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Dobashi

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(54) **IMAGING APPARATUS, METHOD FOR CONTROLLING IMAGING APPARATUS, AND STORAGE MEDIUM**

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G06T 5/00 (2006.01)
H04N 23/67 (2023.01)

(52) **U.S. Cl.**
CPC ***H04N 25/674*** (2023.01); ***G06T 5/003*** (2013.01); ***H04N 23/67*** (2023.01)

(58) **Field of Classification Search**
CPC H04N 5/3656
USPC 348/222.1
See application file for complete search history.

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(57) **ABSTRACT**

An apparatus includes an acquisition unit configured to acquire distance information that indicates a distance to a subject on each predetermined region in a captured image, a control unit configured to adjust a focus position, and a storage unit configured to store first distance information acquired by the acquisition unit in response to the adjusted focus position. The control unit readjusts the focus position based on the first distance information and second distance information acquired by the acquisition unit.

20 Claims, 14 Drawing Sheets

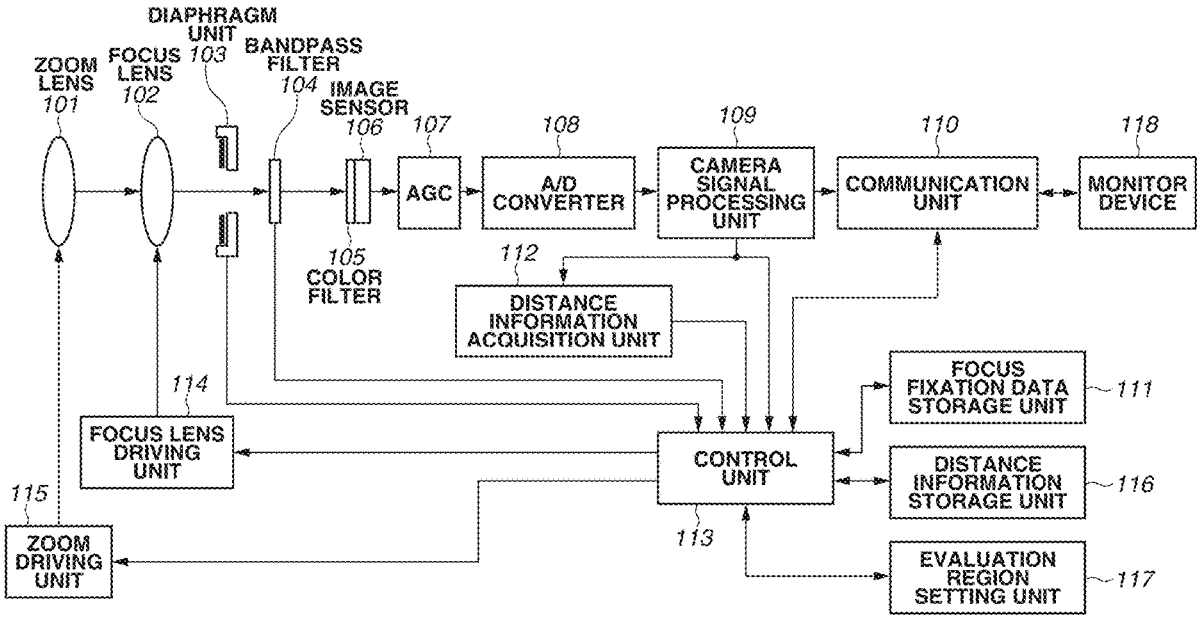


FIG.1

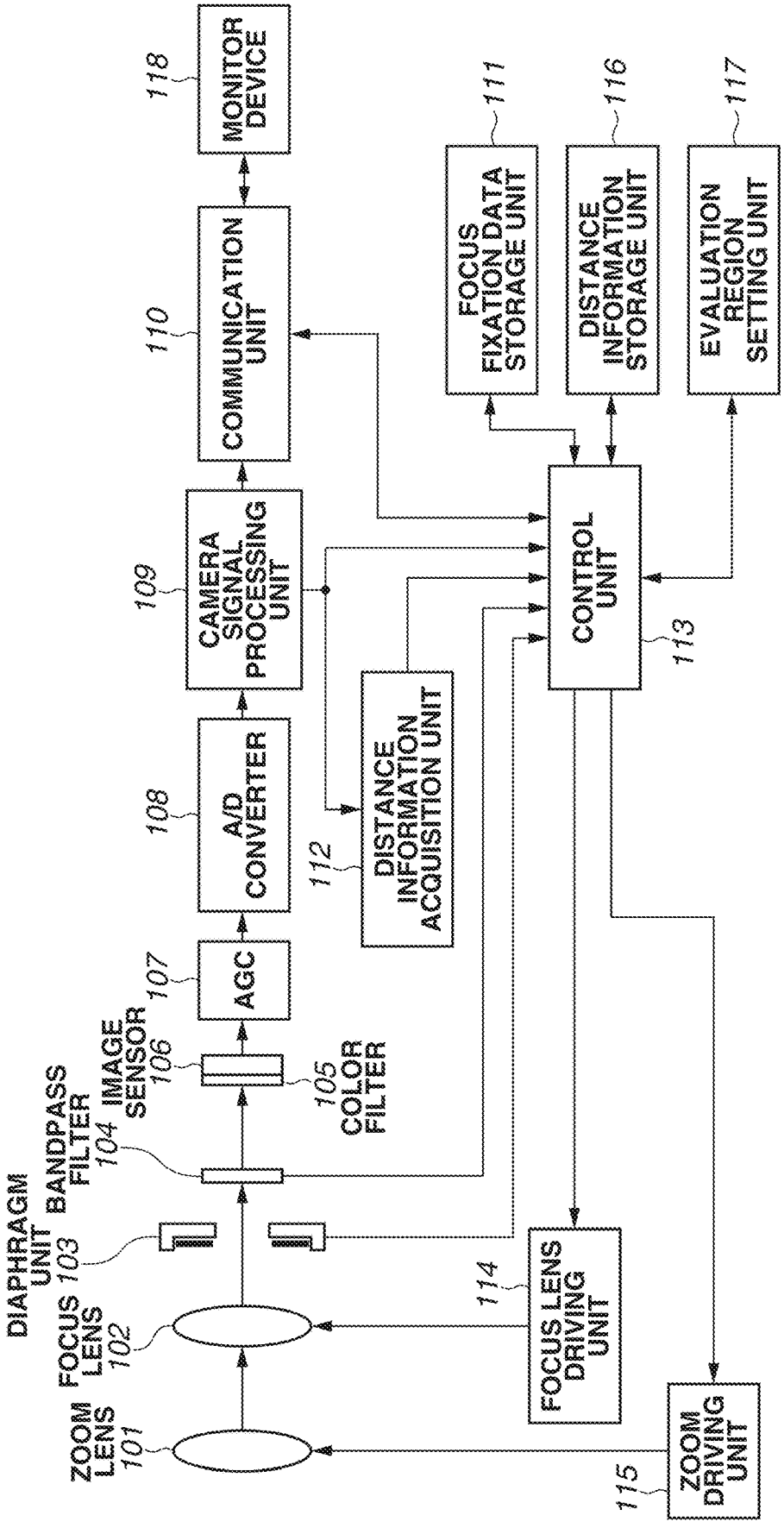

ZOOM LENS 101
FOCUS LENS 102
DIAPHRAGM UNIT 103
BANDPASS FILTER 104
COLOR FILTER 105
IMAGE SENSOR 106
AGC 107
A/D CONVERTER 108
CAMERA SIGNAL PROCESSING UNIT 109
COMMUNICATION UNIT 110
MONITOR DEVICE 118
FOCUS FIXATION DATA STORAGE UNIT 111
DISTANCE INFORMATION STORAGE UNIT 116
EVALUATION REGION SETTING UNIT 117
DISTANCE INFORMATION ACQUISITION UNIT 112
CONTROL UNIT 113
FOCUS LENS DRIVING UNIT 114
ZOOM DRIVING UNIT 115

