection area 122 for simplification of the description. In the meantime, when the observation direction vi is directed to a periphery of the effective projection area 122, the conversion to reduce the influence of optical distortion is required.

[0302] In the step S303, the shape of the target visual field 125 established in the step S301 is corrected (converts distortion) in consideration of the observation direction vi and the optical property of the image pickup lens 16 to generate the target visual field 125i. Similarly, the image-stabilization-margin pixel number Pis set in the step S302 is also corrected in consideration of the observation direction vi and the optical property of the image pickup lens 16.

[0303] For example, the field-angle set value V_{ang} shall be 90° and the user shall observe a right 45° direction from the center o. In this case, the observation direction vr (vector information [45°, 0°]) is determined in the step S212, and the area of 45° in left and right and 45° in up and down centering on the observation direction vr becomes the target visual field 125. Furthermore, the target visual field 125 is corrected to the target visual field 125r shown in FIG. 12B in

consideration of the optical property of the image pickup lens 16.

[0304] As shown in FIG. 12B, the target visual field 125r becomes wider toward the periphery of the effective projection area 122. And the position of the observation direction vr approaches inside a little from the center of the target visual field 125r. This is because the optical design of the image pickup lens 16 in this embodiment is close to that of a stereographic projection fish-eye lens. It should be noted that contents of the correction depend on the optical design of the image pickup lens 16. If the image pickup lens 16 is designed as an equidistant projection fish-eye lens, an equal-solid-angle projection fish-eye lens, or an orthogonal projection fish-eye lens, the target visual field 125 is corrected according to its optical property.

[0305] FIG. 12F is a view showing an example that gives an image stabilization margin 126r corresponding to the same image stabilization level "middle" of the image stabilization margin in FIG. 12E around the target visual field 125r shown in FIG. 12B.

[0306] The image stabilization margin 126o (FIG. 12E) is established at the left, right, upper, and lower sides of the target visual field 125o with the width of "100 pixels" that is the image-stabilization-margin pixel number Pis. As compared with this, the image-stabilization-margin pixel number Pis of the image stabilization margin 126r (FIG. 12F) is corrected so as to increase toward the periphery of the effective projection area 122.

[0307] In this way, the shape of the image stabilization margin established around the target visual field 125r is also corrected as with the shape of the target visual field 125r so that the correction amount will increase toward the periphery of the effective projection area 122 as shown by the image stabilization margin 126r in FIG. 12F. This is also because the optical design of the image pickup lens 16 in this embodiment is close to that of a stereographic projection fish-eye

lens. It should be noted that contents of the correction depend on the optical design of the image pickup lens 16. If the image pickup lens 16 is designed as an equidistant projection fish-eye lens, an equal-solid-angle projection fish-eye lens, or an orthogonal projection fish-eye lens, the image stabilization margin 126r is corrected according to its optical property.

[0308] The process executed in the step S303 that switches successively the shapes of the target visual field 125 and its image stabilization margin in consideration of the optical property of the image pickup lens 16 is a complicated process. Accordingly, in this embodiment, the process in the step S303 is executed using a table that keeps shapes of the target visual field 125i and its image stabilization margin for every observation direction vi stored in the internal nonvolatile memory 102. It should be noted that the overall control CPU 101 may have a computing equation corresponding to the optical design of the image pickup lens 16. In such a case, the overall control CPU 101 can calculate an optical distortion value using the computing equation.

[0309] In a step S304, a position and size of an image recording frame are calculated. As mentioned above, the image stabilization margin 126i is established around the target visual field 125i. However, when the position of the observation direction vi is close to the periphery of the effective projection area 122, the shape of the image stabilization margin becomes considerably special as shown by the image stabilization margin 126r, for example.

[0310] The overall control CPU 101 can extract an image only in such a special-shaped area and apply the development process to the extracted image. However, it is not general to use an image that is not rectangular in recording as image data in the step S600 or in transmitting image data to the display apparatus 800 in the step S700. Accordingly, in the step S304, the position and size of the image recording frame 127i of a rectangular shape that includes the entire image

stabilization margin 126i are calculated.

[0311] FIG. 12F shows the image recording frame 127r that is calculated in the step S304 to the image stabilization margin 126r by an alternate long and short dash line.

[0312] In a step S305, the position and size of the image recording frame 127i that are calculated in the step S304 are recorded into the primary memory 103.

[0313] In this embodiment, an upper-left coordinate (Xi, Yi) of the image recording frame 127i in the superwide-angle image is recorded as the position of the image recording frame 127i, and a lateral width WXi and a vertical width WYi that start from the coordinate (Xi, Yi) are recorded as the size of the image recording frame 127i. For example, a coordinate (Xr, Yr), a lateral width WXr, and a vertical width WYr of the image recording frame 127r shown in FIG. 12F are recorded in the step S305. It should be noted that the coordinate (Xi, Yi) is a XY coordinate of which an origin is a predetermined reference point, specifically the optical center of the image pickup lens 16.

[0314] When the image stabilization margin 126i and the image recording frame 127i have been determined in this way, the process exits from this subroutine shown in FIG. 7D.

[0315] In the description so far, the observation directions of which the horizontal angle is 0°, such as the observation direction v0 (the vector information [0°, 0°]) and the observation direction vr (the vector information [45°, 0°]), have been described for simplifying the description of the complicated optical distortion conversion. In the meantime, an actual observation direction vi of the user is arbitrary. Accordingly, the recording area development process executed in a case where the horizontal angle is not 0° will be described hereinafter. For example, when the field-angle set value V_{ang} is 90° and the observation direction

vm is [-42°, -40°], the target visual field 125m appears as shown in FIG. 12C.

[0316] Moreover, even when the observation direction vm (the vector information [-42°, -40°]) is the same as the target visual field 125m, when the field-angle set value V_{ang} is 45°, a target visual field 128m, which is slightly smaller than the target visual field 125m, appears as shown in FIG. 12D.

[0317] For a target visual field that is set (determined) according to the field-angle set value V_{ang} and the observation direction vm, an image stabilization margin and image recording frame that correspond to the image stabilization level set in any one of the steps S103, S106, and S108 are set. For example, when the image stabilization level is set as "Middle", an image stabilization margin 129m and an image recording frame 130m are set for the target visual field 128m as shown in FIG. 12G.

[0318] Since the process in the step S400 is a fundamental image pickup operation and employs a general sequence of the image pickup unit 40, its detailed description is omitted. It should be noted that the image signal processing circuit 43 in the image pickup unit 40 in this embodiment also performs a process that converts signals of an inherent output format (standard examples: MIPI, SLVS) output from the solid state image sensor 42 into pickup image data of a general sensor reading system.

[0319] When the video image mode is selected by the image pickup mode switch 12, the image pickup unit 40 starts recording in response to a press of the start switch 14. After that, the recording is finished when the stop switch 15 is pressed. In the meantime, when the still image mode is selected by the image pickup mode switch 12, the image pickup unit 40 picks up a static image every time when the start switch 14 is pressed.

[0320] FIG. 7E is a flowchart showing a subroutine of the recording-area development process in the step S500 in FIG. 7A.

[0321] In a step S501, Raw data of the entire area of the pickup image data (superwide-angle image) generated by the image pickup unit 40 in the step S400 is obtained and is input into an image capturing unit called a head unit (not shown) of the overall control CPU 101.

[0322] Next, in a step S502, the image within the image recording frame 127i is extracted from the superwide-angle image obtained in the step S501 on the basis of the coordinate (Xi, Yi), lateral width WXi, and vertical width WYi that are recorded into the primary memory 103 in the step S305. After the extraction, the processes in steps S503 through S508 mentioned later are executed only to the pixels within the image stabilization margin 126i. In this way, a crop development process (FIG. 7F) consisting of the steps S502 through S508 begins. This can reduce a calculation amount significantly as compared with a case where the development process is executed to the entire area of the superwide-angle image read in the step S501. Accordingly, calculation time and electric power consumption can be reduced.

[0323] As shown in FIG. 7F, when the video image mode is selected by the image pickup mode switch 12, the processes of the steps S200 and S300 and the process of the step S400 are executed in parallel by the same frame rate or different frame rates. Whenever the Raw data of the entire area of one frame generated by the image pickup unit 40 is obtained, the crop development process is executed on the basis of the coordinate (Xi, Yi), lateral width WXi, and vertical width WYi that are recorded in the primary memory 103 at that time point.

[0324] When the crop development process is started to the pixels within the image stabilization margin 126i, and when the part within the image recording frame 127i is extracted in the step S502, color interpolation that interpolates data of color pixels arranged in the Bayer arrangement is executed in the step S503. After that, a white balance is adjusted in a step S504, and then, a color conversion

is executed in a step S505. In a step S506, gamma correction that corrects gradation according to a gamma correction value set up beforehand is performed. In a step S507, edge enhancement is performed in accordance with an image size.

[0325] In the step S508, the image data is converted into a data format that can be stored primarily by applying processes like compression. The converted image data is stored into the primary memory 103. After that, the process exits from the subroutine. Details of the data format that can be stored primarily will be mentioned later.

[0326] The order and presences of the processes in the crop development process executed in the steps S503 through S508 may be set up according to the property of the camera system and they do not restrict the present invention. Moreover, when the video image mode is selected, the processes of the steps S200 through S500 are repeatedly executed until the recording is finished.

[0327] According to this process, the calculation amount is significantly reduced as compared with a case where the development process is executed to the entire area read in the step S501. Accordingly, an inexpensive and low-power consumption microcomputer can be employed as the overall control CPU 101. Moreover, heat generation in the overall control CPU 101 is reduced and the life of the battery 94 becomes longer.

[0328] Moreover, in order to reduce a control load on the overall control CPU 101, the optical correction process (the step S800 in FIG. 7A) and the image stabilization process (the step S900 in FIG. 7A) to the image are not executed by the camera body 1 in this embodiment. These processes are executed by the display-apparatus controller 801 after transferring the image to the display apparatus 800. Accordingly, if only data of a partial image extracted from a projected superwide-angle image is transferred to the display apparatus 800, neither the optical correction process nor the image stabilization process can be

executed. That is, since the data of the extracted image does not include position information that will be substituted to a formula of the optical correction process and will be used to refer the correction table of the image stabilization process, the display apparatus 800 cannot execute these processes correctly. Accordingly, in this embodiment, the camera body 1 transmits correction data including information about an extraction position of an image from a superwide-angle image together with data of the extracted image to the display apparatus 800.

[0329] When the extracted image is a still image, since the still image data corresponds to the correction data one-to-one, the display apparatus 800 can execute the optical correction process and image stabilization process correctly, even if these data are separately transmitted to the display apparatus 800. In the meantime, when the extracted image is a video image, if the video image data and the correction data are separately transmitted to the display apparatus 800, it becomes difficult to determine correspondence between each frame of the video image data and the correction data. Particularly, when a clock rate of the overall control CPU 101 in the camera body 1 slightly differs from a clock rate of the display-apparatus controller 801 in the display apparatus 800, the synchronization between the overall control CPU 101 and the display-apparatus controller 801 will be lost during the video image pickup operation for several minutes. This may cause a defect that the display-apparatus controller 801 corrects a frame with correction data different from the corresponding correction data.

