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**(54) Ophthalmic photographing apparatus, method and program**

Ophthalmische Fotografiervorrichtung, -verfahren und Programm

Appareil, procédé et programme de photographie ophtalmique

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(56) References cited:  
**EP-A1- 2 382 913 EP-A1- 2 382 914**  
**EP-A2- 1 882 445**

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## Description

### BACKGROUND OF THE INVENTION

#### Field of the Invention

**[0001]** The present invention relates to a photographing apparatus and photographing method. More particularly, the present invention relates to a photographing apparatus and photographing method which acquire desired fundus tomographic images by reflecting moving amounts of the fundus in tomographic fundus imaging in real time.

#### Description of the Related Art

**[0002]** Recently, OCT (Optical Coherence Tomography) apparatus capable of acquiring fundus tomographic images have been attracting attention. One of the contributing factors in attracting attention is the capability to noninvasively examine the internal structure of the fundus which cannot be observed with other apparatus. FD-OCT (Fourier Domain OCT) which has a proven track record in high-speed imaging serves the center of the market.

**[0003]** The OCT apparatus incorporates a fundus camera and a SLO (Scanning Laser Ophthalmoscope) and thereby allows OCT images to be acquired around a desired location by displaying which area of the fundus to be OCT-scanned.

**[0004]** On the other hand, for the purposes of detection of minute tumors or abnormalities in early diagnosis and early treatment, there is demand for improvements in image quality of OCT images. To achieve high image quality, a technique related to an apparatus (Japanese Application Publication No. 2004-512125) which makes an OCT beam follow fundus movements, i.e., changes in fundus location resulting from eye ball movements has been disclosed.

**[0005]** Also, a technique for capturing SLO images and OCT images alternately is disclosed (EP 1 882 445 A2 and Japanese Patent Application Laid-Open No. 2008-029467) in relation to the above-described OCT apparatus equipped with the SLO apparatus.

**[0006]** In the configuration disclosed in the Japanese Application Publication No. 2004-512125, a device adapted to detect fundus movements is added to the OCT apparatus. The device acquires OCT images of a desired site by tracking the optic disk in the fundus and controlling an OCT scanner in real time.

**[0007]** Also, by capturing SLO images and OCT images alternately, the configuration disclosed in EP 1 882 445 A2 and Japanese Patent Application Laid-Open No. 2008-029467 acquires the SLO images and OCT images while reducing the burden on the patient.

**[0008]** As a result of FD-OCT's speedup, it may take a shorter time to acquire OCT images than to acquire fundus movement information. This will be described with

reference to FIG. 3. When the OCT beam O is moved to a desired location and measurements are started, a plurality of OCT images 311 to 322 is acquired while SLO images 301 to 304 are acquired to calculate positional information. In this case, there is a problem in that positional information corresponding to all the OCT images is not available. High-speed tracking will solve the above problem as with the invention disclosed in the Japanese Application Publication No. 2004-512125, but it becomes essential to add a special device dedicated to tracking, resulting in a size increase of the apparatus, and furthermore in the need for expensive parts such as a tracking scanner. Also, there is a problem of increased initial operations such as setting of a target to be tracked, resulting in an increased imaging time.

**[0009]** Also, the invention disclosed in EP 1 882 445 A2 and Japanese Patent Application Laid-Open No. 2008-029467 has a problem in that since SLO images and OCT images are acquired alternately, imaging takes much time, which can cause long delay times in the case of real-time tracking, resulting in a large deviation from the fundus location.

**[0010]** The EP 2 382 914 A1 discloses an ophthalmologic apparatus for detecting an eye movement from movements of a plurality of characteristic points within a fundus image. It is determined whether or not the plurality of characteristic points are included in a new fundus image when a position of a fixation index is changed, based on a relationship between a displacement amount of the fixation index and positions of the characteristic points within a fundus plane. If it is determined that at least one of the plurality of characteristic points is not included in the new fundus image, new characteristic points are extracted from a limited range within a new fundus plane image. Accordingly, the characteristic points can be efficiently reacquired for eye movement detection performed when an imaging target region of an eye to be inspected is changed by the fixation index.

### SUMMARY OF THE INVENTION

**[0011]** An object of the present invention is to allow real-time tracking to be performed appropriately even when an acquisition rate of fundus images is lower than an acquisition rate of tomographic images.