FIG.2

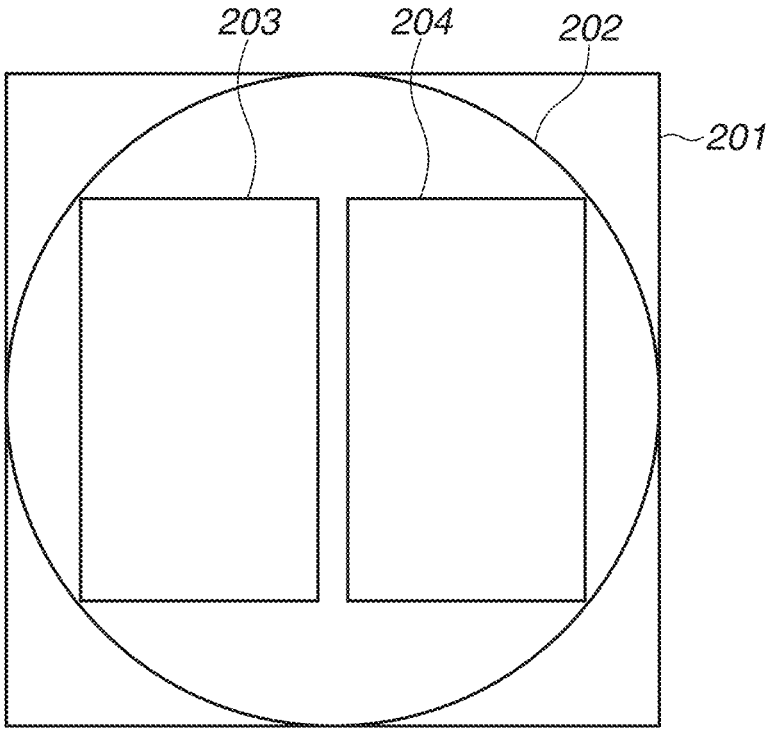


FIG.3

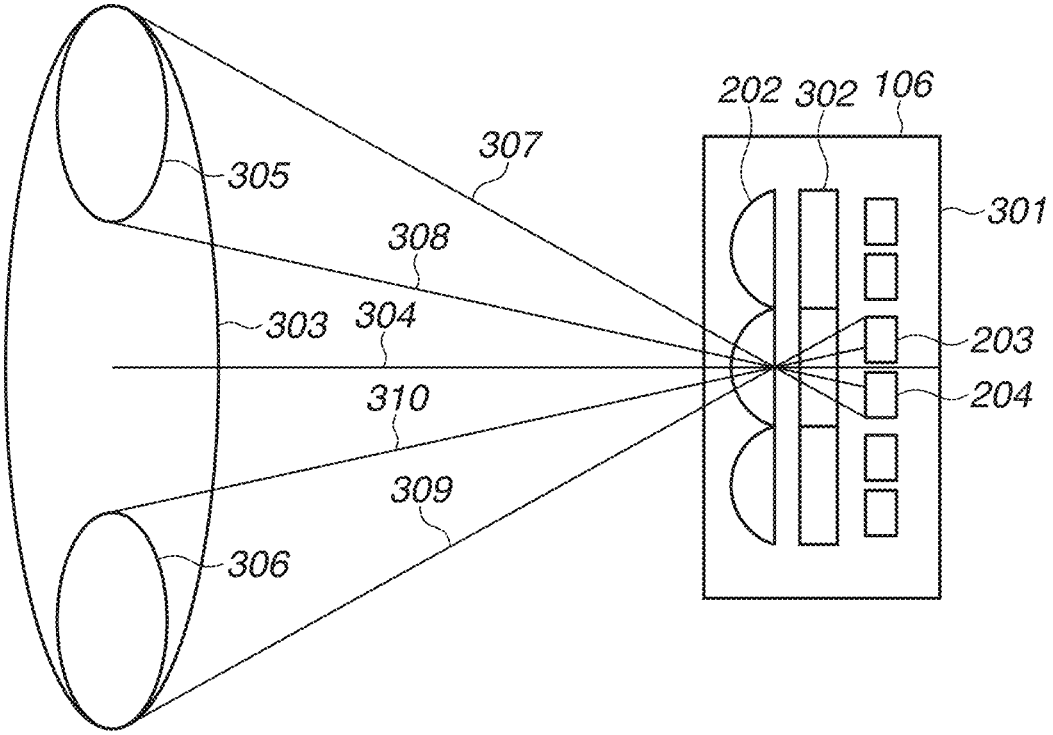


FIG.4

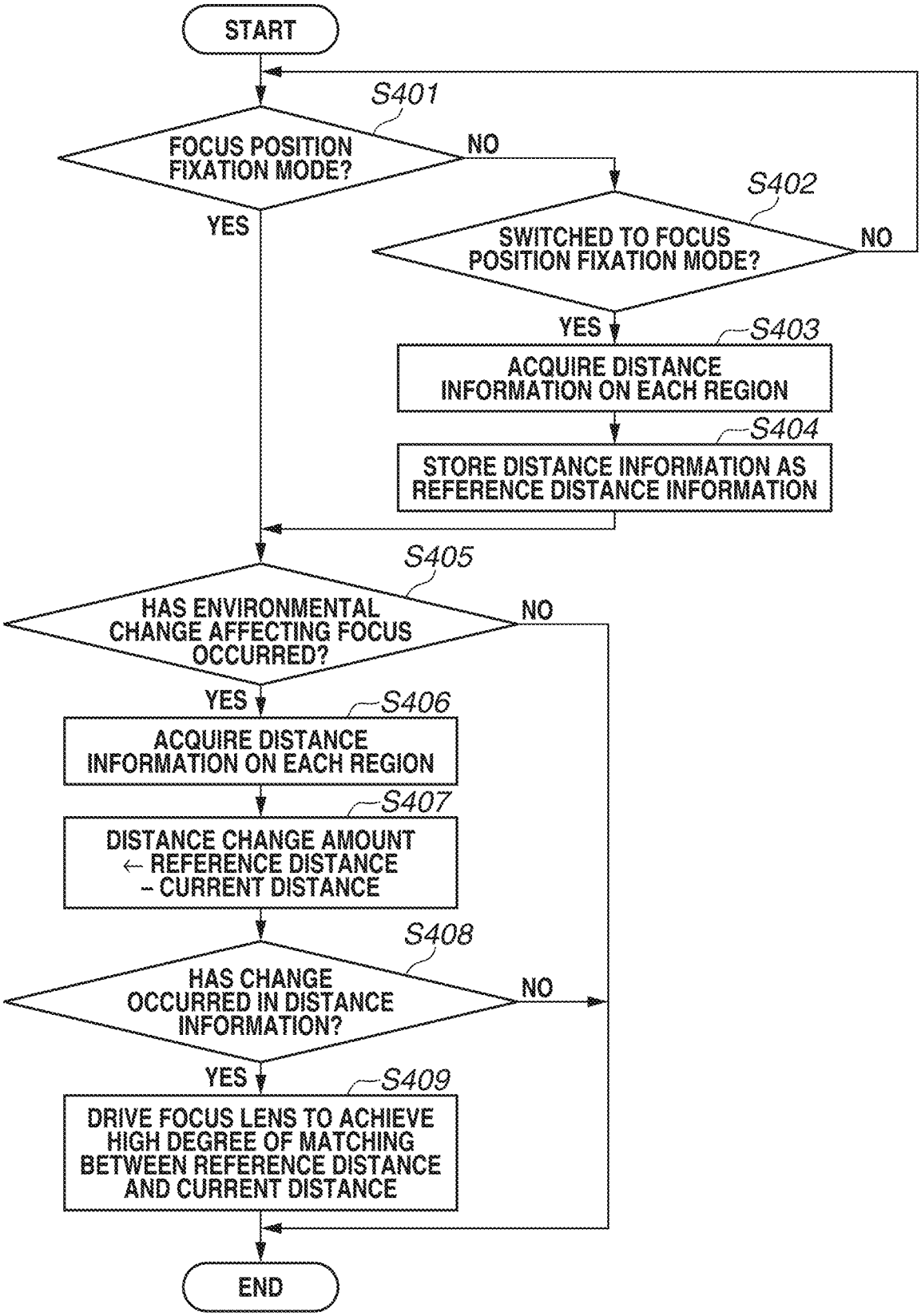

START
S401
FOCUS POSITION FIXATION MODE?
NO
YES
S402
SWITCHED TO FOCUS POSITION FIXATION MODE?
NO
YES
S403
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S404
STORE DISTANCE INFORMATION AS REFERENCE DISTANCE INFORMATION
S405
HAS ENVIRONMENTAL CHANGE AFFECTING FOCUS OCCURRED?
NO
YES
S406
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S407
DISTANCE CHANGE AMOUNT ← REFERENCE DISTANCE - CURRENT DISTANCE
S408
HAS CHANGE OCCURRED IN DISTANCE INFORMATION?
NO
YES
S409
DRIVE FOCUS LENS TO ACHIEVE HIGH DEGREE OF MATCHING BETWEEN REFERENCE DISTANCE AND CURRENT DISTANCE
END