[0330] Accordingly, in this embodiment, when transmitting data of an extracted video image to the display apparatus 800, the camera body 1 gives its correction data appropriately to the data of the video image. Hereinafter, the method is described.

[0331] FIG. 14 is a flowchart showing the subroutine of the primary recording process in the step S600 in FIG. 7A. Hereinafter, this process will be

described by also referring to FIG. 15. FIG. 14 shows the process of a case where the video image mode is selected by the image pickup mode switch 12. When the still image mode is selected, this process starts from a step S601 and is finished after a process of a step S606.

[0332] In a step S601a, the overall control CPU 101 reads an image of one frame to which the processes in steps S601 through S606 have not been applied from among the video image developed in the recording area development process (FIG. 7E). Moreover, the overall control CPU (a metadata generation unit) 101 generates correction data that is metadata of the read frame.

[0333] In the step S601, the overall control CPU 101 attaches the information about the extraction position of the image of the frame read in the step S601a to the correction data. The information attached in this step is the coordinate (Xi, Yi) of the image recording frame 127i obtained in the step S305. It should be noted that the information attached in this step may be the vector information that shows the observation direction vi.

[0334] In a step S602, the overall control CPU (an optical-correction-value obtainment unit) 101 obtains an optical correction value. The optical correction value is the optical distortion value set up in the step S303. Alternatively, the optical correction value may be a correction value corresponding to the lens optical property, such as a marginal-light-amount correction value or a diffraction correction value.

[0335] In a step S603, the overall control CPU 101 attaches the optical correction value used for the distortion conversion in the step S602 to the correction data.

[0336] In a step S604, the overall control CPU 101 determines whether the image stabilization mode is effective. Specifically, when the image stabilization mode set up in advance is "Middle" or "Strong", it is determined that the image

stabilization mode is effective and the process proceeds to a step S605. In the meantime, when the image stabilization mode set up in advance is "OFF", it is determined that the image stabilization mode is not effective and the process proceeds to the step S606. The reason why the step S605 is skipped when the image stabilization mode is "OFF" is because the calculation data amount of the overall control CPU 101 and the data amount of the wireless communication are reduced and the power consumption and heat generation of the camera body 1 can be reduced by skipping the step S605. Although the reduction of the data used for the image stabilization process is described, the data about the marginal-light-amount value or the data about the diffraction correction value obtained as the optical correction value in the step S602 may be reduced.

[0337] Although the image stabilization mode is set up by the user's operation to the display apparatus 800 in advance in this embodiment, it may be set up as a default setting of the camera body 1. Moreover, when the camera system is configured to switch the effectiveness of the image stabilization process after transferring image data to the display apparatus 800, the process may directly proceed to the step S605 from the step S603 by omitting the step S604.

[0338] In the step S605, the overall control CPU (a moving amount detection unit) 101 attaches the image stabilization mode, which is obtained in the step S302, and the gyro data, which associates with the frame read in the step S601a and stored in the primary memory 813, to the correction data.

[0339] In the step S606, the overall control CPU 101 updates a video file 1000 (FIG. 15) by data obtained by encoding the image data of the frame read in the step S601a and the correction data to which the various data are attached in the steps S601 through S605. It should be noted that when a first frame of the video image is read in the step S601a, the video file 1000 is generated in the step S606.

[0340] In a step S607, the overall control CPU 101 determines whether all

the frames of the video image developed by the recording area development process (FIG. 7E) have been read. When not all the frames have been read, the process returns to the step S601a. In the meantime, when all the frames have been read, the process exits from this subroutine. The generated video file 1000 is stored into the internal nonvolatile memory 102. The video file may be stored into the large-capacity nonvolatile memory 51 too in addition to the primary memory 813 and the internal nonvolatile memory 102. Moreover, the transmission process (the step S700 in FIG. 7A) that transfers the generated image file 1000 to the display apparatus 800 immediately is executed. The image file 1000 may be stored into the primary memory 813 after transferring it to the display apparatus 800.

[0341] In this embodiment, the encoding means combines the image data and the correction data into one file. At that time, the image data may be compressed or the data file that is combined by the image data and correction data may be compressed.

[0342] FIG. 15 is a view showing a data structure of the video file 1000. The video file 1000 consists of a header part 1001 and a frame part 1002. The frame part 1002 consists of frame data sets each of which consists of an image of each frame and corresponding frame metadata. That is, the frame part 1002 includes frame data sets of the number of the total frames of the video image.

[0343] In this embodiment, the frame metadata is information obtained by encoding correction data to which an extraction position (in-image position information), an optical correction value, and gyro data are attached if needed. However, the frame metadata is not limited to this. An information amount of the frame metadata may be changed. For example, other information may be added to the frame metadata according to the image pickup mode selected by the image pickup mode switch 12. Alternatively, a part of the information in the

frame metadata may be deleted.

[0344] An offset value to the frame data sets of each frame or a head addresses of each frame is recorded in the header part 1001. Alternatively, metadata like the time and size corresponding to the video file 1000 may be stored in the header part 1001.

[0345] In the primary recording process (FIG. 14), the video file 1000 is transferred to the display apparatus 800 in this way. The video file 100 includes data sets each of which consists of a frame of the video image developed by the recording area development process (FIG. 7E) and its metadata. Accordingly, even when the clock rate of the overall control CPU 101 in the camera body 1 slightly differs from the clock rate of the display-apparatus controller 801 in the display apparatus 800, the display-apparatus controller 801 appropriately applies the correction process to the video image developed in the camera body 1.

[0346] Although the optical correction value is included in the frame metadata in this embodiment, the optical correction value may be given to the entire video image.

[0347] FIG. 16 is a flowchart showing the subroutine of the transmission process to the display apparatus 800 in the step S700 in FIG. 7A. FIG. 16 shows the process of a case where the video image mode is selected by the image pickup mode switch 12. It should be noted that when the still image mode is selected, this process starts from a process in a step S702.

[0348] In a step S701, it is determined whether the image pickup process (the step S400) of the video image by the image pickup unit 40 is finished or is under recording. When the video image is recording, the recording area development process (the step S500) for each frame and the update of the image file 1000 (the step S606) in the primary recording process (the step S600) are executed sequentially. Since a power load of wireless transmission is large, if

the wireless transmission is performed during the video image pickup operation in parallel, the battery 94 is needed to have large battery capacity or a new measure against heat generation is needed. Moreover, from a viewpoint of arithmetic capacity, if the wireless transmission is performed during the video image pickup operation in parallel, an arithmetic load will become large, which needs to prepare a high-specification CPU as the overall control CPU 101, increasing the cost.

[0349] In view of these points, in this embodiment, the overall control CPU 101 proceeds with the process to a step S702 after the video image pickup operation is finished (YES in the step S701), and establishes the wireless connection with the display apparatus 800. In the meantime, if the camera system of the embodiment has a margin in the electric power supplied from the battery 94 and a new measure against heat generation is unnecessary, the overall control CPU 101 may beforehand establish the wireless connection with the display apparatus 800 when the camera body 1 is started or before starting the recording.

[0350] In the step S702, the overall control CPU 101 establishes the connection with the display apparatus 800 through the high-speed wireless communication unit 72 in order to transfer the video file 1000 having much data volume to the display apparatus 800. It should be noted that the small-power wireless communication unit 71 is used for transmission of a low-resolution image for checking a field angle to the display apparatus 800 and is used for exchange of various set values with the display apparatus 800. In the meantime, the small-power wireless communication unit 71 is not used for transfer of the video file 1000 because a transmission period becomes long.

[0351] In a step S703, the overall control CPU 101 transfers the video file 1000 to the display apparatus 800 through the high-speed wireless communication unit 72. When the transmission is finished, the overall control CPU 101

proceeds with the process to a step S704. In the step S704, the overall control CPU 101 closes the connection with the display apparatus 800 and exits from this subroutine.

[0352] The case where one image file includes the images of all the frames of one video image has been described so far. In the meantime, if the recording period of the video image is longer than several minutes, the video image may be divided by a unit time into a plurality of image files. When the video file has the data structure shown in FIG. 15, even if one video image is transferred to the display apparatus 800 as a plurality of image files, the display apparatus 800 can correct the video image without the timing gap with the correction data.

[0353] FIG. 17 is a flowchart showing a subroutine of the optical correction process in the step S800 in FIG. 7A. Hereinafter, this process will be described by also referring to FIG. 18A through FIG. 18E. As mentioned above, this process is executed by the display-apparatus controller 801 of the display apparatus 800.

[0354] In a step S801, the display-apparatus controller (a video file reception unit) 801 first receives the video file 1000 from the camera body 1 transferred in the transmission process (the step S700) to the display apparatus 800. After that, the display-apparatus controller (a first extraction unit) 801 obtains the optical correction values extracted from the received video file 1000.

[0355] In the next step S802, the display-apparatus controller (a second extraction unit) 801 obtains an image (an image of one frame obtained by the video image pickup operation) from the video file 1000.

[0356] In a step S803, the display-apparatus controller (a frame image correction unit) 801 corrects optical aberrations of the image obtained in the step S802 with the optical correction value obtained in the step S801, and stores the corrected image into the primary memory 813. When the extraction from the

image obtained in the step S802 is performed in the optical correction, an image area (extraction-development area) that is narrower than the development area (target visual field 125i) determined in the step S303 is extracted and is subjected to the process.

[0357] FIG. 18A through FIG. 18F are views for describing a process of applying distortion correction in the step S803 in FIG. 17.

[0358] FIG. 18A is a view showing a position of an object 1401 at which the user looks with a naked eye in picking up an image. FIG. 18B is a view showing an image of the object 1401 formed on the solid state image sensor 42.

[0359] FIG. 18C is a view showing a development area 1402 in the image in FIG. 18B. The development area 1402 is the extraction-development area mentioned above.

[0360] FIG. 18D is a view showing an extraction-development image obtained by extracting the image of the development area 1402. FIG. 18E is a view showing an image obtained by correcting distortion in the extraction-development image shown in FIG. 18D. Since an extraction process is performed in correcting distortion of the extraction-development image, a field angle of the image shown in FIG. 18E becomes still smaller than that of the extraction-development image shown in FIG. 18D.

[0361] FIG. 19 is a flowchart showing a subroutine of the image stabilization process in the step S900 in FIG. 7A. As mentioned above, this process is executed by the display-apparatus controller 801 of the display apparatus 800.