**[0012]** To solve the above problem, the present invention provides a photographing apparatus and a photographing method as defined in appended claims.

**[0013]** The present invention allows real-time tracking to be performed appropriately with a reduced delay time between position detection and position correction.

**[0014]** 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

**[0015]**

FIG. 1 is a schematic diagram of a function system of an apparatus according to a first embodiment of the present invention.

FIG. 2 is a schematic diagram of an ophthalmological apparatus according to the first embodiment of the present invention.

FIG. 3 is a schematic diagram of SLO images and OCT images according to a conventional example in the present invention.

FIG. 4 is a schematic diagram of a fundus image and templates according to the first embodiment of the present invention.

FIG. 5 is a schematic diagram of SLO images and OCT images according to the first embodiment of the present invention.

FIG. 6 is a schematic diagram of a fundus image and templates according to a second embodiment of the present invention.

FIG. 7 is a schematic diagram of SLO images and OCT images according to the second embodiment of the present invention.

FIG. 8 is a schematic diagram of a processing flow according to the first embodiment of the present invention.

FIG. 9 is a schematic diagram of process A according to the first embodiment of the present invention.

FIG. 10 is a schematic diagram of process B according to the first embodiment of the present invention.

FIG. 11 is a schematic diagram of process C according to the first embodiment of the present invention.

## DESCRIPTION OF THE EMBODIMENTS

**[0016]** Preferred embodiments of the present invention will now be described in detail in accordance with the accompanying drawings.

## First Embodiment

**[0017]** A first embodiment of the present invention will be described below.

**[0018]** According to the present embodiment, a fundus image is acquired using SLO, a plurality of feature points

(also referred to as characteristic images) are extracted from the image (SLO image) acquired by SLO, and a moving amount of the fundus is measured each time a feature point is detected. Results are fed back to a scanner of an OCT apparatus in real time to acquire an OCT image and thereby control a scan area of an OCT beam to be at a desired position in the fundus. Description will be given of a configuration in which after the entire SLO image is acquired, relative rotation and magnification of the fundus image are calculated based on the plurality of feature points and the relative rotation and magnification of the fundus image are fed back to scanning of the OCT beam.

(Configuration of OCT imaging unit)

**[0019]** An optical configuration of an imaging unit serving as a tomographic image acquisition unit according to the present invention will be described with reference to FIG. 1.

**[0020]** Regarding a light source, a low-coherence light source 101 is used. As the light source 101, an SLD (Super Luminescent Diode) light source or ASE (Amplified Spontaneous Emission) light source can be used suitably. Regarding low-coherence light, wavelengths around 850 nm and 1050 nm are used suitably for fundus photography. An SLD light source with a center wavelength of 840 nm and a half-wavelength of 45 nm is used in the present embodiment.

The low-coherence light emitted from the low-coherence light source 101 enters a fiber coupler 102 through fiber and is divided into measuring light (OCT beam) and reference light. An interferometer configuration using fiber is described herein, but a configuration using a beam splitter in a space optical system may be adopted alternatively.

**[0021]** The measuring light is emitted as parallel light from a fiber collimator 104 through a fiber 103. The parallel light passes through an OCT scanner (Y) 105, relay lenses 106 and 107, an OCT scanner (X) 108, a dichroic beam splitter 109, a scan lens 110, a dichroic mirror 111, and an eyepiece 112 and illuminates a subject's eye (eye to be inspected) e. Galvano scanners are used as the OCT scanner (X) 108 and OCT scanner (Y) 105 serving as a scanning unit according to the present invention. In the subject's eye e, the measuring light is reflected off the retina and returns to the fiber coupler 102 through the same optical path. The reference light is led from the fiber coupler 102 to a fiber collimator 113 and emitted therefrom as parallel light. The emitted reference light is passed through dispersion correction glass 114 and reflected by a reference mirror 116 on a stage 115 whose optical path length is variable. The reference light reflected by the reference mirror 116 returns to the fiber coupler 102 through the same optical path.