FIG.5

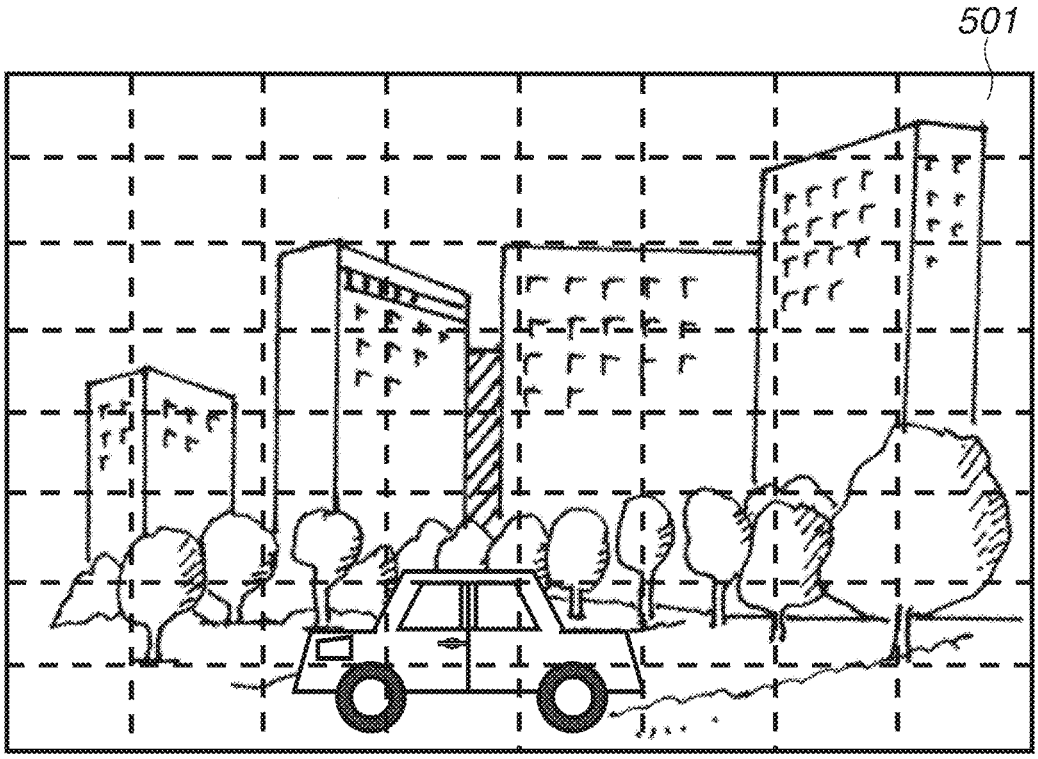


FIG.6

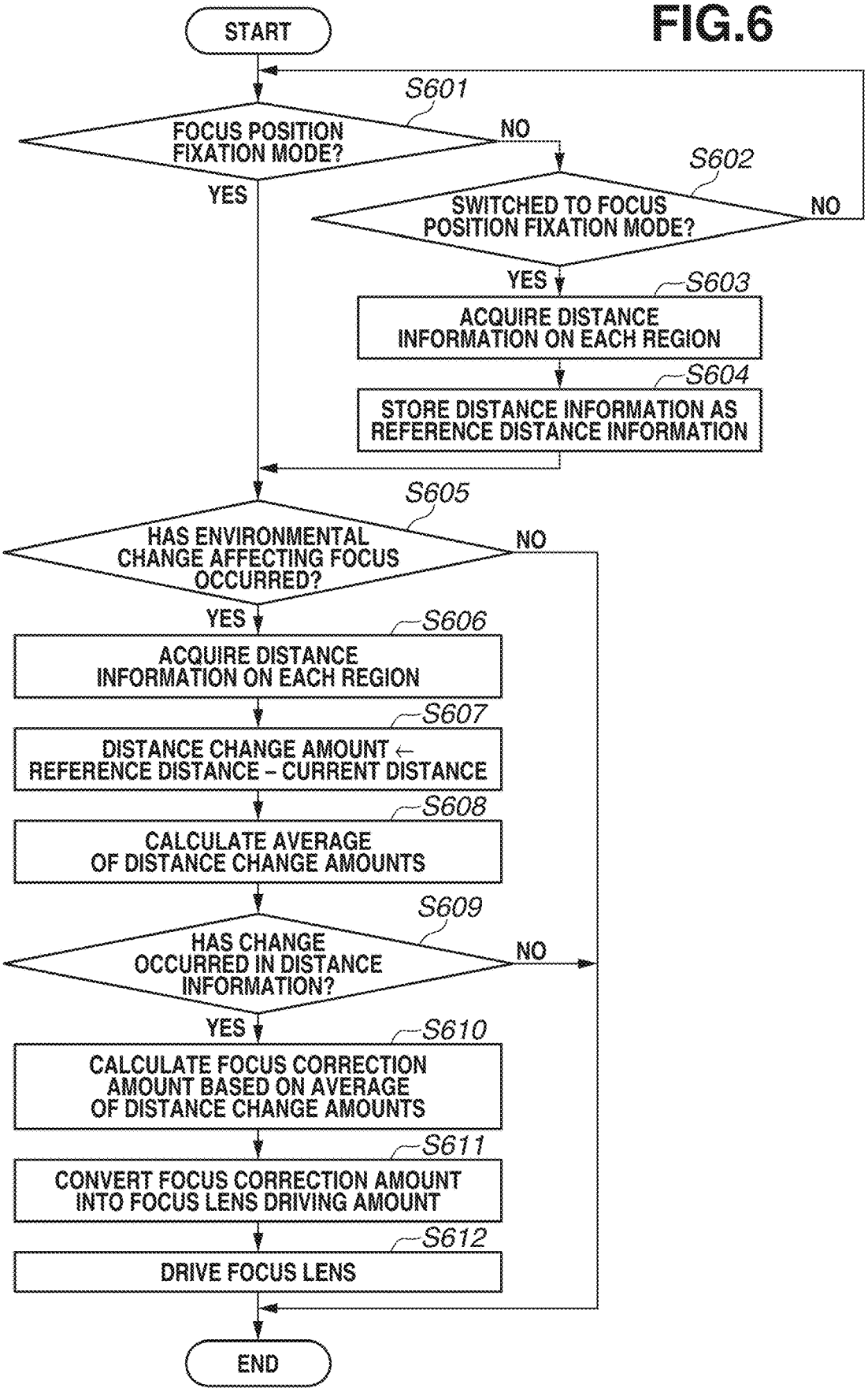

START
S601
FOCUS POSITION FIXATION MODE?
NO
YES
S602
SWITCHED TO FOCUS POSITION FIXATION MODE?
NO
YES
S603
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S604
STORE DISTANCE INFORMATION AS REFERENCE DISTANCE INFORMATION
S605
HAS ENVIRONMENTAL CHANGE AFFECTING FOCUS OCCURRED?
NO
YES
S606
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S607
DISTANCE CHANGE AMOUNT ← REFERENCE DISTANCE – CURRENT DISTANCE
S608
CALCULATE AVERAGE OF DISTANCE CHANGE AMOUNTS
S609
HAS CHANGE OCCURRED IN DISTANCE INFORMATION?
NO
YES
S610
CALCULATE FOCUS CORRECTION AMOUNT BASED ON AVERAGE OF DISTANCE CHANGE AMOUNTS
S611
CONVERT FOCUS CORRECTION AMOUNT INTO FOCUS LENS DRIVING AMOUNT
S612
DRIVE FOCUS LENS
END

FIG.7

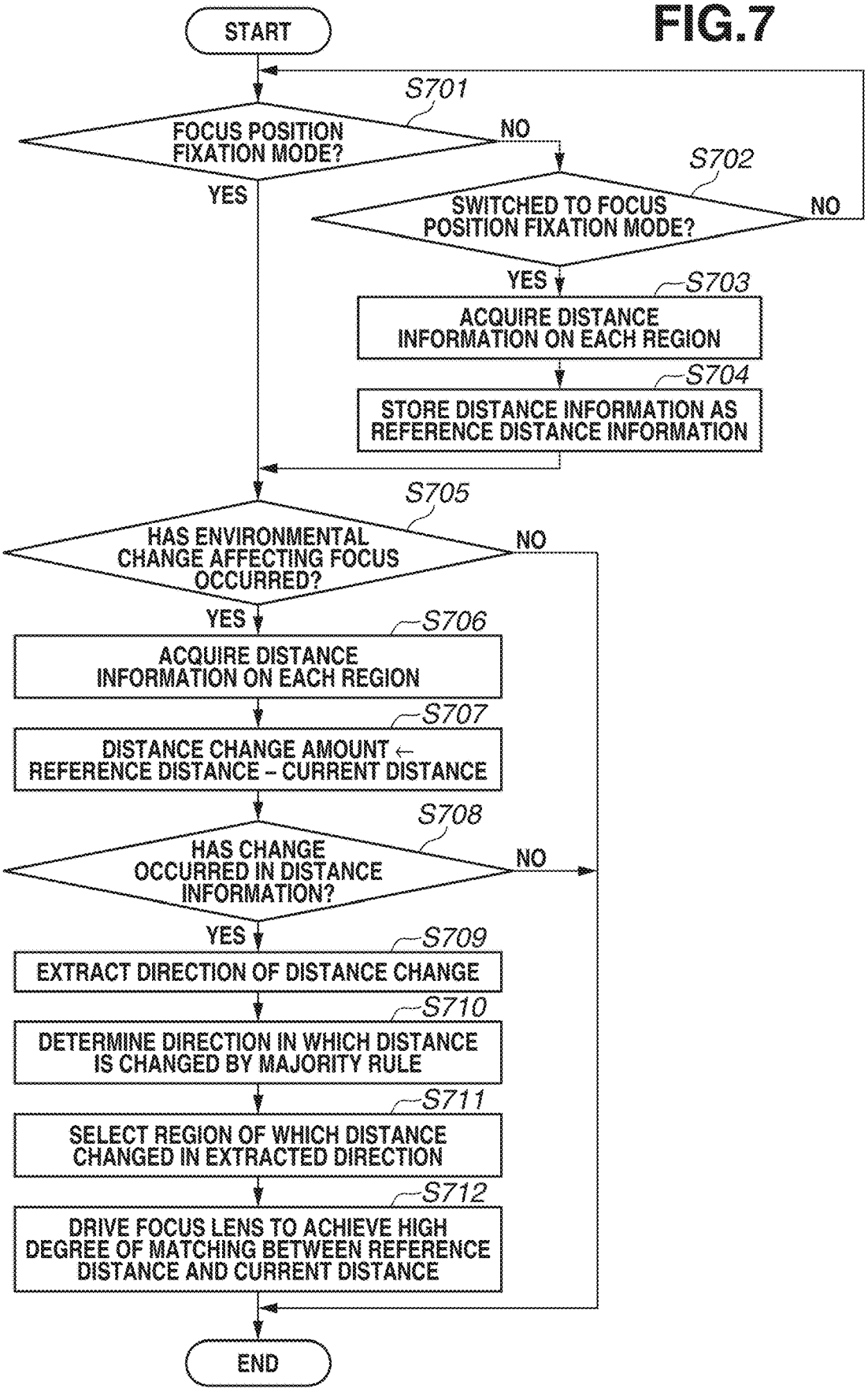

START
S701
FOCUS POSITION FIXATION MODE?
NO
YES
S702
SWITCHED TO FOCUS POSITION FIXATION MODE?
NO
YES
S703
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S704
STORE DISTANCE INFORMATION AS REFERENCE DISTANCE INFORMATION
S705
HAS ENVIRONMENTAL CHANGE AFFECTING FOCUS OCCURRED?
NO
YES
S706
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S707
DISTANCE CHANGE AMOUNT ← REFERENCE DISTANCE – CURRENT DISTANCE
S708
HAS CHANGE OCCURRED IN DISTANCE INFORMATION?
NO
YES
S709
EXTRACT DIRECTION OF DISTANCE CHANGE
S710
DETERMINE DIRECTION IN WHICH DISTANCE IS CHANGED BY MAJORITY RULE
S711
SELECT REGION OF WHICH DISTANCE CHANGED IN EXTRACTED DIRECTION
S712
DRIVE FOCUS LENS TO ACHIEVE HIGH DEGREE OF MATCHING BETWEEN REFERENCE DISTANCE AND CURRENT DISTANCE
END

FIG.8

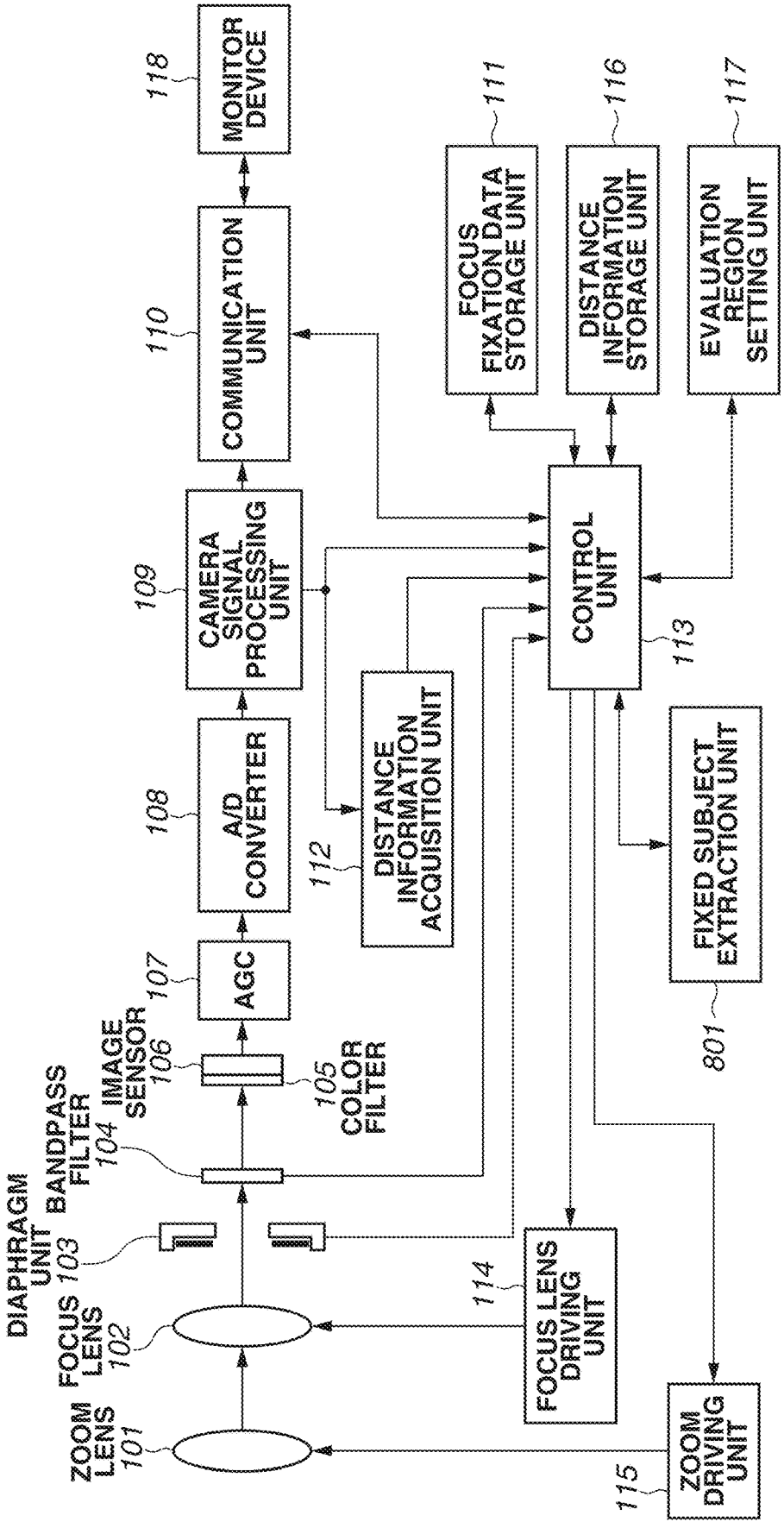

ZOOM LENS 101
FOCUS LENS 102
DIAPHRAGM UNIT 103
BANDPASS FILTER 104
COLOR FILTER 105
IMAGE SENSOR 106
AGC 107
A/D CONVERTER 108
CAMERA SIGNAL PROCESSING UNIT 109
COMMUNICATION UNIT 110
MONITOR DEVICE 118
FOCUS FIXATION DATA STORAGE UNIT 111
DISTANCE INFORMATION STORAGE UNIT 116
EVALUATION REGION SETTING UNIT 117
CONTROL UNIT 113
DISTANCE INFORMATION ACQUISITION UNIT 112
FIXED SUBJECT EXTRACTION UNIT 801
FOCUS LENS DRIVING UNIT 114
ZOOM DRIVING UNIT 115