[0362] In a step S901, the display-apparatus controller 801 obtains gyro data of a frame (current frame) that is currently processed, gyro data of a frame (previous frame) that is an immediately preceding frame, and a blur amount V_{n-1}^{Det} that is calculated for the previous frame are obtained from the frame

metadata of the video file 1000. After that, a rough blur amount V_n^{Pre} is calculated from these pieces of information. Since the calculation method of the blur amount V_{n-1}^{Det} is the same as that of the calculation method of a blur amount V_n^{Det} in the next step S902, its description is omitted.

[0363] In the step S902, the display-apparatus controller 801 calculates a fine blur amount V_n^{Det} from the video file. A blur amount is detected by calculating a moving amount of a feature point in the image from a previous frame to a current frame.

[0364] A feature point can be extracted by a known method. For example, a method using a luminance information image that is generated by extracting only luminance information of an image of a frame may be employed. This method subtracts an image that shifts the original luminance information image by one or several pixels from the original luminance information image. A pixel of which an absolute value of difference exceeds a threshold is extracted as a feature point. Moreover, an edge extracted by subtracting an image generated by applying a high-pass filter to the above-mentioned luminance information image from the original luminance information image may be extracted as a feature point.

[0365] Differences are calculated multiple times while shifting the luminance information images of the current frame and previous frame by one or several pixels. The moving amount is obtained by calculating a position at which the difference at the pixel of the feature point diminishes.

[0366] Since a plurality of feature points are needed as mentioned later, it is preferable to divide each of the images of the present frame and previous frame into a plurality of blocks and to extract a feature point for each block. A block division depends on the number of pixels and aspect ratio of the image. In general, 12 blocks of 4 * 3 or 54 blocks of 9 * 6 are preferable. When the

number of blocks is too small, trapezoidal distortion due to a tilt of the image pickup unit 40 of the camera body 1 and rotational blur around the optical axis, etc. cannot be corrected correctly. In the meantime, when the number of blocks is too large, a size of one block becomes small, which shortens a distance between adjacent feature points, causing an error. In this way, the optimal number of blocks is selected depending on the pixel number, ease of detection of feature points, a field angle of an object, etc.

[0367] Since the calculation of the moving amount needs a plurality of difference calculations while shifting the luminance information images of the current frame and previous frame by one or several pixels, the calculation amount increases. Since the moving amount is actually calculated on the basis of the rough blur amount V_n^{Pre} and deviation (the number of pixels) therefrom, the difference calculations are performed only near the rough blur amount, which can significantly reduce the calculation amount.

[0368] Next, in a step S903, the display-apparatus controller 801 performs the image stabilization process using the fine blur amount V_n^{Det} obtained in the step S902. And then, the process exits form this subroutine.

[0369] It should be noted that Euclidean transformation and affine transformation that enable rotation and parallel translation, and projective transformation that enables keystone correction are known as the method of the image stabilization process.

[0370] Although the Euclidean transformation can correct movement in an X-axis direction and a Y-axis direction and rotation, it cannot correct blur caused by camera shake of the image pickup unit 40 of the camera body 1 in a front-back direction or directions of pan and tilt. Accordingly, in this embodiment, the image stabilization process is executed using the affine transformation that enables correction of skew. The affine transformation from a coordinate (x, y) of

the feature point used as criteria to a coordinate (x', y') is expressed by the following formula 1.

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{pmatrix} a & b & c \\ d & e & f \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \quad Formula\ 1$$

[0371] Affine coefficients of a 3*3 matrix of the formula 1 are computable if deviations of at least three feature points are detected. However, when the detected feature points are mutually near or are aligned on a straight line, the image stabilization process becomes inaccurate in areas distant from the feature points or distant from the straight line. Accordingly, it is preferable to select the feature points to be detected that are mutually distant and do not lie on a straight line. Accordingly, when a plurality of feature points are detected, mutually near feature points are excluded and remaining feature points are normalized by a least square method.

[0372] FIG. 18F is a view showing an image obtained by applying the image stabilization process in the step S903 to the distortion-corrected image shown in FIG. 18E. Since the extraction process is performed in executing the image stabilization process, a field angle of the image shown in FIG. 18F becomes smaller than that of the image shown in FIG. 18E.

[0373] It is available to obtain a high quality image of which blur is corrected by performing such an image stabilization process.

[0374] In the above, the series of operations executed by the camera body 1 and display apparatus 800 that are included in the camera system of this embodiment have been described.

[0375] When the user selects the video image mode by the image pickup mode switch 12 after turning the power switch 11 ON and observes the front without turning the face in the vertical and horizontal directions, the face direction defection unit 20 detects the observation direction vo (vector information [0°, 0°])

as shown in FIG. 12A. After that, the recording-direction/field-angle determination unit 30 extracts the image (FIG. 11B) in the target visual field 125o shown in FIG. 12A from the superwide-angle image projected onto the solid state image sensor 42.

[0376] After that, when the user starts observing the child (A-object) 131 in FIG. 11A, for example, without operating the camera body 1, the face direction detection unit 20 detects the observation direction vm (vector information [-42°, -40°]) as shown in FIG. 11C. After that, the recording-direction/field-angle determination unit 30 extracts the image (FIG. 11C) in the target visual field 125m from the superwide-angle image picked up by the image pickup unit 40.

[0377] In this way, the display apparatus 800 applies the optical correction process and image stabilization process to the extracted image of the shape depending on the observation direction in the steps S800 and S900. Thereby, even if the specification of the overall control CPU 101 of the camera body 1 is low, the significantly distorted image in the target visual field 125m (FIG. 11C) is converted into the image around the child (A-object) 131 of which the blur and distortion are corrected as shown in FIG. 11D. That is, the user is able to obtain an image picked up in the own observation direction, even if the user does not touch the camera body 1 except to turn the power switch 11 ON and to select the mode with the image pickup mode switch 12.

[0378] Hereinafter, the preset mode will be described. Since the camera body 1 is a compact wearable device as mentioned above, operation switches, a setting screen, etc. for changing advanced set values are not mounted on the camera body 1. Accordingly, in this embodiment, the advanced set values of the camera body 1 are changed using the setting screen (FIG. 13) of the display apparatus 800 as an external device.

[0379] For example, a case where the user would like to change the field

angle from 90° to 45° while picking up a video image continuously is considered. In such a case, the following operations are needed. Since the field angle is set to 90° in a regular video image mode, the user performs the video image pickup operation in the regular video image mode, once finishes the video image pickup operation, displays the setting screen of the camera body 1 on the display apparatus 800, and changes the field angle to 45° on the setting screen. However, this operation to the display apparatus 800 during the continuous image pickup operation is troublesome and an image that the user wants to pick up may be missed.

[0380] In the meantime, when the preset mode is preset to a video image pickup operation at the field angle of 45°, the user can change to a zoom-up video image pickup operation at the field angle of 45° immediately by only sliding the image pickup mode switch 12 to "Pre" after finishing the video image pickup operation at the field angle of 90°. That is, the user is not required to suspend the current image pickup operation and to perform the above-mentioned troublesome operations.

[0381] The contents of the preset mode may include the image stabilization level ("Strong", "Middle", or "OFF") and a set value of voice recognition that is not described in this embodiment in addition to the field angle.

[0382] For example, when the user switches the image pickup mode switch 12 from the video image mode to the preset mode while continuously observing the child (A-object) 131 in the previous image pickup situation, the field-angle set value V_{ang} is changed from 90° to 45°. In this case, the recording-direction/field-angle determination unit 30 extracts the image in the target visual field 128m shown by a dotted line frame in FIG. 11E from the superwide-angle image picked up by the image pickup unit 40.

[0383] Also in the preset mode, the optical correction process and image

stabilization process are performed in the display apparatus 800 in the steps S800 and S900. Thereby, even if the specification of the overall control CPU 101 of the camera body 1 is low, the zoom-up image around the child (A-object) 131 of which the blur and distortion are corrected as shown in FIG. 11F is obtained.

Although the case where the field-angle set value V_{ang} is changed from 90° to 45° in the video image mode has been described, the process in the still image mode is similar. Moreover, a case where the field-angle set value V_{ang} of a video image is 90° and the field-angle set value V_{ang} of a static image is 45° is also similar.

[0384] In this way, the user is able to obtain the zoom-up image that picks up the own observation direction by just switching the mode with the image pickup mode switch 12 of the camera body 1.

[0385] It should be noted that the optical correction process (the step S800) and image stabilization process (the step S900) that are executed by the display apparatus 800 in this embodiment may be executed by the camera body 1 in order to lower the processing load of the display apparatus 800.

[0386] Although the case where the face direction detection unit 20 and the image pickup unit 40 are integrally constituted in the camera body 1 is described in this embodiment, the configuration is not limited to this as long as the face direction detection unit 20 is worn on the user's body part other than the head and the image pickup unit 40 is worn on the user's body. For example, the image pickup unit 40 of this embodiment can be worn on a shoulder or an abdomen. However, when the image pickup unit 40 is worn on a right shoulder, an object of the left side is obstructed by the head. In such a case, it is preferable that a plurality of image pickup units are worn on places including a right shoulder. Moreover, when the image pickup unit 40 is worn on an abdomen, spatial parallax occurs between the image pickup unit 40 and the head. In such a case, it is preferable to perform a correction calculation of the observation direction that

compensate such parallax.

[0387] Hereinafter, a second embodiment will be described. In the second embodiment, a method to calibrate individual difference and adjustment difference of a user who wears the camera body 1 is described in detail using FIG. 20A through FIG. 23E.

[0388] This embodiment is described as a derivation from the first embodiment basically. Accordingly, configurations of the camera system in the second embodiment that are identical to the configurations of the camera system in the first embodiment are indicated by the same reference numerals and duplicated descriptions are omitted. A different configuration will be described by adding details.

[0389] A user who wears the camera body 1 has individual size differences and adjustment differences, such as a physique, a tilt angle of periphery of a neck to which the camera body 1 is worn, a state of worn clothes (e.g. presence or absence of a collar), and adjustment states of the band parts 82L and 82R. Accordingly, the optical axis center of the image pickup lens 16 of the camera body 1 and the visual field center in a state (hereinafter, referred to as a natural state of a user) where the user faces the front do not coincide usually. It is preferable for a user to match a center of an extraction recording area (target visual field 125) to a visual field center of the user in a current posture or operation rather than to match the center of the recording area to the optical axis center of the image pickup lens 16 of the camera body 1.

[0390] Moreover, there is individual difference not only in a visual field center of a user in the natural state but also in a visual field center depending on a head direction (up, down, right, left, or slants) and in a motion space of a head. Accordingly, individual difference also factors into the relationship between the face direction (observation direction) detected by the face direction detection unit

20 and the center position (hereinafter referred to as a visual field center position) of the target visual field 125 established according to the observation direction. Accordingly, a calibration operation that associates a face direction to a visual field center position is needed.