**[0022]** The fiber coupler 102 combines the returning measuring light and reference light and the resulting light is led to a fiber collimator 117. The combined light is re-

ferred to herein as interfering light. The fiber collimator 117 makes up a spectroscope in conjunction with a transmission grating 118, a lens 119 and a line sensor 120. The interfering light is measured as intensity information at each wavelength by the spectroscope. The wavelength-specific intensity information measured by the line sensor 120 is transferred to a PC (not shown) to generate a tomographic image of the subject's eye e.

(Configuration of SLO imaging unit)

**[0023]** Next, an optical configuration of an SLO imaging unit will be described also with reference to FIG. 1, where the SLO imaging unit acquires fundus images by serving as a fundus image acquisition unit according to the present invention. As a laser light source 130, a semiconductor laser or SLD light source is used suitably. There are no constraints on usable wavelengths as long as the usable wavelengths can be separated from each other by the wavelength of the low-coherence light source 101 of the OCT imaging unit and the dichroic beam splitter 109, but the near-infrared wavelength region from 700 nm to 1000 nm is used suitably when image quality of fundus observation is taken into consideration. A semiconductor laser with a wavelength of 760 nm is used in the present embodiment. A laser (SLO beam) emitted from the laser light source 130 is passed through a fiber 131, emitted as parallel light from a fiber collimator 132, and led to an SLO scanner (Y) 135 through a perforated mirror (ring mirror) 133 and a lens 134. Then, after passing through lenses 136 and 137 and a SLO scanner (X) 138 and being reflected by the dichroic beam splitter 109, the SLO beam enters the subject's eye e. The dichroic beam splitter 109 is configured to transmit OCT beams and reflect SLO beams. As with the OCT imaging unit, galvano scanners are used as the scanners of the SLO imaging unit. The SLO beam incident upon the subject's eye e illuminates the fundus of the subject's eye e. The beam is reflected or scattered by the fundus of the subject's eye e and returns to the ring mirror 133 through the same optical path. Position of the ring mirror 133 is conjugate to pupil position of the subject's eye e. Consequently, when the beam illuminating the fundus backscatters, rays passing through the periphery of the pupil are reflected by the annular mirror 133 and focused onto an APD (avalanche photodiode) 140 by a lens 139. Based on intensity information from the APD 140, the PC (not shown) generates a planar image (fundus image) of the fundus.

(Internal fixation lamp)

**[0024]** According to the present embodiment, to enable stable fixation, an internal fixation lamp to fix the subject's eye e on is provided. The internal fixation lamp will be described with reference to FIG. 1 as in the case of the OCT imaging unit and SLO imaging unit. The internal fixation lamp 150 used herein is made up of a plurality

of light-emitting diodes (LDs) arranged in a matrix. Lighting position of the light-emitting diodes is changed according to a desired imaging region under the control of the PC. The light-emitting diodes have a wavelength of 500 nm. A beam emitted from the internal fixation lamp 150 illuminates the subject's eye e by passing through a lens 151 and the dichroic mirror 111. Consequently, a tomographic image can be captured at a desired position by making the subject's eye e gaze at the beam. The dichroic mirror 111 is located between the scan lens 110 and eyepiece 112 and adapted to separate the wavelength of the fixation light (about 500 nm) from the wavelengths of the OCT beam and SLO beam (700 nm or above).

(Unit configuration and control)

**[0025]** A function system used in the present embodiment is shown in FIG. 2. The function system includes a CPU 201 adapted to control the entire system; controllers 202 and 203 adapted to respectively control the SLO imaging unit and OCT imaging unit which are main components; a fixation lamp controller 208; an APD 204 (140) and line sensor 205 (120) adapted to acquire SLO images and OCT images, respectively; a display device 206 adapted to display system states; and a recording unit 207 adapted to record fundus images, imaging conditions, and the like. During fundus imaging, the fixation lamp controller 208 controls the lighting position of the internal fixation lamp 150, on which the subject's eye is then caused to be fixed, the CPU 201 specifies imaging conditions to the controllers 202 and 203, the scanners are driven, and the fundus is imaged. After the fundus is imaged, images are sent from the APD 204 and line sensor 205 to the CPU 201, subjected to image processing (to generate an SLO image and OCT image), displayed on the display unit 206, and simultaneously or subsequently saved in the recording unit 207.