FIG.9

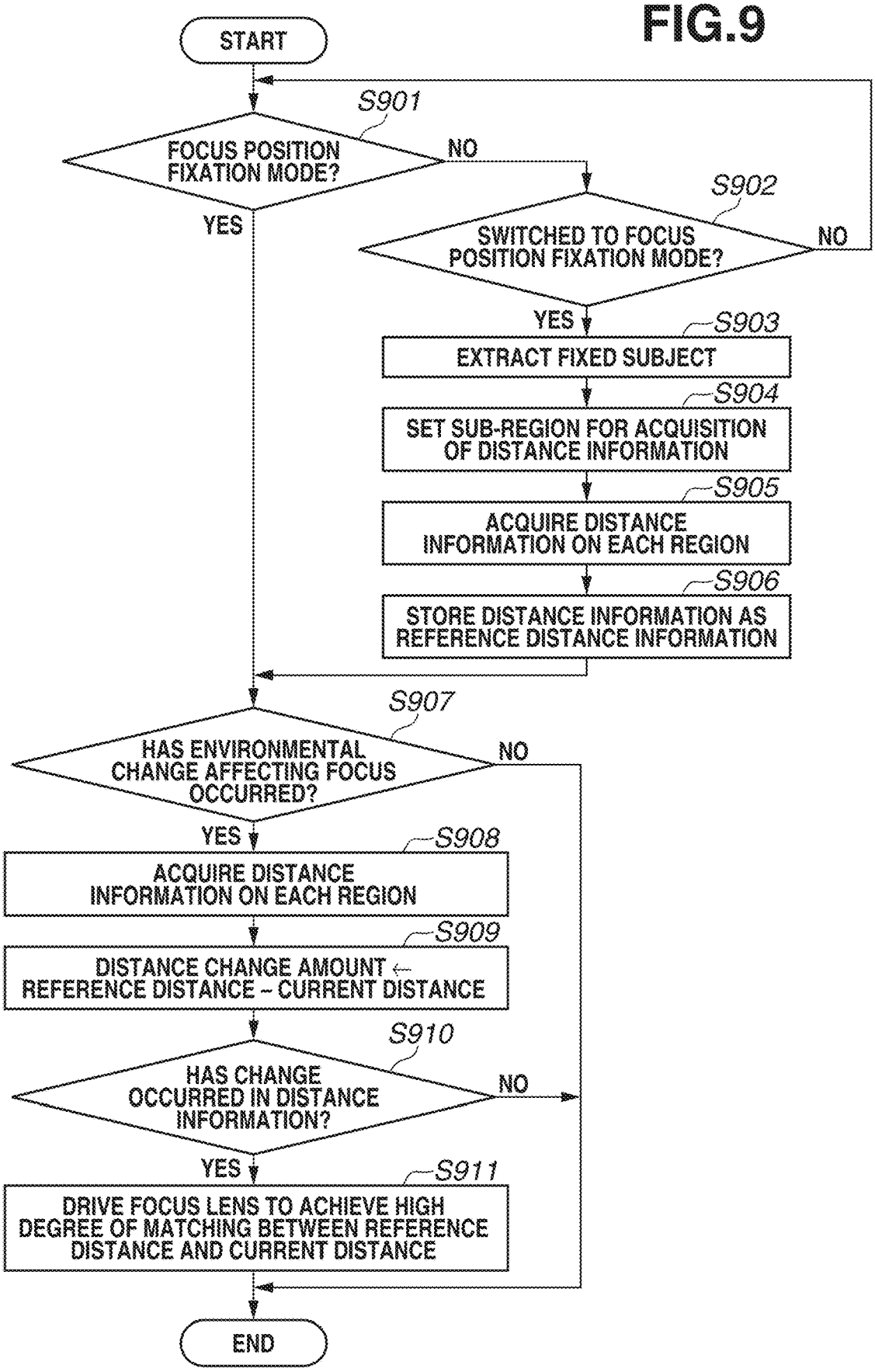

START
S901
FOCUS POSITION FIXATION MODE?
NO
YES
S902
SWITCHED TO FOCUS POSITION FIXATION MODE?
NO
YES
S903
EXTRACT FIXED SUBJECT
S904
SET SUB-REGION FOR ACQUISITION OF DISTANCE INFORMATION
S905
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S906
STORE DISTANCE INFORMATION AS REFERENCE DISTANCE INFORMATION
S907
HAS ENVIRONMENTAL CHANGE AFFECTING FOCUS OCCURRED?
NO
YES
S908
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S909
DISTANCE CHANGE AMOUNT ← REFERENCE DISTANCE − CURRENT DISTANCE
S910
HAS CHANGE OCCURRED IN DISTANCE INFORMATION?
NO
YES
S911
DRIVE FOCUS LENS TO ACHIEVE HIGH DEGREE OF MATCHING BETWEEN REFERENCE DISTANCE AND CURRENT DISTANCE
END