[0391] Usually, the calibration operation is preferably performed as a part of the preparation process (the step S100) in FIG. 7A. Although it is estimated of performing the calibration operation at the first start-up of the camera body 1 usually, the calibration operation may be performed when a predetermined time elapses after the previous calibration or when the position of the camera body 1 to the user is changed from the position at the previous calibration. The calibration operation may be performed when the face direction detection unit 20 becomes impossible to detect a user's face. Moreover, when it is detected that the user detaches the camera body 1, the calibration operation may be performed at the time when the user again wears the camera body 1. In this way, it is preferable to perform the calibration operation suitably at a timing when it is determined that the calibration is needed to use the camera body 1 appropriately.

[0392] FIG. 20A and FIG. 20B are the views showing details of the calibrator 850 used for the calibration process according to the second embodiment. In this embodiment, the calibrator 850 shall combine the function of the display apparatus 800.

[0393] The calibrator 850 includes a positioning index 851 and calibration button 854 in addition to the A-button 802, display unit 803, in-camera 805, face sensor 806, and angular speed sensor 807 that are the components of the display apparatus 800 shown in FIG. 1D. The B-button 804 provided in the first embodiment is not illustrated in FIG. 20A because it is not used in this embodiment and is replaceable with the calibration button 854 as mentioned later.

[0394] FIG. 20A shows a case where the positioning index 851 is a specific

pattern displayed on the display unit 803. FIG. 20B shows a case where the external appearance of the calibrator 850 is used as the positioning index. In the case of FIG. 20B, a positioning index center 852 mentioned later is calculated from the information about the contour of the calibrator 850.

[0395] It should be noted that the positioning index is not limited to the examples of FIG. 20A and FIG. 20B. For example, the positioning index may be separated from the calibrator 850. The positioning index may be anything as long as its size is easily measured and its shape is suitable to be looked at by the user. For example, the positioning index may be a lens cap of the image pickup lens 16 or a charge unit for the camera body 1. Anyway, since a fundamental way of thinking in the calibration operation is common, the calibrator 850 shown in FIG. 20A is exemplified and is mainly described hereinafter.

[0396] It should be noted that the calibrator 850 in this embodiment shall combine the function of the display apparatus 800. Moreover, the calibrator 850 may be a dedicated device, a general smart phone, or a tablet terminal, for example.

[0397] The positioning index 851 is displayed on the display unit 803 of the calibrator 850 and is a diagram of which a lateral width L851a, vertical width L851b, and positioning index center 852 can be calculated. Since the user directs the face toward the vicinity of the central part of the positioning index 851 in the calibration process mentioned later, the positioning index 851 is preferably shaped so as to be caught at the visual field center. In FIG. 20A, the positioning index 851 is shown by a circle in which a cross and a small black circle at the center of the cross are arranged. However, the shape of the positioning index 851 is not limited to this shape. Otherwise, the positioning index may be a rectangle, a triangle, a star-shaped figure, or an illustration of a character.

[0398] The positioning index 851 is picked up by the image pickup unit 40

of the camera body 1. The display-apparatus controller (a position calculation unit and a distance calculation unit) 801 calculates a distance between the image-pickup/detection unit 10 and the calibrator 850 and calculates a positional coordinate of the positioning index 851 appeared in an image area on the basis of the pickup image. The calibrator 850 equipped with the function of the display apparatus 800 performs these calculations in this embodiment. If the calibrator 850 does not combine the function of the display apparatus 800, these calculations are performed by the overall control CPU 101 of the camera body 1.

[0399] The angular speed sensor 807 can measure movement of the calibrator 850. On the basis of the measurement value of the angular speed sensor 807, the display-apparatus controller 801 calculates later-mentioned movement information that shows the position and posture of the calibrator 850.

[0400] The calibration button 854 is pressed when the user directs the face toward the vicinity of the central part of the positioning index 851 in the calibration process mentioned later. Although the calibration button 854 is a touch button displayed on the touch-sensitive display unit 803 in FIG. 20A, the A-button 802 may function as the calibration button.

[0401] Next, the calibration process executed in extracting an image from a superwide-angle image picked up by the image pickup unit 40 according to a user's face direction and in applying the image process to the extracted image will be described in detail using a flowchart in FIG. 21.

[0402] FIG. 21 is the flowchart showing the calibration process according to the second embodiment executed by the camera body (a first calibration unit) 1 and calibrator 805.

[0403] In order to assist the description, a step in which the camera body 1 or the calibrator 850 receives a user's instruction is included in a frame of which an operation subject is the user. Moreover, in FIG. 21, a step executed by the

display-apparatus controller 801 of the calibrator 850 in response to the user's instruction is included in a frame of which an operation subject is the calibrator 850. Similarly, in FIG. 21, a step executed by the overall control CPU 101 of the camera body 1 in response to the user's instruction is included in a frame of which an operation subject is the camera body 1.

[0404] Specifically, the operation subject of steps S3104 and S3108 in FIG. 21 is the camera body 1. And the operation subject of steps S3101, S3105, and S3106 is the user. Moreover, the calibrator 850 is the operation subject of steps S3102, S3103, S3106a, S3107, S3107b, and S3110.

[0405] In this process, when the power of the calibrator 850 is not ON, the user turns the power of the calibrator 850 ON by operating the A-button 802 in the step S3101. Similarly, when the power of the camera body 1 is not ON, the user turns the power of the camera body 1 ON by switching the power switch 11 to ON. After that, the user establishes a connection between the calibrator 850 and the camera body 1. When this connection is established, the display-apparatus controller 801 and the overall control CPU 101 enter a calibration mode, respectively.

[0406] Moreover, in the step S3101, the user wears the camera body 1, and adjusts the lengths of the band parts 82L and 82R and the angle of the camera body 1 so that the camera body 1 will be arranged in a suitable position and the image-pickup/detection unit 10 can pick up an image.

[0407] In the step S3102, the display-apparatus controller (a first display unit) 801 displays the positioning index 851 on the display unit 803.

[0408] In the next step S3103, the display-apparatus controller 801 designates a designation position at which the user should hold the calibrator 850 as an instruction display 855 (FIG. 22A). In this embodiment, five positions including front, upper right, lower right, upper left, and lower left are designated

as the designation positions in order. The designation positions may be set to other positions as long as the calibration is available.

[0409] In the step S3104, the overall control CPU 101 activates the image pickup unit 40 so as to enable an image pickup operation and activates the face direction detection unit 20 so as to enable detection of a user's face direction. In the step S3105, the user holds the calibrator 850 at the designation position designated in the step S3103.

[0410] In the next step S3106, the user directs the face in the direction of the positioning index 851 to match a user's visual field center with the positioning index 851 and presses the calibration button 854 while maintaining the position of the calibrator 850 at the designation position. [0411] In the step S3106a, the display-apparatus controller (a second display unit) 801 determines whether the user looks at the positioning index center 852 of the positioning index 851, i.e., determines whether the user's visual field center matches the positioning index center 852. When it is determined that the user looks at the positioning index center 852 (YES in the S3106a), the display-apparatus controller 801 notifies the user of start of the calibration for the designation position by the instruction display 855 in a step S3107 and redisplays the calibration button 854. When the determination result in the step S3106a is NO, the user repeats the process from the step S3105.

[0411] When the user presses the calibration button 854 in the step S3107a, the display-apparatus controller 801 transmits a calibration instruction to the camera body 1 in the step S3107b.

[0412] In the step S3108, the overall control CPU (an obtainment/detection unit) 101 obtains a superwide-angle image including the positioning index 851 picked up by the image pickup unit 40 and detects a face direction by the face direction detection unit 20 in response to the calibration instruction from the

calibrator 850. After that, the overall control CPU (a generation unit) 101 calculates positional coordinate information about the positioning index center 852 in the obtained superwide-angle image and generates the information showing the relationship between the calculated positional coordinate information and the detected face direction.

[0413] Hereinafter, the details of the process in the steps S3103 through S3108 will be described using FIG. 22A through FIG. 22F. FIG. 22A through FIG. 22F are views for describing the calibration operation for the front direction of the user. The calibration operation is performed so that the center position of the target visual field 125 in the image picked up by the image pickup unit 40 of the camera body 1 will match the visual field center position of the user in the natural state.

[0414] FIG. 22A is a view showing a screen displayed on the display unit 803 of the calibrator 850 in the step S3103 in FIG. 21 during the calibration operation for the front direction of the user.

[0415] As shown in FIG. 22A, the positioning index 851 and the instruction display 855 that indicates a position at which the user should locate the positioning index 851 are displayed on the display unit 803 of the calibrator 850.

[0416] The instruction display 855 is a character string that instructs the user to locate the positioning index 851 at the visual field center of the user in directing the face to the front. It should be noted that the instruction displayed as the instruction display 855 is not restricted to the character string. For example, the instruction may be displayed by another method using an illustration, a picture, a moving image, or the like. Moreover, the instruction display 855 (or a similar general tutorial) may be displayed first and the positioning index 851 may be displayed after that.

[0417] FIG. 22B is a view showing a state where the user holds the

calibrator 850 in the front according to the instruction displayed as the instruction display 855 in FIG. 22A.

[0418] In the step S3105, the user holds the calibrator 850 in the front according to the instructions displayed as the instruction display 855 in FIG. 22A. Then, in the step S3106, the user holds the calibrator 850 so that the positioning index 851 will match the visual field center of the user in directing the face to the front, and the user presses the calibration button 854 (FIG. 22A). In response to the press of the calibration button 854, the determination in the step S3106a is performed. The concrete procedure of this determination method will be mentioned later. When the determination result in the step S3106a is YES, the display-apparatus controller 801 changes the instruction display 855 shown in FIG. 22A to a notification of "Calibration for Front Direction is Started" and displays the calibration button 854.

[0419] Then, the user presses the calibration button 854 after confirming the change of the instruction display 855 shown in FIG. 22A to the notification of "Calibration for Front Direction is Started" (the step S3107a). In response to the press of the calibration button 854, a calibration instruction is transmitted to the camera body 1 in the step S3107b. And the image pickup unit 40 obtains a pickup image in the step S3108.

[0420] FIG. 22C is a schematic view showing the entire superwide-angle image that is caught by the image pickup lens 16 in the state of FIG. 22B. FIG. 22D is a schematic view showing an image obtained by correcting aberrations of the superwide-angle image shown in FIG. 22C.

[0421] Moreover, in response to the press of the calibration button 854 by the user in the state of FIG. 22B, the face direction detection unit 20 obtains a face direction in the step S3108.

[0422] FIG. 22E is a schematic view showing a face direction image that is

recorded by the face direction detection unit 20 in the step S3108 in FIG. 21 during the calibration operation for the front direction of the user.

[0423] As described in the first embodiment using FIG. 8G through FIG. 8K, the face direction detection unit 20 calculates the angles in the lateral and vertical directions of the face using the distances and angles of the chin positions 207, 207r, and 207u with respect to the throat position 206. However, since the distances and angles of the chin positions 207, 207r, and 207u with respect to the throat position 206 also have the individual difference and adjustment difference due to the user's physique etc. mentioned above as with the image center, they are not fixed. Accordingly, in this embodiment, the relationship between the chin position and the throat position 206 at the time of pressing the calibration button 854 is defined as a value of a case where the user puts the visual field center in the front. This enables correct calculation of the user's face direction irrespective of the individual difference and adjustment difference.