(Tracking control)

**[0026]** Using the apparatus described above, movement amounts of the fundus of the subject's eye are calculated from the SLO image and fed back to the X and Y scanners of the OCT imaging unit. While the fundus of the subject's eye is being monitored, a fundus image of the patient is acquired using the SLO imaging unit and a plurality of feature points is extracted from the fundus image and recorded in the recording unit. After the feature points are extracted and recorded, it is checked whether an SLO image being newly acquired contains any feature point already recorded. If any such feature point is detected, X and Y shift amounts are calculated from coordinates of the extracted feature point and detected feature point. After the shift amounts are calculated, voltages to be applied to the scanners of the OCT imaging unit are determined from the calculated values and the X and Y galvano scanners 108 and 105 of the OCT imaging

unit are driven. The above processes will be described with reference to a flowchart in FIG. 8. First, in a fundus image acquisition step of acquiring a fundus image, a fundus image is acquired by the SLO apparatus (step 802). Feature points (hereinafter referred to as templates) are extracted from the acquired SLO image (step 803). The extracted template images and their coordinates are saved in PC memory (step 804). A scan reference position of the OCT apparatus is recorded (step 805). OCT imaging is started (step 806). An SLO image is acquired at the same time (step 807). In process A, a moving amount of the fundus is fed back to the OCT scanners and real-time tracking is performed (step 808). Steps 807 to 809 described above are repeated until the OCT imaging is completed. The above steps are carried out under the control of the CPU 201 (FIG. 2).

**[0027]** Process A will be described with reference to FIG. 9. While a fundus image is being constructed from an SLO signal (step 902), an image of an *i*th template which corresponds to a template T1 is searched for and pattern matching is executed (step 903). The coordinates of the matching template are saved (step 904). A moving amount ( $\Delta x$ ,  $\Delta y$ ) of the fundus is calculated based on the coordinates of the matching template and coordinates of the extracted template image (step 905). These steps correspond to a measuring step according to the present invention, where the measuring step involves measuring the movements of the subject's eye by executing pattern matching using a plurality of feature points extracted from the acquired fundus image. Also, these operations are performed by that section of the CPU 201 which functions as a measuring unit adapted to select one of the plurality of feature points extracted from the acquired fundus image and measure the movements of the subject's eye by executing pattern matching using the selected feature point. Incidentally, the matching operation is not limited to those which use so-called image patterns, and thus preferably the operation is referred to as matching. In process B, the calculated moving amount of the fundus is fed back to the X and Y galvano scanners 108 and 105 of the OCT imaging unit (step 906). The above processes are also performed for T2 to T4 (steps 907 to 910, steps 911 to 914, and steps 915 to 918). In process C, after information on all the templates T1 to T4 of the fundus image is obtained, recalculation is performed to calculate rotation and magnification changes of the fundus based on the coordinates and moving amounts of T1 to T4 (step 919). In performing the recalculation, preferably at least one feature point, and more preferably two or more feature points are extracted or specified. The scanning unit adapted to obtain a tomographic image based on the movements of the subject's eye thus measured by the measuring unit is controlled by that section of the CPU 201 which functions as a control unit. Also, when the movements of the subject's eye are measured based on the extracted or specified feature points, preferably measurements are taken in the order in which the feature points are extracted.

**[0028]** Process B will be described with reference to FIG. 10. OCT scan position is read out (step 1002), power to be supplied to the OCT scanners is determined based on the moving amount ( $\Delta x$ ,  $\Delta y$ ) of the fundus (step 1003), the supplied power is transferred from the CPU to the OCT controller (step 1004), and the X and Y OCT scanners are driven (step 1005). The OCT scan position is recorded (step 1006) and various information is displayed on the display (step 1007).

**[0029]** Process C will be described with reference to FIG. 11. The coordinates of templates are read out (step 1102), affine transformations are applied to the coordinates, and thereby rotation amounts and magnification changes of the fundus are calculated (step 1103). Furthermore, position data of the OCT scanners is read out (step 1104) and the power to be supplied to the OCT scanners is determined based on the rotation amounts (step 1105). The supplied power is transferred from the CPU to the OCT controller (step 1106), it is confirmed that the scanners have moved (step 1107), and the various information is saved (step 1108) and displayed (step 1109).