FIG.10

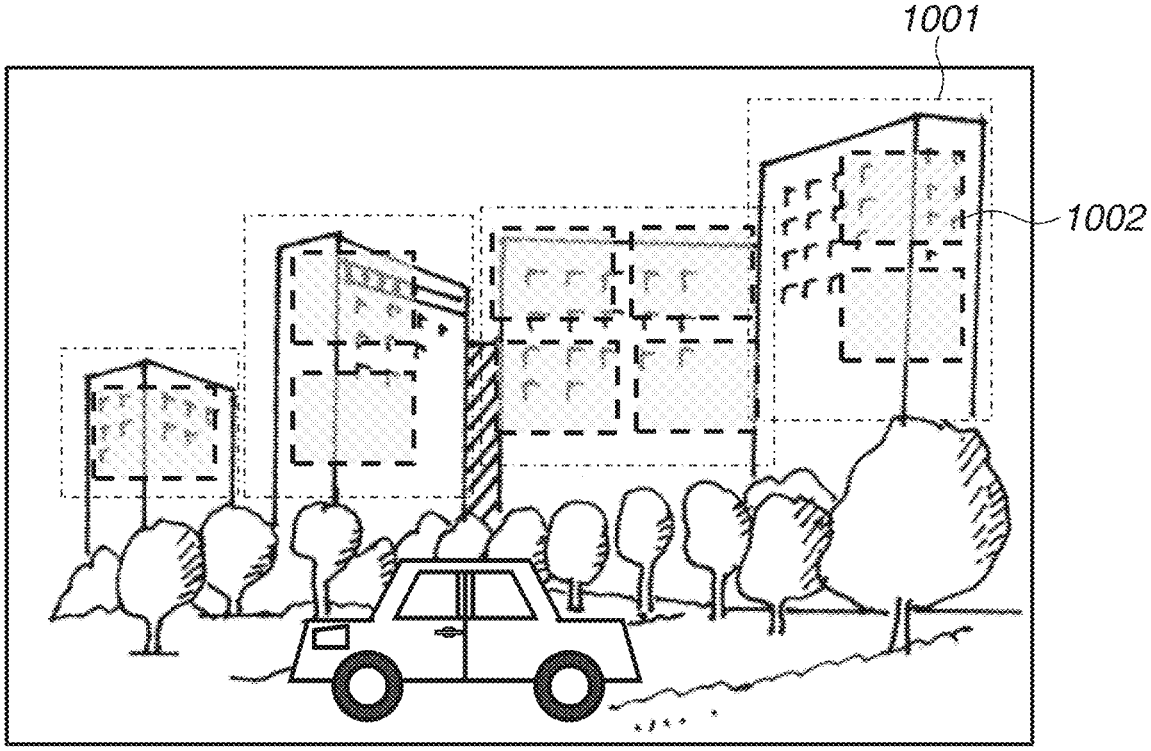


FIG.11

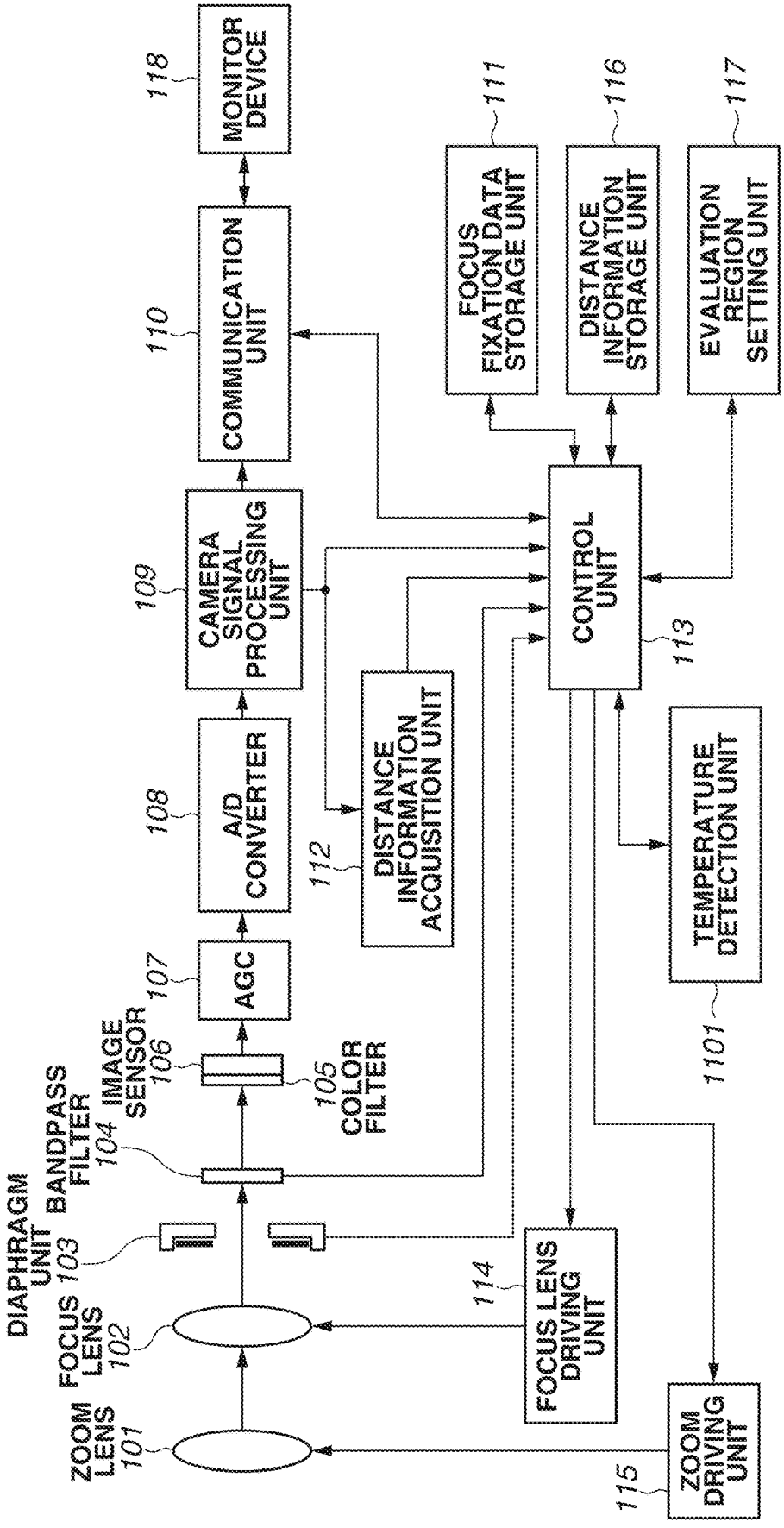

ZOOM LENS 101
FOCUS LENS 102
DIAPHRAGM UNIT 103
BANDPASS FILTER 104
COLOR FILTER 105
IMAGE SENSOR 106
AGC 107
A/D CONVERTER 108
CAMERA SIGNAL PROCESSING UNIT 109
COMMUNICATION UNIT 110
MONITOR DEVICE 118
FOCUS FIXATION DATA STORAGE UNIT 111
DISTANCE INFORMATION STORAGE UNIT 116
EVALUATION REGION SETTING UNIT 117
CONTROL UNIT 113
DISTANCE INFORMATION ACQUISITION UNIT 112
TEMPERATURE DETECTION UNIT 1101
FOCUS LENS DRIVING UNIT 114
ZOOM DRIVING UNIT 115

FIG.12

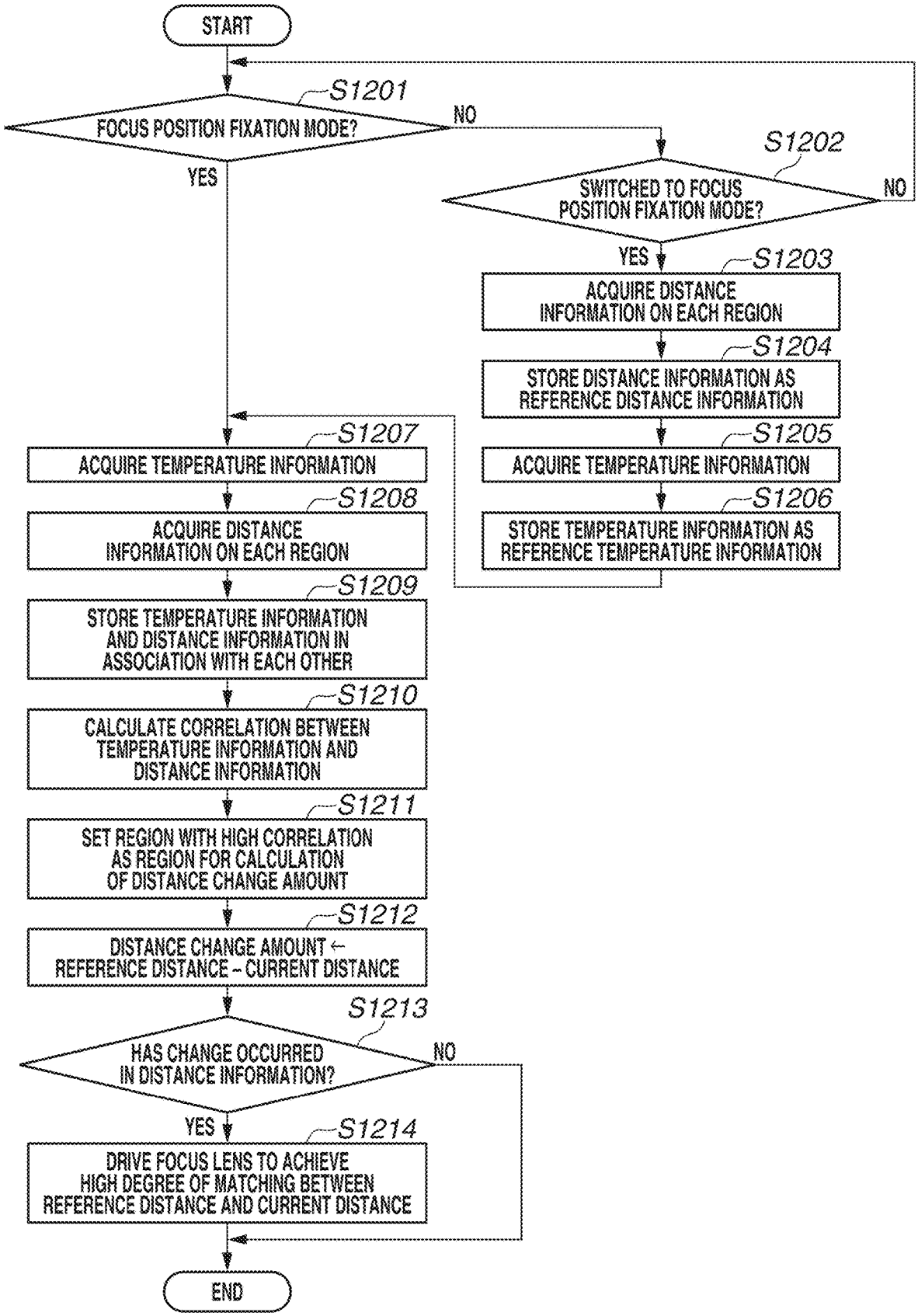

START
S1201
FOCUS POSITION FIXATION MODE?
NO
YES
S1202
SWITCHED TO FOCUS POSITION FIXATION MODE?
NO
YES
S1203
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S1204
STORE DISTANCE INFORMATION AS REFERENCE DISTANCE INFORMATION
S1205
ACQUIRE TEMPERATURE INFORMATION
S1206
STORE TEMPERATURE INFORMATION AS REFERENCE TEMPERATURE INFORMATION
S1207
ACQUIRE TEMPERATURE INFORMATION
S1208
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S1209
STORE TEMPERATURE INFORMATION AND DISTANCE INFORMATION IN ASSOCIATION WITH EACH OTHER
S1210
CALCULATE CORRELATION BETWEEN TEMPERATURE INFORMATION AND DISTANCE INFORMATION
S1211
SET REGION WITH HIGH CORRELATION AS REGION FOR CALCULATION OF DISTANCE CHANGE AMOUNT
S1212
DISTANCE CHANGE AMOUNT ← REFERENCE DISTANCE - CURRENT DISTANCE
S1213
HAS CHANGE OCCURRED IN DISTANCE INFORMATION?
NO
YES
S1214
DRIVE FOCUS LENS TO ACHIEVE HIGH DEGREE OF MATCHING BETWEEN REFERENCE DISTANCE AND CURRENT DISTANCE
END

FIG.13A

FIG.13B

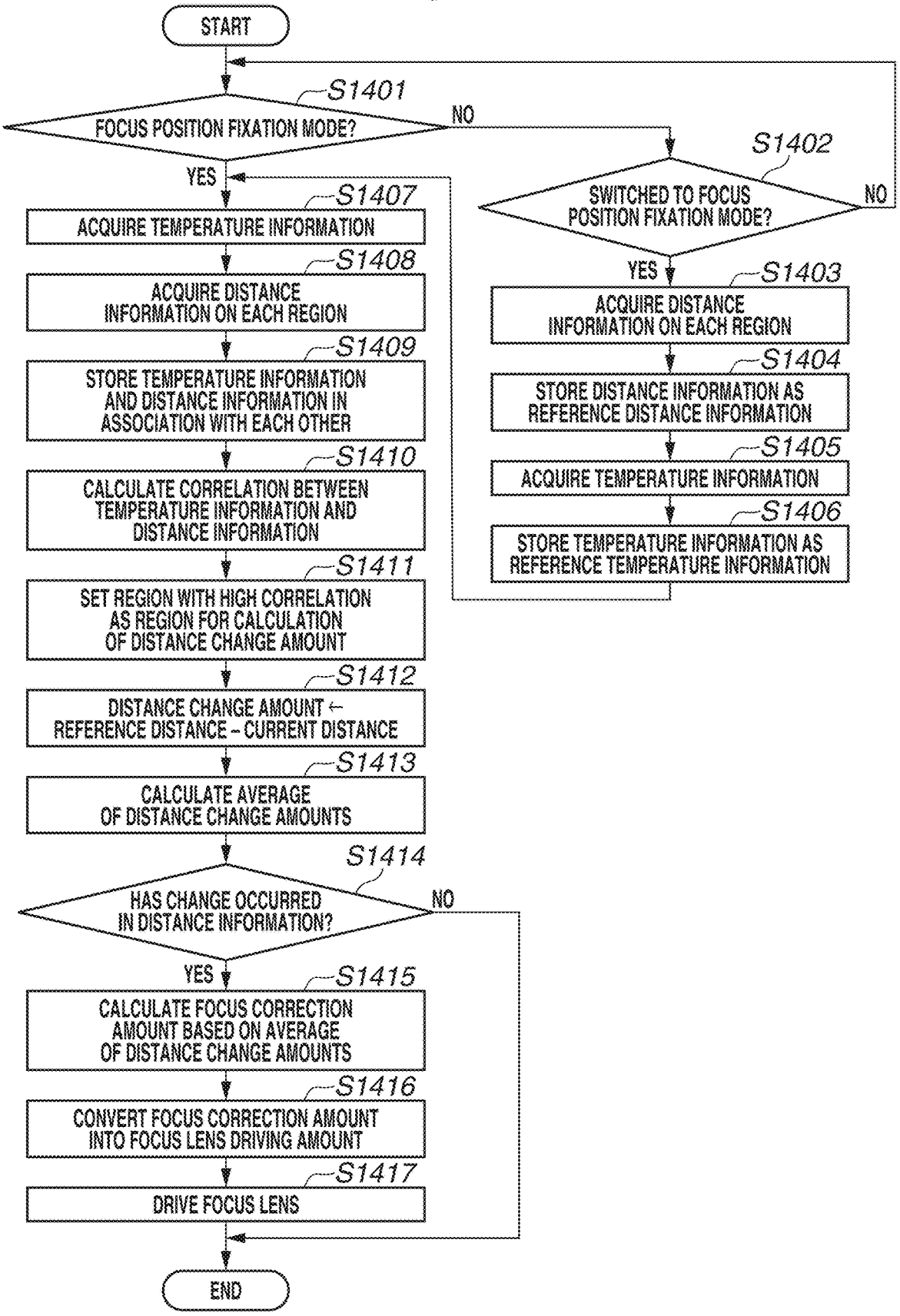
FIG.13C

FIG.13D

RELATIONSHIP BETWEEN TEMPERATURE INFORMATION AND DISTANCE INFORMATION ON EACH REGION

	20°C	25°C	30°C
REGION A	3 m	3.5 m	3.8 m
REGION B	2 m	2.2 m	2.7 m
REGION C	1 m	2.2 m	0.3 m