[0424] Returning back to FIG. 21, in a step S3109, the overall control CPU 101 determines whether the calibration for the front direction is prepared. That is, it is determined whether the information required to calculate the chin position 207, throat position 206, and positioning index center 852 has been obtained.

[0425] At this time, when the obtainment of the required information is not completed, it is determined that the calibration is not prepared (NO in the step S3109), and the operations from the step S3102 are repeated so as to obtain correct information corresponding to information deemed to be deficient among the required information. When the obtainment of the required information is not completed, not all the operations from the step S3102 are necessary. Only the operations to obtain correct information corresponding to the information deemed to be deficient information may be performed again.

[0426] The determination in the step S3106a is performed using the face

sensor 806 or in-camera 805 mounted in the calibrator 850. Hereinafter, the concrete procedure of this determination method will be described using a case where the calibration operation for the front direction is performed using the in-camera 805. Although a case using the face sensor 806 is different from the case using the in-camera 805 in the dimension of information (two-dimensional information or three-dimensional information), a fundamental way of thinking is common. Accordingly, detailed description of the case using the face sensor 806 is omitted. When the face sensor 806 is used in the determination in the step S3106a, the face direction detection unit 20 of the camera body 1 does not perform the face detection that irradiates the user with the infrared light 23 during a period when the user is irradiated with the infrared light 823 from the face sensor 806. This aims to prevent interference of the infrared lights 23 and 823.

[0427] First, when the user presses the calibration button 854 in FIG. 22A in the step S3106, the display-apparatus controller 801 obtains an in-camera image 858 (FIG. 22F) in which the user appears by picking up an image with the in-camera (a face detection unit) 805. Furthermore, the display-apparatus controller 801 detects the position information about the neck front part 201, chin 203, face 204 including a nose, and image-pickup/detection unit 10 (the image pickup unit 40) from the obtained in-camera image 858.

[0428] The display-apparatus controller (a determination unit) 101 determines whether the user is looking at the positioning index center 852 of the positioning index 851 at the visual field center in the step S3106a using the position information detected from the in-camera image 858.

[0429] As a result of the determination, when it is determined that the user is looking in a different direction, the display-apparatus controller 801 displays a message indicating that the correct information cannot be obtained as the instruction display 855. This can instruct the user to perform the calibration

operation again.

[0430] The display-apparatus controller 801 can determine that the correct calibration operation cannot be performed using the in-camera image 858 when the image-pickup/detection unit 10 tilts beyond a certain angle or when the face direction detection window 13 is blocked or is dirty. In such a case, the display-apparatus controller 801 may display the message indicating that the correct information cannot be obtained as the instruction display 855.

[0431] When the overall control CPU 101 determines that the required information is obtained and that the preparation of the calibration for the front direction is completed in the step S3109 according to the above-mentioned method, the process proceeds to the step S3110.

[0432] In the step S3110, the display-apparatus controller (the first calibration unit) 801 calculates information required to offset the extraction center position so as to absorb the individual difference and adjustment difference and offsets the extraction center position on the basis of the information.

[0433] Details of the calculation in the step S3110 will be described as follows. If the user is in an ideal state according to design values and the camera body 1 is worn ideally, a center 856 of the superwide-angle image obtained in the step S3108 shown in FIG. 22C should be almost coincident with the positioning index center 852 appeared in the superwide-angle image. However, since there are individual difference and adjustment difference due to the user's physique etc. actually, the center 856 of the superwide-angle image does not match the positioning index center 852 usually.

[0434] It is preferable for a user to match the extraction center position to a visual field center of the user in a current posture or operation (i.e., the positioning index center 852 in the superwide-angle image) rather than to match to the center 856 of the superwide-angle image shown by the camera body 1.

[0435] Accordingly, a deviation amount of the positioning index center 852 from the center 856 of the superwide-angle image is measured, and the extraction center position is offset to a position based on the positioning index center 852 that differs from the center 856 of the superwide-angle image. Moreover, the face direction that is detected by the face direction detection unit 20 in that time is also offset in a similar way.

[0436] Concrete offset methods will be described by referring to FIG. 22C and FIG. 22D. The deviation amount of the positioning index center 852 to the center 856 of the superwide-angle image is measured, and the measured deviation amount is divided into a lateral deviation amount 857a and a vertical deviation amount 857b as shown in FIG. 22C. An offset amount is determined on the basis of the deviation amounts 857a and 857b after performing a suitable conversion process in accordance with the projection method of the entire field angle.

[0437] Moreover, as shown in FIG. 22D, the offset amount may be determined after applying the suitable conversion process to the superwide-angle image in accordance with the projection method. That is, the deviation amount of the center 856a from the positioning index center 852 in the pickup image after conversion is measured. And the deviation amount is divided into a lateral deviation amount 857c and a vertical deviation amount 857d. Then, the offset amount may be determined on the basis of the deviation amounts 857c and 857d.

[0438] The offset method can be arbitrarily selected from among the methods shown in FIG. 22C and FIG. 22D in consideration of a processing load and a purpose of the camera system.

[0439] By performing the above-mentioned calibration operation for the front direction, a face direction of a user who wears the camera body 1, a visual field center in the face direction within a superwide-angle image, and a face

direction detected by the face direction detection unit 20 are appropriately associated irrespective of individual difference and adjustment difference.

[0440] The calibration operation for the front direction is described up to here among the five directions (front, upper right, lower right, upper left, and lower left). It is necessary to execute similar calibration operations for the remaining four directions.

[0441] Accordingly, when the process in the step S3110 in FIG. 21 is completed, the process proceeds to a step S3111. In the step S3111, when there is a direction for which the calibration operation is not performed among the five directions, a target direction of the calibration operation is changed, and the process returns to the step S3103. Thereby, the calibration operation is similarly repeated for the remaining four directions other than the already finished front direction.

[0442] Although it is not shown in FIG. 21, when it is determined that there is no direction for which the calibration operation is not performed in the step S3111, this process is finished as-is.

[0443] FIG. 23A through FIG. 23E are views for describing the calibration operation for an upper right direction of the user (the upper right direction in the superwide-angle image). FIG. 23A through FIG. 23E respectively correspond to FIG. 22A through FIG. 22E and the fundamental operation is also identical. Accordingly, the common description is omitted.

[0444] As shown in FIG. 23A, the instruction display 855 displays a character string that instructs the user to locate the positioning index 851 at the visual field center of the user in directing the face to the upper right.

[0445] FIG. 23B is a view showing a state where the user holds the calibrator 850 to upper right according to the instruction shown by the instruction display 855 in FIG. 23A. FIG. 23C is a schematic view showing the entire

superwide-angle image that is caught by the image pickup lens 16 in the state in FIG. 23B.

[0446] As shown in FIG. 23C, a deviation amount between the center 856 of the superwide-angle image and the positioning index center 852 is measured first according to a concrete offset method. After that, the measured deviation amount is divided into a radial deviation amount 857e and an angular deviation amount 857f. An offset amount is determined on the basis of the deviation amounts 857e and 857f after performing a suitable conversion process in accordance with the projection method of the entire field angle.

[0447] Moreover, as shown in FIG. 23D, the offset amount may be determined after applying the suitable conversion process to the superwide-angle image in accordance with the projection method. That is, the deviation amount of the center 856a from the positioning index center 852 in the pickup image after conversion is measured. And the deviation amount is divided into a radial deviation amount 857g and an angular deviation amount 857h. Then, the offset amount may be determined on the basis of the deviation amounts 857g and 857h.

[0448] The determination of the offset amount described using FIG. 22A through FIG. 22E employs the method of dividing the deviation amount into the lateral deviation amount and vertical deviation amount. As compared with this, the determination of the offset amount described using FIG. 23A through FIG. 23E employs the method of dividing the deviation amount into the radial deviation amount and angular deviation amount. The difference in method is only for convenience of description, and either method can be employed.

[0449] Moreover, the face direction detection unit 20 has obtained, as shown in FIG. 23E, the throat position 206 and the chin position 207ru required to calculate the face direction in directing the face to the upper right. Accordingly, the face direction of the user in looking in the direction (in this case, the upper

right direction) toward the positioning index center 852 can be correctly measured irrespective of individual difference and adjustment difference of the user.

[0450] As mentioned above, the calibration operations for upper right, lower right, upper left, and lower left directions in addition to the front direction are performed in the calibration process shown in FIG. 21. Thereby, when the user turns the head in either of the upper, lower, right, and left directions, the face direction detection unit 20 can correctly detect the direction in which the user turns. Accordingly, the user can use the camera body 1 appropriately irrespective of individual difference and adjustment difference.

[0451] In the above description, the method of performing the calibration operation repeatedly for the five directions (front, upper right, lower right, upper left, and lower left) is described to simplify the description.

[0452] However, the calibration operation is not limited to this method. For example, the following method may be employed. That is, a user continuously moves the calibrator 850 along a Z-shaped locus, a spiral locus, a polygonal locus, or the like according to the instruction display 855. At the same time, the user continuously catches the positioning index 851 displayed on the calibrator 850 at the visual field center. In this method, the display-apparatus controller 801 transmits the calibration instructions to the camera body 1 multiple times while the calibrator 850 is moving.

[0453] Whenever receiving the calibration instruction, the overall control CPU 101 obtains the face direction detected by the face direction detection unit 20 and the positional coordinate information about the positioning index center 852 in the superwide-angle image picked up by the image pickup unit 40, and saves them as history information. After that, the overall control CPU 101 calculates the relationship of the extraction center position of the image and the face direction of the user by combining the information extracted from the obtained

history information. Furthermore, in this method, the information extracted from the history information may be limited to the information obtained when the user looks at the positioning index 851. The information is limited using the information about the in-camera 805 and face sensor 806 obtained by the calibrator 850 during movement of the calibrator 850. Thereby, the information obtained when the user is looking away is no longer extracted from the history information, which raises the accuracy of calculation of the relationship.

[0454] Moreover, the display-apparatus controller 801 may transmit a measurement value of the angular speed sensor 807 to the camera body 1 together with the calibration instruction. In this case, the overall control CPU 101 obtains movement information showing a moving locus of the calibrator 850 by the user and the position and posture of the calibrator 850 from the transmitted measurement value of the angular speed sensor 807. The movement information is also saved as the history information. Thereby, the calibration operation can be performed easily and correctly on the basis of the movement information based on the measurement value of the angular speed sensor 807, the face direction detected by the face direction detection unit 20, and the positional coordinate information about the positioning index center 852 in the superwide-angle image picked up by the image pickup unit 40.

[0455] In this case, the movement information based on the measurement value of the angular speed sensor 807 should be coincident with the movement information based on the positional coordinate information about the positioning index 851. Accordingly, when the measurement value of the angular speed sensor 807 is used, it is required to synchronize communication between the camera body 1 and the calibrator 850.