(Concrete example)

**[0030]** Using the apparatus described above, the OCT imaging unit acquires  $6 \times 2$  mm (*x*, *z*) images at 60 Hz and the SLO imaging unit acquires  $8 \times 6$  mm (*x*, *y*) images at 20 Hz. Hereinafter, a direction along the optic axis will be designated as a *z* direction, a direction parallel to the fundus plane will be designated as an *x* direction, and a direction vertical to the fundus plane will be designated as a *y* direction. Images acquired by the two imaging units are shown in FIG. 3. The OCT imaging unit and SLO imaging unit are controlled by the same CPU. Three OCT images are acquired while one SLO image is acquired.

**[0031]** As shown in FIG. 4, an SLO image is acquired and four templates T1, T2, T3 and T4 are extracted from the SLO image as feature points. According to the present embodiment, intersections of blood vessels are extracted as feature points. The extracted template information is recorded in the recording unit 207. The template information includes coordinate position corresponding to an origin of the SLO image (e.g., scan start position or center position), size, and image information (feature value). Then, an OCT image covering a range (indicated by a thick line O) from the macula to an edge of the optic disk in the SLO image is acquired.

**[0032]** Next, tracking control will be described with reference to FIGS. 4 and 5. The SLO beam is scanned by operating the SLO imaging unit at the instant when the OCT imaging unit starts imaging. Consequently, while acquiring an SLO image S-1, T1-1 which corresponds to the template T1 closest to scan start position is acquired from part of the SLO image S-1. The moving amount ( $\Delta x$ ,  $\Delta y$ ) of the fundus is calculated from a difference between T1 coordinates of the initial SLO image S and T1-1 co-

ordinates of the image S-1. The calculated moving amount is fed back to the X and Y scanners of the OCT imaging unit in real time. The feedback allows the OCT beam to scan the same location in the fundus. According to the invention, similar control is performed for the templates T2 to T4 in order of increasing distance from the scan start position. According to the invention, even during acquisition of the SLO image, feedback at an average of approximately 80 Hz allows the OCT imaging unit to scan a desired position. After the entire SLO image S-1 is acquired,  $\Delta x$ ,  $\Delta y$ , rotation and magnification are calculated by applying affine transformations to T1 to T4 of the SLO image S and T1-1 to T4-1 of the SLO image S-1, and results are reflected in the galvano scanners of the OCT imaging unit, allowing corrections to be made even to parameters other than the shift amounts. The above process is also applied to SLO images S-2 to S-4 in sequence. Regarding the scan position, the OCT imaging unit can scan the same position in the fundus and thereby acquire OCT images at the same position as is the case with O-1 to O-12 in FIG. 5.

**[0033]** That is, according to the present invention, a plurality of fundus images (S, S1, and S2 to S4) of the subject's eye is acquired at different times, a plurality of characteristic images (T1-1 to T4-1) is extracted from each of the fundus images, and the movements of the subject's eye are measured based on the extracted characteristic images. Therefore, the fundus image acquisition unit acquires a plurality of fundus images. Also, the scanning unit according to the present invention scans the subject's eye with measuring light to acquire tomographic images of the subject's eye. The measuring unit measures the movements of the subject's eye by executing matching of characteristic images extracted from each of the fundus images acquired at different times as described above and the control unit controls the scanning unit according to the movements of the subject's eye found as measurement results. Also, the measuring unit measures the movements of the subject's eye while the plurality of fundus images is being acquired at different times.

**[0034]** Incidentally, the pattern matching using the template T1 may be started when an SLO image for one scan is acquired or when that part of an SLO image which includes the coordinates of the stored template T1 is acquired.

**[0035]** The scanners of the OCT imaging unit makes corrections according to movements of the fundus, but the scanners of the SLO imaging unit do not make corrections according to movements.

**[0036]** That is, according to the present invention, a fundus image is acquired by the SLO imaging unit, a plurality of feature points is extracted from the fundus image, and pattern matching is performed by extracting feature points from another SLO image. Furthermore, when movements are measured in relation to one feature point, the subject's eye is scanned with measuring light to acquire a tomographic image.

**[0037]** As described above, a plurality of tomographic images can be acquired at the same position by scanning the same location of the fundus with the OCT beam. Also, the plurality of fundus tomographic images thus acquired can be superimposed to enable observation of minute blood vessels, their abnormalities, edema, tumors or treatment scars, without using image processing to align the images.