FIG.14


START
S1401
FOCUS POSITION FIXATION MODE?
NO
YES
S1402
SWITCHED TO FOCUS POSITION FIXATION MODE?
NO
YES
S1403
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S1404
STORE DISTANCE INFORMATION AS REFERENCE DISTANCE INFORMATION
S1405
ACQUIRE TEMPERATURE INFORMATION
S1406
STORE TEMPERATURE INFORMATION AS REFERENCE TEMPERATURE INFORMATION
S1407
ACQUIRE TEMPERATURE INFORMATION
S1408
ACQUIRE DISTANCE INFORMATION ON EACH REGION
S1409
STORE TEMPERATURE INFORMATION AND DISTANCE INFORMATION IN ASSOCIATION WITH EACH OTHER
S1410
CALCULATE CORRELATION BETWEEN TEMPERATURE INFORMATION AND DISTANCE INFORMATION
S1411
SET REGION WITH HIGH CORRELATION AS REGION FOR CALCULATION OF DISTANCE CHANGE AMOUNT
S1412
DISTANCE CHANGE AMOUNT ← REFERENCE DISTANCE − CURRENT DISTANCE
S1413
CALCULATE AVERAGE OF DISTANCE CHANGE AMOUNTS
S1414
HAS CHANGE OCCURRED IN DISTANCE INFORMATION?
NO
YES
S1415
CALCULATE FOCUS CORRECTION AMOUNT BASED ON AVERAGE OF DISTANCE CHANGE AMOUNTS
S1416
CONVERT FOCUS CORRECTION AMOUNT INTO FOCUS LENS DRIVING AMOUNT
S1417
DRIVE FOCUS LENS
END

IMAGING APPARATUS, METHOD FOR CONTROLLING IMAGING APPARATUS, AND STORAGE MEDIUM

BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

The aspect of the embodiments relates to a technique for correcting defocus in an imaging apparatus.

Description of the Related Art

Some imaging apparatuses perform automatic focus (AF) control of controlling the position of a focus lens at which the imaging optical system is focused on a subject. Further, some imaging apparatuses include a memory that stores electronic cam data indicating the positions of the focus lens at individual zoom positions of the zoomable (variable power) imaging optical system for each of the plural distances to a subject, with the subject in focus at each of the distances. Such an imaging apparatus can keep the subject located at a distance in focus and fix the focus position even as the zoom position is changed, by carrying out zoom tracking of controlling the position of the focus lens with the electronic cam data in response to the imaging apparatus being zoomed.

However, even though the focus position is fixed in the above-described manner, the focus lens may be displaced, causing a blur (defocus) due to a cause such as expansion or compression of the imaging optical system or the imaging apparatus through a change in the temperature. For a correction of such a blur, the position of the focus lens is corrected for the amount of the blur. The amount of the blur due to the change in temperature varies among imaging optical systems or imaging apparatuses. This may prevent the blur from being corrected well with a common correction amount.

Japanese Patent Application Laid-Open No. 2012-128314 discusses an imaging apparatus that performs the AF control to correct a blur due to a change in temperature detected by a temperature sensor.

However, the imaging apparatus discussed in Japanese Patent Application Laid-Open No. 2012-128314 may fail to make a sufficient correction, for example, when a subject targeted for AF control moves.

SUMMARY OF THE DISCLOSURE

According to an aspect of the embodiments, an apparatus includes an acquisition unit configured to acquire distance information that indicates a distance to a subject on each predetermined region in a captured image, a control unit configured to adjust a focus position, and a storage unit configured to store first distance information acquired by the acquisition unit in response to the adjusted focus position. The control unit readjusts the focus position based on the first distance information and second distance information acquired by the acquisition unit.

Further features of the present disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating an example of the configuration of an imaging apparatus according to a first exemplary embodiment.

FIG. **2** is a diagram illustrating the configuration of an image sensor according to the first exemplary embodiment.

FIG. **3** is a diagram illustrating the configuration of the image sensor according to the first exemplary embodiment.

FIG. **4** is a flowchart illustrating an example of focus control processing according to the first exemplary embodiment.

FIG. **5** is a diagram illustrating region segmentation according to the first exemplary embodiment.

FIG. **6** is a flowchart illustrating an example of focus control processing according to a second exemplary embodiment.

FIG. **7** is a flowchart illustrating an example of focus control processing according to a third exemplary embodiment.

FIG. **8** is a block diagram illustrating an example of the configuration of an imaging apparatus according to a fourth exemplary embodiment.

FIG. **9** is a flowchart illustrating an example of focus control processing according to the fourth exemplary embodiment.

FIG. **10** is a diagram illustrating an example of region selection according to the fourth exemplary embodiment.

FIG. **11** is a block diagram illustrating an example of the configuration of an imaging apparatus according to a fifth exemplary embodiment.

FIG. **12** is a flowchart illustrating an example of focus control processing according to the fifth exemplary embodiment.

FIGS. **13**A to **13**D are diagrams each illustrating an example of a relationship between temperature and distance according to the fifth exemplary embodiment.

FIG. **14** is a flowchart illustrating another example of the focus control processing according to the fifth exemplary embodiment.

DESCRIPTION OF THE EMBODIMENTS

Exemplary embodiments of the disclosure will be described with reference to the drawings.

A first exemplary embodiment of the disclosure will be described. FIG. **1** is a block diagram illustrating an example of the configuration of an imaging apparatus according to the first exemplary embodiment. An imaging optical system of the imaging apparatus according to the present exemplary embodiment includes a zoom lens **101** to change a focal length by travelling in the optical axis direction, a focus lens **102** to adjust a focal point by moving in the optical axis direction, and a diaphragm unit **103** to adjust a quantity of light. Light passing through the imaging optical system forms a subject image as an optical image on an image sensor **106** through a bandpass filter **104** and a color filter **105**. The bandpass filter **104** can be moved forward and backward along the optical path of the imaging optical system.

The subject image formed on the image sensor **106** is photoelectrically converted by the image sensor **106** into an analog electric signal (an imaging signal). The analog electric signal (the imaging signal) output from the image sensor **106** is subjected to a gain adjustment by an automatic gain control (AGC) **107** and is converted into a digital imaging signal by an analog-digital (A/D) converter **108**. The digital imaging signal is then input to a camera signal processing unit **109**. The camera signal processing unit **109** generates an image signal through performing various kinds of image processing on the digital imaging signal. This image signal is output to a monitor device **118** connected to the imaging

apparatus through wired or wireless communication via a communication unit **110**, and is also output to a control unit **113** in the imaging apparatus.

A focus fixation data storage unit **111** stores ON/OFF information on a focus position fixation mode, which is a mode of fixing a focus position at which the subject is in focus, and mode information indicating a mode selected in the focus position fixation mode. These pieces of mode information are written into the focus fixation data storage unit **111** via the control unit **113** and the communication unit **110** in communication with the monitor device **118** operated by a user (a surveillant). OFF mode information is automatically changed to ON mode information that indicates that the focus position fixation mode is set upon completion of manual focus (MF) processing or automatic focus (AF) processing triggered by an operation by the user.

A distance information acquisition unit **112** acquires distance information on each region in an image set by an evaluation region setting unit **117**, based on the image signal acquired by the camera signal processing unit **109**. The distance information acquisition unit **112** is, for example, a phase difference sensor. Now, how to calculate the distance information will be described with reference to FIG. **2**. FIG. **2** schematically illustrates a configuration of one pixel in the image sensor **106**. As illustrated in FIG. **2**, one pixel **201** includes a microlens **202**. Further, the one pixel **201** includes a plurality of photodiodes (PDs) as a plurality of photoelectric conversion regions. FIG. **2** illustrates an example in which the one pixel **201** includes two PDs **203** and **204**. One pixel includes at least two PDs, and the number of PDs is not limited.

FIG. **3** conceptually illustrates how a luminous flux emitted from an exit pupil **303** of the focus lens **102** is incident on the image sensor **106**. FIG. **3** illustrates a cross section **301** of a pixel array, the microlens **202** of FIG. **2**, a color filter **302**, and the PDs **203** and **204** of FIG. **2**. In this example, the center of the luminous flux emitted from the exit pupil **303** of the focus lens **102** into the pixel **201** including the microlens **202** is taken as an optical axis **304**. The light emitted from the exit pupil **303**, about the optical axis **304**, is incident on the image sensor **106**. Regions **305** and **306** are partial regions of the exit pupil **303** of the focus lens **102**. Rays **307** and **308** are outermost rays of the light passing through one partial region **305**, and rays **309** and **310** are outermost rays of the light passing through the other partial region **306**.

As understood from FIG. **3**, the luminous flux emitted from the exit pupil **303** is divided at the optical axis **304** into an upper part and a lower part. The upper luminous flux is incident on the PD **204**, and the lower luminous flux is incident on the PD **203**. In other words, the PDs **203** and **204** each receive the light of a different region of the exit pupil **303** of the focus lens **102** from each other. Then, assuming that an A image is formed from a signal received by the PD **203** and a B image is formed from a signal received by the PD **204**, a defocus amount can be calculated based on a parallax between the A image signal and the B image signal as a pair, and the distance information can be acquired based on that result. An expanded or compressed lens barrel due to a cause such as a change in temperature results in a different parallax between the A image and the B image from that before the change, thereby yielding a change in distance information acquired.

The control unit **113** performs automatic focus (AF) control using a contrast evaluation value indicating a contrast state of the image signal that is calculated based on an image signal and the distance information acquired by the distance information acquisition unit **112**. A focus lens driving unit **114** drives the focus lens **102** under control of the control unit **113**. A zoom driving unit **115** drives the zoom lens **101** under control of the control unit **113**. A distance information storage unit **116** acquires the distance information acquired by the distance information acquisition unit **112** via the control unit **113**, and stores the distance information.

Next, focus control processing (a focus control method) will be described that is performed by the control unit **113** according to the present exemplary embodiment. FIG. **4** is a flowchart illustrating an example of the focus control processing performed by the control unit **113** according to the present exemplary embodiment. The control unit **113**, which is a computer, performs the focus control processing based on a focus control program as a computer program. In the present processing, the focus control program is called and executed every predetermined time.

In step S**401**, the control unit **113** determines whether the focus position fixation mode is set. If the control unit **113** determines that the focus position fixation mode is set (YES in step S**401**), the processing proceeds to step S**405**. On the other hand, if the control unit **113** determines that the focus position fixation mode is not set (NO in step S**401**), the processing proceeds to step S**402**, and returns to step S**401** until the focus position fixation mode is set.