[0456] As mentioned above, the second embodiment describes the calibration method that enables to associate the face direction of the user with the

center position of the target visual field 125 set in the superwide-angle image irrespective of individual difference and adjustment difference. In the meantime, the present invention is not limited to the various configurations exemplified in the second embodiment and various modifications are available within the scope of the present invention.

[0457] Next, a third embodiment will be described. As shown in FIG. 11A through FIG. 11F that are used to describe the recording-direction/area determination process (see the step 300 in FIG. 7A and FIG. 7D), the FOV angle of the outermost periphery of the effective projection area 122 of the image pickup lens 16 is about 180°. Accordingly, when the user who wears the camera body 1 around the neck turns the head upward after pressing the start switch 14, a user's own jaw 134 appears in a frame image as shown in FIG. 24. If the image in the observation direction should be extracted in this state, the jaw of the user is recorded. Such an image cannot be a desired image because the user does not want to record the own jaw when turning the head upward. Furthermore, the image in which the bottom of the own jaw appears may be an image that the user does not want to show to others.

[0458] Consequently, this embodiment restricts extraction of an image in order to avoid such a situation where the user's jaw 134 appears in a recorded image.

[0459] As described in the face direction detection process (see FIG. 7C) in the first embodiment, the face direction detection unit 20 employs a method that obtains a face image by extracting infrared reflection intensity as a two-dimensional image by the infrared detection device 27.

[0460] The image pickup lens 16 and the face direction detection window 13 are fixed to the camera body 1. Accordingly, the position of the user's jaw in the frame image obtained from the solid state image sensor 42 can be specified on

the basis of values (an arrangement position, an arrangement angle, and a detection range) of the face direction detection window 13, values (an arrangement position, an arrangement angle, and an FOV) of the image pickup lens 16, and a positional relationship of the face direction detection window 13 and face of the user. Accordingly, in this embodiment, the position of the image recording frame is determined in the step S304 in FIG. 7D so as to avoid an area in which the user's jaw is located.

[0461] That is, in this embodiment, when the face direction of the user is moving upwardly from the front, the movement of the image recording frame is restricted depending on the position of the user's jaw detected through the face direction detection window 13.

[0462] When the positional relationship of the image pickup lens 16 and face direction detection window 13 and the arrangement angles, etc. are adjustable, the position of the user's jaw in the frame image can be specified depending on the positional relationship and the arrangement angles. Since such specifying method is a well-known technique, its description is omitted.

[0463] Although the solid state image sensor 42 according to this embodiment includes an infrared cut filter that intercepts infrared light, this infrared cut filter is not perfect. Accordingly, when the object is close to the infrared LEDs 22, an infrared light component cannot be cut completely. Accordingly, the solid state image sensor 42 detects the infrared light from the area of the user's jaw. Accordingly, this embodiment prevents the user's jaw from entering into the image recording frame by detecting the area of the user's jaw including the infrared component from the image obtained from the solid state image sensor 42.

[0464] That is, the V-signal for the solid state image sensor 42 is synchronized with the V-signal for the face direction detection shown in FIG. 9,

and each frame image is picked up by the solid state image sensor 42. Hereinafter, a frame image picked up by the solid state image sensor 42 during a period (LED lighting period) when the infrared LEDs 22 are lightened is called an entire lighting image. Moreover, a frame image picked up by the solid state image sensor 42 during a period (LED extinction period) when the infrared LEDs 22 are extinguished is called an entire extinction image. After that, the user's jaw is extracted from a difference image (FIG. 28A) of the entire lighting image and entire extinction image in the same manner as the extraction of the user's face described using FIG. 8E. Then, the image recording frame is set so as not to include the area of the user's jaw that is extracted. Actually, it is preferable to specify the area of the user's jaw after removing minute difference by applying a LPF or a minimum value filter to the difference image by an image processing unit (not shown).

[0465] It should be noted that a configuration in which the V-signal for the face direction detection is not synchronized with the V-signal for the solid state image sensor 42 can also be achieved. FIG. 25 is a timing chart showing a case where the V-signal for the face direction detection that is generated by the infrared detection device 27 and the V-signal for the solid state image sensor are asynchronous. The V-signal for the solid state image sensor 42, an exposure state of the solid state image sensor 42 (image pickup timing), the V-signal for the face direction detection, an exposure state of the face detection (image pickup timing by the sensor of the infrared detection device 27), and the lighting state of the infrared LEDs 22 (LED lighting timing) are shown in FIG. 25 in the order from the top.

[0466] In the example in FIG. 25, the solid state image sensor 42 is exposed at 30fps and the sensor of the infrared detection device 27 used for the face detection is exposed at 10fps. The infrared LEDs 22 blink at 5 Hz, and the face

detection is performed 5 times in 1 second in this example. In this way, since the cycle of the solid state image sensor 42 does not match the cycle of the face detection, the frame images obtained by the solid state image sensor 42 are not only the entire lighting images and the entire extinction images. That is, as shown in FIG. 26A and FIG. 26B, the frame images obtained by the solid state image sensor 42 include frame images each of which consists of an area illuminated by the infrared LEDs 22 during exposure and an area exposed during a period when the infrared LEDs 22 are extinguished. Hereinafter, the area illuminated by the infrared LEDs 22 during exposure is called an "exposure area during LED lighting", and the area exposed during a period when the infrared LEDs 22 are extinguished is called an "exposure area during LED extinction".

[0467] As mentioned above, the area of the user's jaw can be specified by comparing an entire lighting image (for example, the second frame image in FIG. 25) with an entire extinction image (for example, the fourth frame image in FIG. 25). However, the user's jaw appears only in a part of an upper portion of the frame image taken by the solid state image sensor 42. Accordingly, the area of the user's jaw can be specified by comparing a frame image of which an upper portion is the exposure area during LED lighting and a lower portion is the LED extinction exposure area (for example, the third frame image in FIG. 25, see FIG. 26B) with an entire extinction image (for example, the fourth frame image in FIG. 25)

[0468] On the contrary, the area of the user's jaw can be specified by comparing a frame image of which an upper portion is the exposure area during LED extinction and a lower portion is the exposure area during LED lighting (for example, the first frame image in FIG. 25, see FIG. 26A) with an entire lighting image (for example, the second frame image in FIG. 25).

[0469] Next, how to obtain the maximal area where the user's jaw appears is

described.

[0470] The calibration described in the second embodiment obtains the superwide-angle image in the step S3108 by picking up with the image pickup unit 40 in each of the cases where the user turns the face in the five directions (front, upper right, lower right, upper left, and lower left). Since the face direction is detected by the face direction detection unit 20 also in obtaining the superwide-angle image, the infrared LEDs 22 are blinking. Accordingly, the area of the user's jaw can be specified in the step S3108 by obtaining the difference image of the entire lighting image and the entire extinction image as mentioned above and by converting it into a binary image as shown in FIG. 28B if needed.

[0471] At this time, an area that is a target of the detection of the user's jaw is a designed area determined beforehand in which the user's jaw may appear. For example, since the user's jaw never appears in the lower half of the superwide-angle image obtained by the configuration shown in FIG. 1B during normal usage, the designed area of the detection of the user's jaw is the upper half (50%) of the superwide-angle image. This designed area is an example and it can be changed suitably according to the positional relationship of the face direction detection unit 20 and the image pickup unit 40, the FOV angle of the image pickup lens 16, etc.

[0472] In this embodiment, as shown in FIG. 28C, the maximal area in which the user's jaw may appear is obtained as a logical sum of five binary images converted from five difference images between entire lighting images and entire extinction images that are respectively obtained when the user faces the above-mentioned five directions. Moreover, the maximal area in which the user's jaw may appear can be obtained even when the V-signal for the face direction detection and the V-signal for the solid state image sensor 42 are asynchronous as

mentioned above.

[0473] Next, a frame correction process for image recording according to this embodiment will be described in detail using a flowchart in FIG. 27A. Since contents from a preparation process in a step S8001 to an image pickup process in a step S8004 among the process in FIG. 27A are the same as that in the steps S100 through S400 in FIG. 7A described in the first embodiment, their descriptions are omitted.

[0474] In a step S8005, the overall control CPU 101 executes a determination process of appearance of a user that checks whether the user appears in the frame image picked up by the solid state image sensor 42. The determination process of appearance of a user is mentioned later using FIG. 27B.

[0475] As a result of the determination process of appearance of a user in the step S8005, the overall control CPU 101 determines whether the user appears in the frame image in a step S8006. As a result of the determination, when the user appears in the frame image (YES in the step S8006), the process proceeds to a step S8007. In the meantime, when the user does not appear in the frame image (NO in the step S8006), the process proceeds to a step S8008 directly. It should be noted that it may be determined whether the user oneself appears only in the designed area that is defined beforehand as the area in which the user's jaw may appear as mentioned above. Moreover, for example, when the user wants to exclude an arm of a hand, which is reached ahead to take something, from the image recording frame, the entire frame image may become a target area of the determination.

[0476] In the step S8007, the overall control CPU (a determination unit) 101 corrects the recording-direction/area determined in the step S8003 so that the user will not appear in the area. That is, when the user moves the face so that the observation direction of the user moves from the front to the upper side gradually,

the recording direction follows the movement of the observation direction. However, when the user's jaw is detected in the step S8005, the recording direction is controlled so as not to move upward more than that. When the user moves the face in an oblique direction and the user's jaw is detected in the step S8005, the recording direction is controlled so as not to move in the moving direction (or only its vertical component direction) of the face.

[0477] After the recording-direction/area is determined so as not to record a part of the user body in this way, the progress proceeds to a step S8008 and the development process of the area is performed. Since the contents from the recording area development process in the step S8008 to the secondary recording process in a step S8013 are the same as that in the steps S500 through S1000 in FIG. 7A described in the first embodiment, their descriptions are omitted.

[0478] Next, the determination process of appearance of a user in the step S8005 executed by the overall control CPU 101 will be described using a flowchart in FIG. 27B.

[0479] In a step S8101, it is first determined that the infrared LEDs 22 were lightened during the image pickup operation in the step S8004. When the entire lighting image is used to specify the area of the user's jaw, it is determined whether the LEDs continued to be lighted over a period exposing the whole area of the frame image. In the meantime, when the exposure area during LED lighting described using FIG. 26A and FIG. 26B is used to specify the area of the user's jaw, it is determined whether the LEDs were lightened over a period exposing an area in which the user may appear in the frame image.

[0480] When the infrared LEDs 22 were lightened during the image pickup operation (YES in the step S8101), the process proceeds to a step S8102. In the step S8102, a frame image picked up during an extinction period of the infrared LEDs 22 is obtained from a buffer, and then, the process proceeds to a step

S8104. In the meantime, when the infrared LEDs 22 were extinguished during the image pickup operation (NO in the step S8101), the process proceeds to a step S8103. In the step S8103, a frame image picked up during a lighting period of the infrared LEDs 22 is obtained from the buffer, and then, the process proceeds to the step S8104.