In step S**402**, if an instruction is issued to set the focus position fixation mode (YES in step S**402**), the processing proceeds to step S**403**. In step S**403**, the control unit **113** acquires the distance information on each region in the image that is calculated by the distance information acquisition unit **112**. A description of regions in the image follows with reference to FIG. **5**. In FIG. **5**, a region **501** surrounded by a broken line indicates one region of which the distance information is acquired. In the present exemplary embodiment, the control unit **113** acquires an average with respect to each of all the regions. Targeted regions are not necessarily all the regions, and may be only part of the regions. In step S**404**, the control unit **113** stores the distance information acquired in step S**403** into the distance information storage unit **116** as reference distance information.

In step S**405**, the control unit **113** determines whether an environmental change affecting the focus has occurred. If the control unit **113** determines that an environmental change affecting the focus has occurred (YES in step S**405**), the processing proceeds to step S**406**. If the control unit **113** determines that no environmental change affecting the focus has occurred (NO in step S**405**), the processing is ended. Examples of environmental changes affecting focus include installation and/or removal of the bandpass filter **104**, a change in temperature of the lens barrel, vibration, and a change in the light source.

In step S**406**, the control unit **113** acquires the distance information on each region in the image that is calculated by the distance information acquisition unit **112**. In step S**407**, the control unit **113** determines a distance change amount by calculating, for each region, a difference between the reference distance information stored in step S**404** and the distance information acquired in step S**406**.

Subsequently, in step S**408**, the control unit **113** determines whether a change has occurred in the distance information based on the distance change amount calculated in step S**407**. For example, the control unit **113** may make a determination based on whether the absolute value of the distance change amount is larger than zero or may determine that a change has occurred in the distance information with the distance change amount larger than or equal to a thresh-

old value. The threshold value used here is a value determined by, for example, the degree of defocus with respect to the change amount of the distance information being measured in advance. If the control unit **113** determines that a change has occurred in the distance information (YES in step S**408**), the processing proceeds to step S**409**; otherwise (NO in step S**408**), the processing is ended.

In step S**409**, the control unit **113** causes the focus lens driving unit **114** to repeatedly drive the focus lens **102** to maximize the degree of matching between the current distance information and the reference distance information stored in step S**404**. For example, a mean error is used as the degree of matching between the current distance information and the reference distance information (in this case, the degree of matching increases as the mean error reduces). For example, a method similar to the known contrast AF can be adopted for driving the focus lens **102**. After driving the focus lens **102**, the control unit **113** stops the focus lens **102** at the position where the degree of matching between the current distance information and the reference distance information is maximized, and ends the processing.

According to the first exemplary embodiment, the focus position can be corrected so that the current distance information and the reference distance information substantially match each other based on the distance information acquired from the image, whereby defocus due to an environmental change in the imaging optical system can be corrected in a simple system.

Next, a second exemplary embodiment of the disclosure will be described. The above-described first exemplary embodiment has been described referring to the example in which the focus correction is carried out based on the degree of matching between the current distance information and the reference distance information. However, this configuration drives the focus lens **102** repeatedly until the focus lens **102** reaches a position at which a high degree of matching is achieved between the current distance information and the reference distance information, which may last longer until the correction operation ends, increasing operations for the readjustment of the focus position.

In the second exemplary embodiment, the focus lens **102** is driven by a focus correction amount that is calculated based on a difference between distance information at a start of the processing and reference distance information, thereby providing a quicker correction process. The configuration of the imaging apparatus according to the second exemplary embodiment is similar to the imaging apparatus according to the first exemplary embodiment, and therefore the description thereof will be omitted.

FIG. **6** is a flowchart illustrating an example of focus control processing (a focus control method) performed by the control unit **113** according to the second exemplary embodiment. In steps S**601** to S**607**, the control unit **113** performs processing similar to that in steps S**401** to S**407** according to the first exemplary embodiment illustrated in FIG. **4**.

In step S**608**, the control unit **113** calculates the average of the distance change amounts of all the regions that have been calculated in step S**607**. In step S**609**, the control unit **113** determines whether a change has occurred in the distance information based on the average of the distance change amounts calculated in step S**608**. For example, the control unit **113** may make this determination based on whether the average of the distance change amounts is larger than zero or may determine that a change has occurred in the distance information if this average is larger than or equal to a given threshold value. The threshold value used here is a value determined by, for example, the extent of defocus being measured with respect to each change amount of the distance information in advance. If the control unit **113** determines that a change has occurred in the distance information (YES in step S**609**), the processing proceeds to step S**610**; otherwise (NO in step S**609**), the present processing is ended.

In step S**610**, the control unit **113** calculates a focus correction amount based on the average of the distance change amounts calculated in step S**608**. In the present exemplary embodiment, the control unit **113** calculates the focus correction amount following an expression, for example, the focus correction amount=(−1)×the average of the distance change amounts (the average of the defocus amounts).

Next, in step S**611**, the control unit **113** converts the focus correction amount calculated in step S**610** into a focus lens driving amount. Subsequently, in step S**612**, the control unit **113** causes the focus lens driving unit **114** to drive the focus lens **102** by the focus driving amount. Then, the present processing is ended.

Next, a third exemplary embodiment of the disclosure will be described. The above-described first exemplary embodiment has been described using the example in which the focus correction is carried out based on the change amounts of the pieces of distance information on all the regions. The first exemplary embodiment provides an effective correction through simple processing. However, a change such as a movement of the subject that has occurred in the focus position fixation mode affects the distance information on the regions in which the subject has moved. This may effect an error in the correction.

If defocus occurs due to an external factor such as a change in temperature or light source, or vibration with no change in the subject, the distance information is likely to be changed in a direction in all the regions. In view of the above, in the third exemplary embodiment, the changed direction in the distance information in each region is extracted and then a defocus direction due to an external factor is estimated by majority rule. Then, the above error is reduced by correction processing with only the distance information on each region of which the distance information has changed in the estimated direction. The configuration of the imaging apparatus according to the third exemplary embodiment is similar to that of the imaging apparatus according to the first exemplary embodiment, and therefore the description thereof will be omitted.

FIG. **7** is a flowchart illustrating an example of focus control processing (a focus control method) performed by the control unit **113** according to the third exemplary embodiment. In steps S**701** to S**708**, the control unit **113** performs processing similar to that in steps S**401** to S**408** according to the first exemplary embodiment illustrated in FIG. **4**.

In step S**709**, the control unit **113** extracts the direction of the distance change in each region based on the distance change amount calculated in step S**707**. The extracted direction of the distance change is determined to be any of three patterns "distancing", "approaching", and "unchanged". A region in which the calculated distance change amount in step S**707** has a negative sign is extracted as "distancing". A region in which the calculated distance change amount has a positive sign is extracted as "approaching". A region with zero calculated as the distance change amount is extracted as "unchanged". In step S**710**, the control unit **113** determines a direction of the distance change by majority rule. The

control unit **113** extracts the most common direction of the directions of the distance changes extracted in step S**709**.

Next, in step S**711**, the control unit **113** selects the regions of which the distance information has changed in the extracted direction in step S**710**. Subsequently, in step S**712**, the control unit **113** drives the focus lens **102** for the regions selected in step S**711** in a similar manner to that in step S**409** in FIG. **4** according to the first exemplary embodiment. Then, the processing is ended.

In the third exemplary embodiment, the first driving of the focus lens **102** in step S**712** may be in the direction of the distance change extracted in step S**710**. This reduces the time for the correction operation. Further, in the present exemplary embodiment, the control unit **113** drives the focus lens **102** repeatedly to maximize the degree of matching between the reference distance information and the current distance information. Alternatively, the focus lens **102** may be driven at a correction amount calculated based on the average of the distance change amounts, similarly to the second exemplary embodiment.

Next, a fourth exemplary embodiment of the disclosure will be described. The above-described first exemplary embodiment has been described using the example in which the focus correction is carried out based on the change amounts of the pieces of distance information on all the regions. According to the first exemplary embodiment, a change such as a movement of the subject in the focus position fixation mode affects the distance information on the regions in which the subject has moved. This may effect an error in the correction. In the fourth exemplary embodiment, the error is reduced by correction processing with only the distance information on each region of the fixed subject through an extraction of a fixed subject from the image.

FIG. **8** is a block diagram illustrating an example of the configuration of the imaging apparatus according to the fourth exemplary embodiment. In FIG. **8**, the components having functions identical to those of the components in FIG. **1** are indicated by the same reference numerals, and the same descriptions will be omitted. A fixed subject extraction unit **801** receives the image signal via the control unit **113** and extracts a fixed subject contained in the image. Fixed subjects are extracted by object detection on machine learning or a semantic segmentation technique. The control unit **113** is notified of the result of the extraction by the fixed subject extraction unit **801** in association with coordinate information, subject type, and reliability of the extraction.

Next, focus control processing (a focus control method) performed by the control unit **113** according to the present exemplary embodiment will be described. FIG. **9** is a flowchart illustrating an example of the focus control processing performed by the control unit **113** according to the fourth exemplary embodiment. In steps S**901** and S**902**, the control unit **113** performs processing similar to that in steps S**401** and S**402** according to the first exemplary embodiment illustrated in FIG. **4**.

In step S**903**, the control unit **113** causes the fixed subject extraction unit **801** to extract a fixed subject in the image signal. Fixed subjects extracted in this step are immobile objects, such as buildings and steel towers. In step S**904**, the control unit **113** sets a sub-region contained in the region of each fixed subject extracted by the fixed subject extraction unit **801** in step S**903** as a sub-region for acquiring the distance information. FIG. **10** illustrates an example of the sub-regions for acquiring the distance information set in step S**904**. FIG. **10** illustrates a fixed subject extraction region **1001**, and the buildings are extracted as fixed subjects in the present example. FIG. **10** further illustrates each distance information acquisition sub-region **1002**, which is set inside each fixed subject extraction region **1001**.

In steps S**905** to S**911**, the control unit **113** performs processing similar to that in steps S**403** to S**409** according to the first exemplary embodiment illustrated in FIG. **4**. Then, a series of processing procedures is ended.

According to the fourth exemplary embodiment, distance information acquisition sub-regions are set in the regions corresponding to fixed subjects such as buildings or steel towers. This reduces the effect of a change in distance information by a subject's movement to accurately extract a change in distance information by varying focus, thereby reducing an error in a correction amount.

Each sub-region contained only in the region of a fixed subject is set as a distance information acquisition sub-region in step S**904**, but how to extract distance information on the region of a fixed subject is not limited thereto. For example, each region may be weighted in calculation of the degree of matching in step S**911**, with a sub-region in the region of a fixed subject weighted higher. This allows correction even with no fixed subject extracted. Further, weighting may be performed based on the value of reliability of an extraction of each fixed subject acquired simultaneously in step S**903**. This allows the distance information on a fixed subject extracted with higher accuracy to be used in priority correction processing, increasing correction accuracy. Additionally, in the present exemplary embodiment, the focus lens **102** is repeatedly driven to maximize the degree of matching between the reference distance information and the current distance information. Alternatively, the focus lens **102** may be driven at a correction amount calculated based on the average of the distance change amounts, similarly to the second exemplary embodiment.