[0481] In the step S8104, the overall control CPU (an obtainment unit) 101 obtains a difference image of the frame image (a first frame image) obtained from the buffer in the step S8102 or step S8103 and the frame image (a second frame image) picked up in the step S8004. It is also preferable to remove minute difference as mentioned above.

[0482] In a step S8105, the overall control CPU (a first specifying unit) 101 specifies the area in which a part of the user's body appears from the difference image obtained in the step S8104.

[0483] In a step S8106, the current frame image picked up in the step S8004 and the lighting state of the infrared LEDs 22 in picking up the image are stored into the buffer, and then this process is finished.

[0484] It should be noted that the primary memory 103 is used as the buffer in this embodiment. When the amount of the data stored into the buffer in the step S8106 is relatively large, the data may be compressed into about half before storing to the buffer. Moreover, since the frame image picked up during the lighting period of the infrared LEDs 22 and the frame image picked up during the extinction period of the infrared LEDs 22 are not necessarily alternately obtained as described using FIG. 25, it is necessary to hold a plurality of frame images in the buffer.

[0485] Moreover, when the area in which the user's jaw appears is specified in the step S8105, it is also preferable to calculate beforehand an area in which the user's jaw may appear in each frame image picked up by the solid state image

sensor 42. In such a case, the user's jaw is detected only from the calculated area and movement of the recording area is restricted so as to avoid the user's jaw. This prevents the user from erroneously specifying something other than the jaw. Specifically, the overall control CPU (an area calculation unit) 101 sets the maximal area where the user's jaw appears shown in FIG. 28C mentioned above to the area in which the user's jaw may appear. Moreover, when an area in which the user's jaw cannot appear is calculated beforehand, the user's jaw may be detected on the basis of the calculated area and movement of the recording area may be restricted so as to avoid the user's jaw.

[0486] It should be noted that the overall control CPU (a second specifying unit) 101 is able to specify the area in which the user's jaw appears by object recognition over the frame image instead of specifying the area using the above-mentioned difference image. In this case, the overall control CPU 101 preferably employs a learned model using deep learning that outputs information about the area in which the user's jaw appears in each frame image when each frame image is input. This learned model preferably learns using a user's skin color, which is detected from the image obtained by the in-camera 805 included in the display apparatus 800 in performing the calibration mentioned above, as a learning parameter. This enables to recognize the area in which the user's jaw appears in each frame image more correctly. That is, the display-apparatus controller 801 specifies the skin color of the user's face from the in-camera image 858 obtained in the step S3106 in FIG. 21 and transmits the specified skin color to the camera body 1 as skin color information. The camera body 1 stores the transmitted skin color information in the primary memory 103 and uses it as the learning parameter. The skin color information is preferably stored into the internal nonvolatile memory 102 too so that it can be used even after the power is resupplied. Moreover, it is also preferable to use a shape of the user's jaw and a

moving pattern thereof as learning parameters.

[0487] Although the user's jaw is described as an example of an article that is wanted to be excluded from the image recording frame in this embodiment, the article is not limited to the jaw. For example, a user's arm of a hand that is reached ahead or user's hair in turning a face downward may be subjected. In this case, it is necessary to select frame images to be compared from among the frame images shown in FIG. 25 depending on an article that is wanted to be excluded from the image recording frame. Such a selection can be performed by a person skilled in the art. Moreover, when the learned model using the deep learning is used, it is also preferable to select optimal learning parameters, such as a color of clothes that the user wears, a hair color of the user, in addition to the skin color of the user.

[0488] Next, a fourth embodiment will be described. In this embodiment, a process when the target visual field 125 (a frame position for recording an image) departs from the effective projection area 122 depending on a user's observation direction will be described using FIG. 29 through FIG. 31. Since the fourth embodiment is basically identical to the first embodiment in the configuration, only a configuration peculiar to the fourth embodiment is described hereinafter.

[0489] FIG. 29 is a schematic diagram describing the target visual field 125 and image height and shows a state where the user observes an observation direction vp that is upper left from the center. FIG. 30 is a schematic diagram for describing an angle of an observation direction and a coordinate system.

[0490] Wide-angle lenses are classified into several types based on projection methods. In this embodiment, a case where an equidistant projection lens is employed as the image pickup lens 16 is described. The equidistant projection lens is designed so that image height (a distance from the center of an

image) is proportional to an incident angle to the lens.

[0491] Accordingly, when the focal length of the lens is f mm and the incident angle is θ rad., the image height r mm is found by a formula 2 (Provided that the front is 0 rad).

$$r[mm] = f[mm] \cdot \theta[rad] \quad Formula\ 2$$

[0492] As shown in FIG. 30, a Cartesian coordinate system that includes an x-coordinate in a lateral direction (a yaw direction, a horizontal direction), a y-coordinate in an up-down direction (a pitch direction, a vertical direction), and a z-coordinate in an optical axis direction (a front direction) is assumed. And a case where a user's observation direction is projected to a pseudo plane 170 of z= 1 is considered. At this time, the vector of a front direction is denoted by a formula 3 and the vector of the user's observation direction is denoted by a formula 4.

$$\vec{a} = (0,0,1) \quad Formula\ 3$$

$$\vec{b} = (\tan(yaw), \tan(pitch), 1) \quad Formula\ 4$$

[0493] Moreover, a corner vector of the target visual field 125 is denoted by a formula 5. Where a horizontal field angle is ωy and a vertical field angle is ωp.

$$\vec{c} = \left(\tan\left(yaw \pm \frac{\omega_y}{2}\right), \tan\left(pitch \pm \frac{\omega_p}{2}\right), 1\right) \quad Formula\ 5$$

[0494] The observation direction vector (formula 4) in FIG. 30 is equivalent to the observation direction vp in FIG. 29. Moreover, the corner vector (formula 5) in FIG. 30 is equivalent to image height r1 in FIG. 29. Although the corner vector (formula 5) of the target visual field 125 indicates the upper left corner in FIG. 30, four corners can be indicated by combining two symbols "±" included in the formula 4.

[0495] At this time, an angle φ formed between the vector (formula 3) of the front direction and the corner vector (formula 4) of the target visual field 125 is

denoted by a formula 6.

$$\cos\varphi = \frac{1}{\sqrt{\tan\left(yaw \pm \frac{\omega_p}{2}\right)^2 + \tan\left(yaw \pm \frac{\omega_y}{2}\right)^2 + 1}} \quad Formula\ 6$$

[0496] When φ calculated by the formula 6 is substituted into θ of the formula 2, the image heights of the four corners of the target visual field 125 are obtained.

[0497] Particularly, when the user directs the face obliquely, a corner of the target visual field 125 may protrude from the effective projection area 122 of the image pickup lens 16. In this case, the part of the target visual field 125 that becomes outside of the effective projection area 122 will be recorded as an image of which resolution is extremely bad, a dark image due to a phenomenon of decreased marginal light amount, or a black image into which external light does not enter. Accordingly, in this embodiment, when a corner of the target visual field 125 becomes the outside of the effective projection area 122, the position of the target visual field 125 is corrected so as to approach the optical center than the user's observation direction.

[0498] Although the example of the equidistant projection lens is described in this embodiment, image height of a corner of the target visual field 125 is calculated by a formula 7 when using a solid-angle projection lens and is calculated by a formula 8 when using an equal-solid-angle projection lens.

$$\mathrm{r}[mm] = 2 \cdot f[mm] \cdot \tan\frac{\theta[rad]}{2} \quad Formula\ 7$$

$$\mathrm{r}[mm] = 2 \cdot f[mm] \cdot \sin\frac{\theta[rad]}{2} \quad Formula\ 8$$

[0499] In this way, the image height can be suitably calculated depending on the property of the image pickup lens 16 used.

[0500] When the user directs the face upward by 30° and rightward by 45°

and when the horizontal field angle ωy is 50° and the vertical field angle ωp is 50°, pitch±(ωp/2) becomes (30±50/2) ° and yaw±(ωy/2) becomes (45±50/2) °. The values of φ are found by substituting these angles into the formula 6. And the image heights r that are obtained by substituting φ into θ of the formula 2 denote the four corners of the target visual field 125.

[0501] That is, the image heights of the upper right corner, lower right corner, lower left corner, and upper lower corner of the target visual field 125 respectively become 72.10°, 70.01°, 20.52°, and 55.84°.

[0502] A case where the user further turns the face to the periphery and a corner of the target visual field 125 becomes the outside of the effective projection area 122 is described. Since the part of the target visual field 125 that becomes outside of the effective projection area 122 is bad in the resolution and is dark due to the phenomenon of decreased marginal light amount of the image pickup lens 16, the part concerned cannot be used in order to keep visual aspect of the image. Accordingly, the image quality is guaranteed by correcting the position of the target visual field 125 so as to approach the optical center than the actual user's observation direction.

[0503] In this embodiment, the method that corrects the position of the target visual field 125 so as to approach the optical center is described using FIG. 31.

[0504] FIG. 31 is a view showing how to correct the position of the target visual field 125 when a corner of the target visual field 125 protrudes from the effective projection area 122 in this embodiment. It should be noted that this correction is executed by the overall control CPU (a frame position determination unit) 101 in calculating the position and size of the image recording frame in the step S304 of the flowchart in FIG. 7D described in the first embodiment.

[0505] The image heights of the target visual field 125 are calculated by the

formula 6 and the formula 2 from the user's observation direction as mentioned above. For example, when the center 150 of the user's observation direction is directed to a periphery, the upper right corner of the target visual field 125 shown by a dotted-line rectangle protrudes from the effective projection area 122. In such a case, the yaw angle and pitch angle are adjusted toward the optical center so that the whole area of a new target visual field 153 falls within the effective projection area 122.

[0506] In the Cartesian coordinate system of which the front is 0° as shown in FIG. 30 mentioned above, an angle β directed from the user's observation direction to the center of the effective projection area 122 is found by the formula 9.

$$\beta[°] = \arctan\frac{\tan(pitch)}{\tan(yaw)} + 180[°] \quad Formula\ 9$$

[0507] When the yaw angle is 0° (i.e., the denominator tan(yaw) becomes 0), β is 270° (downward) in a case where the pitch angle is positive (upward) or β is 90° (upward) in a case where the pitch angle is negative (downward). A case where both the yaw angle and pitch angle are 0° is not covered by the calculation formula 9 because it is obvious not to need the correction. Moreover, a case where the yaw angle becomes 180° is not assumed because the user's observation direction cannot be directed to right behind during normal usage.

[0508] For example, the target visual field 125 in FIG. 31a shows a case where the horizontal field angle is 50°, the vertical field angle is 50°, and the center 150 of the user's observation direction is directed upward by 45° in the pitch direction and rightward by 60° in the yaw direction. In this case, the image heights of the upper right corner, lower right corner, lower left corner, and upper lower corner respectively become 85.14°, 85.00°, 38.28°, and 70.57° from the formula 1 and the formula 5. When a lens of which the FOV angle is 170° is

used, the upper right corner of the target visual field 125 becomes the outside of the effective projection area 122 as shown in FIG. 31.

[0509] Moreover, the angle β becomes 210° from the formula 9. Accordingly, the center 150 of the observation direction is moved to a center 152 of an observation direction along a straight line that connects the center of the effective projection area 122 and the user's observation direction (i.e., in the direction of the angle β) so that the upper right corner of the new target visual field 153 is inscribed to the effective projection area 122. In this way, the target visual field is brought to the center side of the effective projection area 122 so that all the four corners (frame position) of the target visual field will be set inside the effective projection area 122. In this example, the target visual field is specifically corrected so as to be moved in the lower-left direction.

[0510] Although the above description assumes that the optical center coincides with the center of the solid state image sensor 42, they may deviate due to a manufacture error. In this case, the target visual field can be brought to the center side of the solid state image sensor 42 simply. Moreover, it is also preferable to bring the target visual field to an optical center that is corrected by considering the manufacture error that is detected during manufacture and is stored in the internal nonvolatile memory 102.

[0511] Moreover, the image stabilization margin described in the first embodiment is omitted in order to simplify the description. When the target visual field is corrected by taking the image stabilization margin into consideration, this embodiment is applicable to the case where the image stabilization level is other than "OFF".

[0512] Next, a fifth embodiment will be described. The fourth embodiment shows the example that moves the target visual field to the optical center side when the target visual field 125 calculated from the user's observation

direction protrudes partially from the effective projection area 122. As compared with this, this embodiment shows an example that narrows the field angles of an extracted target visual field as shown in FIG. 32.

[0513] Since the fundamental configuration and calculation formulas of the fifth embodiment are the same as that of the fourth embodiment, only difference will be described.

[0514] The fourth embodiment describes how to find the image heights of the four corners of the target visual field 125 in the case where the horizontal field angle of the target visual field 125 is 50° and the vertical field angle is 50° and where the user directs the face upward by 45° and rightward by 60°. Furthermore, in the fourth embodiment, when it is determined that a corner of the target visual field 125 protrudes from the effective projection area 122 on the basis of the image heights found, the new target visual field 153 is set to the optical center side.

[0515] In the meantime, in this embodiment, when a corner of the target visual field 125 protrudes from the effective projection area 122, as shown in FIG. 32, a new target visual field 154 is established by narrowing the field angles of an extracted target visual field without moving the center 150 of the user's observation direction.

[0516] The field angles of the new target visual field 154 to be extracted are calculated using the formula 2 and the formula 6 so that the entire new target visual field 154 will fall within the effective projection area 122. That is, the image height of the upper right corner of the target visual field 125 shown by the dotted line in FIG. 31 is 85.14°, and protrudes from the effective projection area 122 of the lens of which the FOV angle is 170° as described in the fourth embodiment. Accordingly, the field angle of the target visual field 125 of the formula 6 is counted backward. As a result, the image height of the upper right

corner becomes 85.00° by narrowing the horizontal field angle to 49.7° and the vertical field angle to 49.7°. In this way, the field angles of the target visual field 154 is adjusted so as to fall within the effective projection area 122 of the lens of which the FOV angle is 170°.

[0517] After that, the image processing unit included in the overall control CPU 101 enlarges the image obtained in the target visual field 154 of which the field angles are narrowed to the pixel size of the original target visual field 125.

[0518] In this way, even when the user's observation direction is directed so peripherally that a part of the target visual field 125 protrudes from the effective projection area 122, the image quality is guaranteed.

[0519] Moreover, as also described in the fourth embodiment, when the target visual field is corrected by taking the image stabilization margin into consideration, this embodiment is applicable to the case where the image stabilization level is other than "OFF".

Other Embodiments

[0520] Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more

of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)^{TM}), a flash memory device, a memory card, and the like.

[0521] While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all equivalent structures and functions.

WHAT IS CLAIMED IS:

1. An image pickup apparatus comprising:

an observation direction detection unit that is adapted to be worn on a body part other than a head of a user and that is configured to detect an observation direction of the user;

an image pickup unit that is adapted to be worn on a body of the user and that is configured to pick up an image;

an image output unit configured to output an image in an image recording frame corresponding to the observation direction in the image picked up by the image pickup unit; and

a determination unit configured to determine if a part of the body of the user appears in the image, and, in a case where a part of the body of the user appears in the image, restrict the image recording frame such that the part of the body of the user does not appear in an output image.

2. The image pickup apparatus according to claim 1, wherein the observation direction detection unit is configured to detect the observation direction of the user as a three-dimensional observation direction.

3. The image pickup apparatus according to claim 1 or 2, wherein the observation direction detection unit is configured to output an observation direction in a lateral direction of a face of the user as an angle in a first detection direction and to output an observation direction in a vertical direction of the face of the user as an angle in a second detection direction perpendicular to the first detection direction.

4. The image pickup apparatus according to any one of claims 1 to 3, further comprising an area calculation unit configured to calculate a maximal area in which a part of the body of the user may appear in each fame image picked up

by the image pickup unit,

wherein the determination unit is configured to correct the image recording frame to an area in which a part of the body of the user does not appear in a case where the part of the body of the user appears in the maximal area of a frame image picked up by the image pickup unit.

5. The image pickup apparatus according to claim 4, further comprising a calibration unit configured to perform calibration of the observation direction detection unit using a calibrator that is connected to the image pickup apparatus through one of wireless connection and wired connection,

wherein the area calculation unit calculates the maximal area in performing the calibration.

6. The image pickup apparatus according to claim 4 or 5, wherein the observation direction detection unit includes an infrared radiation unit configured to radiate infrared light and an infrared detection unit configured to detect reflected light of the infrared light reflected from an object to be picked up.

7. The image pickup apparatus according to claim 6, further comprising an obtainment unit configured to obtain a difference image between a first frame image picked up by the image pickup unit when the infrared radiation unit radiates the infrared light and a second frame image picked up by the image pickup unit when the infrared radiation unit does not radiate the infrared light; and

a first specifying unit configured to specify an area in which a part of the body of the user appears from the difference image obtained by the obtainment unit,

wherein the determination unit is configured to exclude the area specified by the first specifying unit from the image recording frame.

8. The image pickup apparatus according to claim 7, wherein the infrared radiation unit configured to radiate the infrared light to at least the

maximal area among an area that can be picked up by the image pickup unit in the first frame image.

9. The image pickup apparatus according to any one of claims 1 to 6, further comprising a second specifying unit configured to specify an area in which a part of the body of the user appears in each frame image picked up by the image pickup unit by object recognition,

wherein the determination unit is configured to exclude the area specified by the second specifying unit from the image recording frame.

10. The image pickup apparatus according to claim 9, wherein the second specifying unit is configured to employ a learned model using deep learning that outputs information about the area in which the part of the body of the user appears in the frame image when the frame image is input.

11. The image pickup apparatus according to claim 10, wherein at least one of a skin color of the user, a color of clothes that the user wears, a hair color of the user, a shape of a jaw of the user, and a moving pattern of the jaw is used as a learning parameter in leaning of the learned model.

12. A control method for an image pickup apparatus, the control method comprising:

an observation direction detection step of detecting an observation direction of a user by an observation direction detection unit that is adapted to be worn on a body part other than a head of the user;

an image pickup step of picking up an image by an image pickup unit that is adapted to be worn on a body of the user;

an image output step of outputting an image in an image recording frame corresponding to the observation direction in the image picked up in the image pickup step; and

a determination step of determining if a part of the body of the user

appears in the image, and, in a case where a part of the body of the user appears in the image, restricting the image recording frame such that the part of the body of the user does not appear in an output image.

13. An image pickup apparatus comprising:

an observation direction detection unit that is adapted to be worn on a body part other than a head of a user and that is configured to detect an observation direction of the user;

an image pickup unit that is adapted to be worn on a body of the user and that is configured to pick up an image using an image pickup lens and an image sensor;

a frame position determination unit configured to determine a frame position of an image recording frame corresponding to the observation direction in the image picked up by the image pickup unit; and

an image output unit configured to output an image at the frame position in the image picked up by the image pickup unit,

wherein the frame position determination unit determines the frame position inside an effective projection area that is projected by the image pickup lens onto the image sensor.

14. The image pickup apparatus according to claim 13, wherein the frame position determination unit moves the center of the frame position to a center side of the effective projection area along a straight line that connects the center of the effective projection area and the observation direction in a case where a part of the frame position is located outside the effective projection area.

15. The image pickup apparatus according to claim 13, wherein the frame position determination unit sets the frame position inside the effective projection area by narrowing a field angle of an area extracted as the frame position in a case where a part of the frame position is located outside the

effective projection area.

16. The image pickup apparatus according to claim 14, wherein the frame position determination unit is configured to divide an angle of the observation direction into an angle pitch in a vertical direction and an angle yaw in a horizontal direction and to move the center of the frame position in a direction β denoted by a formula as follows:

$$\beta[°] = \arctan\frac{\tan(pitch)}{\tan(yaw)} + 180[°].$$

17. A control method for an image pickup apparatus, the control method comprising:

an observation direction detection step of detecting an observation direction of a user by an observation direction detection unit that is adapted to be worn on a body part other than a head of the user;

an image pickup step of picking up an image by an image pickup unit, which is adapted to be worn on a body of the user, using an image pickup lens and an image sensor;

a frame position determination step of determining a frame position of an image recording frame corresponding to the observation direction in the image picked up in the image pickup step; and

an image output step of outputting an image at the frame position in the image picked up in the image pickup step,

wherein the frame position is determined inside an effective projection area, which is projected by the image pickup lens onto the image sensor, in the frame position determination step.

18. A non-transitory computer-readable storage medium storing a control program that, when executed by an image pickup apparatus, causes the image pickup apparatus to perform the method according to claim 12.

19. A non-transitory computer-readable storage medium storing a control program that, when executed by an image pickup apparatus, causes the image pickup apparatus to perform the method according to claim 17.

Intellectual Property Office

Application No:	GB2210451.7	**Examiner:**	Matthew Males
Claims searched:	1-19	**Date of search:**	20 January 2023

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A	-	US 2015/0310263 A1 (ZHANG et al.) (ZHANG et al.) See Abstract; paragraph 0012, Figs 1, 4-7, for example.
A	-	EP 3163422 A1 (SONY CORP) EP 3163422 A1(SONY CORP) See Abstract; Figs 5-9, for example.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

Worldwide search of patent documents classified in the following areas of the IPC

G02B; G06F; G06V; H04N

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
H04N	0023/611	01/01/2023
G06F	0001/16	01/01/2006
G06F	0003/01	01/01/2006
H04N	0023/50	01/01/2023
H04N	0023/69	01/01/2023