Next, a fifth exemplary embodiment of the disclosure will be described. In the fifth exemplary embodiment, from among calculated correlations between varying temperatures and distances in individual regions, correction processing uses the distance information on only a region with a high correlation, reducing the occurrence of an error in a correction amount.

FIG. **11** is a block diagram illustrating an example of the configuration of the imaging apparatus according to the fifth exemplary embodiment. In FIG. **11**, the components having functions identical to those of the components illustrated in FIG. **1** are indicated by the same reference numerals, and the same descriptions will be omitted. A temperature detection unit **1101** detects the temperature of the lens barrel (the imaging optical system) of the imaging apparatus. A temperature sensor such as a thermistor is used as the temperature detection unit **1101**. The control unit **113** acquires temperature information via the temperature detection unit **1101** every predetermined time to monitor variation in the temperature.

FIG. **12** is a flowchart illustrating an example of focus control processing (a focus control method) performed by the control unit **113** according to the fifth exemplary embodiment. In steps S**1201** to S**1203**, the control unit **113** performs processing similar to that in steps S**401** to S**403** according to the first exemplary embodiment illustrated in FIG. **4**.

In step S**1204**, the control unit **113** stores the distance information acquired in step S**1203** into the distance information storage unit **116** as the reference distance information, when the previous distance information that has been stored in the processing is deleted. In step S**1205**, the control unit **113** acquires temperature information via the temperature detection unit **1101**. In step S**1206**, the control unit **113**

stores the temperature information acquired in step **S1205** as reference temperature information, when the previous temperature information that has been stored in the processing is deleted.

In step **S1207**, the control unit **113** acquires temperature information via the temperature detection unit **1101**. In step **S1208**, the control unit **113** acquires the distance information on each region in the image in a similar manner to that in step **S406** according to the first exemplary embodiment illustrated in FIG. **4**. In step **S1209**, the control unit **113** associates the temperature information acquired in step **S1207** with the distance information on each region acquired in step **S1208** and then stores them.

In step **S1210**, the control unit **113** calculates a correlation coefficient between the temperature information and the distance information stored in step **S1209**, using the reference distance information stored in step **S1204** and the reference temperature information stored in step **S1206**. Denoting the correlation coefficient by r, r can be found using the following equation (1).

$$r = \text{a covariance between temperatures and distances} / (\text{a standard deviation of temperatures} \times \text{a standard deviation of distances}) \quad \text{Equation (1)}$$

The correlation coefficient r has a value in the range of (−1) to 1. A negative value indicates a negative correlation, and a positive value indicates a positive correlation. A higher absolute value indicates a higher correlation.

FIGS. **13**A to **13**C illustrate examples indicating relationships between temperatures and distances in different regions A, B, and C, respectively. FIG. **13**D illustrates examples of the respective specific numerical values. In FIG. **13**D, the shaded portions indicate the reference distance information and the reference temperature information. When the correlation coefficients are calculated using the equation (1), 0.99, 0.97, and −0.36 are found, respectively.

In step **S1211**, the control unit **113** sets a region with a higher absolute correlation coefficient calculated in step **S1210** (over a threshold value) as a region for the calculation of the distance change amount. The threshold value is set at a high value for accuracy-oriented correction, or is adjusted to a low value when disturbance such as noise is allowed. In the present exemplary embodiment, the threshold value is set at 0.5 as an example. In the examples illustrated in FIGS. **13**A to **13**D, the regions A and B are set as the regions for the calculation of the distance change amount.

In step **S1212**, the control unit **113** calculates the distance change amounts of the regions set in step **S1211**. If no region is set in step **S1211**, the control unit **113** determines that the distance change amount is zero.

In step **S1213**, the control unit **113** determines whether a change has occurred in the distance information in a similar manner to that in step **S408** according to the first exemplary embodiment illustrated in FIG. **4**. Lastly, in step **S1214**, the control unit **113** performs processing on the region set in step **S1211**, similarly to that in step **S409** according to the first exemplary embodiment illustrated in FIG. **4**. Then a series of processing procedures is ended.

In the present exemplary embodiment, the control unit **113** drives the focus lens **102** repeatedly to maximize the degree of matching between the reference distance information and the current distance information. Alternatively, the focus lens **102** may be driven at a correction amount calculated based on the average of the distance change amounts similarly to the second exemplary embodiment.

FIG. **14** is a flowchart illustrating an example of the focus control processing performed by the control unit **113** according to the fifth exemplary embodiment, and illustrates an example in which the control unit **113** drives the focus lens **102** at a correction amount calculated based on the average of the distance change amounts. In steps **S1401** to **S1412**, the control unit **113** performs processing similar to that in steps **S1201** to **S1212** illustrated in FIG. **12**.

In step **S1413**, the control unit **113** calculates the average of the distance change amounts calculated in step **S1412** in the regions set in step **S1411** in a similar manner to that in step **S608** according to the second exemplary embodiment illustrated in FIG. **6**. In step **S1414**, the control unit **113** determines whether a change has occurred in the distance information based on the average of the distance change amounts calculated in step **S1413** in a similar manner to that in step **S609** according to the second exemplary embodiment illustrated in FIG. **6**.

In step **S1415**, the control unit **113** calculates a focus correction amount based on the average of the distance change amounts calculated in step **S1413** in a similar manner to that in step **S610** according to the second exemplary embodiment illustrated in FIG. **6**. In step **S1416**, the control unit **113** converts the focus correction amount calculated in step **S1415** into a focus lens driving amount in a similar manner to that in step **S611** according to the second exemplary embodiment illustrated in FIG. **6**. Subsequently, in step **S1417**, the control unit **113** drives the focus lens **102** by the focus lens driving amount in a similar manner to that in step **S612** according to the second exemplary embodiment illustrated in FIG. **6**. Then, the present processing is ended.

In each of the exemplary embodiments, if distance information cannot be acquired due to some cause such as a low illuminance, correction processing may be executed at a correction amount or a driving amount saved in advance per factor that changes a focus position.

OTHER EMBODIMENTS

Embodiment(s) of the present disclosure 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)™), a flash memory device, a memory card, and the like.

While the disclosure has been described with reference to exemplary embodiments, it is to be understood that the disclosure 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 such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2019-213416, filed Nov. 26, 2019, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. An apparatus comprising:

at least one processor; and

a memory coupled to the at least one processor, the memory having instructions that, when executed by the processor, perform operations as:

a control unit configured to adjust a focus position;

an acquisition unit configured to acquire first distance information that indicates a distance to a subject on each of a plurality of regions within a predetermined region in a captured image, in a state where the focus positon is adjusted by the control unit; and

a storage unit configured to store the first distance information acquired by the acquisition unit,

wherein the acquisition unit is configured to acquire second distance information that indicates a distance to a subject on each of the plurality of regions within the predetermined region in a captured image, after the first distance information is stored,

wherein the control unit adjusts the focus position so that a degree of matching between the first distance information and second distance information becomes higher, and

wherein the control unit adjusts the focus position to maximize the degree of matching.

2. The apparatus according to claim **1**, wherein the control unit adjusts the focus position based on the first distance information on a region selected in the captured image and the second distance information on the region.

3. The apparatus according to claim **1**, wherein the control unit adjusts the focus position so that the first distance information and the second distance information substantially match each other.

4. The apparatus according to claim **1**, wherein the control unit adjusts the focus position repeatedly to maximize the degree of matching.

5. The apparatus according to claim **1**,

wherein the control unit detects in each region a direction in which the second distance information is changed from the first distance information, and

wherein the control unit adjusts the focus position based on the first distance information and the second distance information, the first distance information and the second distance information being on each region of which the second distance information is changed in a most common direction of the directions.

6. The apparatus according to claim **1**, wherein the control unit detects in each region a direction in which the second distance information is changed from the first distance information, wherein the control unit starts adjusting the focus position in a most common direction of the directions.

7. The apparatus according to claim **1**, wherein the control unit adjusts the focus position based on a change amount between the first distance information and the second distance information.

8. The apparatus according to claim **1**, further comprising a detection unit configured to detect a fixed subject in the image,

wherein the control unit adjusts the focus position based on the first distance information and the second distance information, the first distance information and the second distance information being on a region corresponding to the detected fixed subject.

9. The apparatus according to claim **1**, further comprising:

a sensing unit configured to sense a temperature; and

a calculation unit configured to calculate a correlation between a change amount of the sensed temperature and the acquired distance information,

wherein the control unit adjusts the focus position based on the first distance information and the second distance information, the first distance information and the second distance information being on a region with a high correlation calculated by the calculation unit.

10. The apparatus according to claim **1**,

wherein the storage unit stores in advance a relationship between a correction amount for the focus position and a factor in a focus position change in response to the focus position being adjusted, and

wherein the control unit adjusts the focus position based on the relationship with no acquired distance information.

11. The apparatus according to claim **1**, wherein the control unit adjusts the focus position based on the first distance information and the second distance information for an environmental change affecting the focus position that has occurred.

12. The apparatus according to claim **1**, wherein the acquisition unit is a phase difference sensor.

13. A method for controlling an apparatus comprising:

adjusting a focus position;

acquiring first distance information that indicates a distance to a subject on each of a plurality of regions within a predetermined region in a captured image, in a state where the focus positon is adjusted;

storing the first distance information into a storage unit;

acquiring second distance information that indicates a distance to a subject on each of a plurality of regions within the predetermined region in a captured image, after the first distance information is stored; and

adjusting the focus position so that a degree of matching between the stored first distance information and second distance information,

wherein the adjusting adjusts the focus position to maximize the degree of matching.

14. The method according to claim **13**, wherein the adjusting includes adjusting the focus position based on the first distance information on a selected region in the captured image and the second distance information on the region.

15. The method according to claim **13**, wherein the adjusting includes adjusting the focus position so that the first distance information and the second distance information substantially match each other.

16. The method according to claim **13**, wherein the adjusting includes adjusting the focus position repeatedly to maximize the degree of matching.

17. A non-transitory computer-readable medium storing a program for causing a computer to execute a method for controlling an apparatus, the method comprising:

adjusting a focus position;

acquiring first distance information that indicates a distance to a subject on each of a plurality of regions within a predetermined region in a captured image, in a state where the focus positon is adjusted;

storing the first distance information into a storage unit;

acquiring second distance information that indicates a distance to a subject on each of a plurality of regions within the predetermined region in a captured image, after the first distance information is stored; and

adjusting the focus position so that a degree of matching between the stored first distance information and second distance information becomes higher,

wherein the adjusting adjusts the focus position to maximize the degree of matching.

18. The non-transitory computer-readable medium according to claim **17**, wherein the adjusting includes adjusting the focus position based on the first distance information on a selected in the captured image and the second distance information on the region.

19. The non-transitory computer-readable medium according to claim **17**, wherein the adjusting includes adjusting the focus position so that the first distance information and the second distance information substantially match each other.

20. The non-transitory computer-readable medium according to claim **17**, wherein the adjusting includes adjusting the focus position repeatedly to maximize the degree of matching.

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