**[0038]** Although in the present embodiment, tracking control is performed by extracting templates from four locations, similar effects can be obtained if templates are extracted from two or more locations.

**[0039]** Also, in the present invention, the start of a template matching process is controlled based on positional information about a plurality of feature points extracted from a fundus image.

#### Second Embodiment

**[0040]** The present embodiment includes an internal fixation lamp, an SLO imaging unit, and an OCT imaging unit and involves comparing an acquisition rate of fundus tomographic images by the OCT imaging unit and an acquisition rate of SLO images by the SLO imaging unit, determining the number of templates to be extracted from each SLO image according to the acquisition rate of OCT images, correcting acquisition position of the next OCT image based on each template, thereby linking tracking speed and imaging speed of the OCT imaging unit to each other, and thereby performing optimal tracking. The apparatus configuration is the same as the first embodiment, and thus description thereof will be omitted.

**[0041]** According to the present embodiment, the OCT imaging unit acquires  $6 \times 2$  mm images at 40 Hz and the SLO imaging unit acquires  $8 \times 6$  mm images at 20 Hz. While the SLO imaging unit acquires one SLO image, two OCT images can be acquired, and thus templates, i.e., feature points, are extracted from two locations. An extracted image is shown in FIG. 6. Templates T1' and T2' are extracted from the acquired SLO image S' and the extracted template information is recorded in the recording unit 207. An OCT imaging area O' corresponds to a scan range from the macula to an edge of the optic disk.

**[0042]** Before imaging is started by the OCT imaging unit, while part of an image S1' is being acquired, a location which corresponds to the templates T1' extracted from the SLO image S' is searched for as shown in FIGS. 6 and 7. When T1'-1 which corresponds to the template T1' is acquired from part of the SLO image S1', the moving amount ( $\Delta x$ ,  $\Delta y$ ) of the fundus is calculated from a difference between T1' coordinates of the initial SLO image S' and T1'-1 coordinates of the image S1'. The calculated moving amount is fed back to the X and Y scanners of the OCT imaging unit in real time. Simultaneously with the feedback, an OCT image is captured by the OCT imaging unit. Similar control is performed for the template T2'. Even during acquisition of the SLO image, if the ac-

quisition of the SLO image is synchronized with the OCT image by means of real-time feedback, a desired position can be scanned with the OCT beam at about 40 Hz on a template by template basis. The control described above allows calculation results to be used in capturing each OCT image, and an OCT image O'-1 corresponding to the template T1'-1 and an OCT image O'-2 corresponding to the template T2'-1 are acquired as shown in FIG. 7. Once the entire SLO image S1' is captured, the rotation amount of the fundus is calculated from the SLO image S1' and templates of the SLO image S1'. The calculated rotation amount is fed back to the OCT galvano scanners.

**[0043]** A similar process is performed for SLO images S2' to S4', allowing tracking to be performed at about 40 Hz in synchronization with the image acquisition rate of the OCT imaging unit.

**[0044]** As described above, a plurality of tomographic images can be acquired at the same position by scanning the same location of the fundus with the OCT beam. Also, the plurality of fundus tomographic images can be superimposed to enable observation of minute blood vessels, edema, or tumors, without using image processing to align the images. Incidentally, in the present embodiment, after the movements of the subject's eye are measured, the rotation amount of the fundus or rotation amount of the subject's eye is measured by the measuring unit, but the magnification of the subject's eye rather than the rotation amount may be found by a similar technique. Alternatively, both rotation amount and magnification may be found.

**[0045]** In the present embodiment, templates are extracted at two locations because the acquisition rate of OCT images is twice as high as the acquisition rate of SLO images, and templates can be extracted from as many locations as the ratio of the acquisition rates.

**[0046]** That is, preferably the acquisition rate of OCT images is an integral multiple of the acquisition rate of SLO images, and thus the number of feature points extracted initially is preferably set equal to the quotient of the acquisition rate of the OCT images divided by the acquisition rate of the SLO images.

#### Other Embodiments

**[0047]** Although an internal fixation lamp is used in the first and second embodiments, an external fixation lamp may be used alternatively. When an external fixation lamp is used, ocular fixation becomes less stable than when an internal fixation lamp is used.

**[0048]** Also, the fundus photographing apparatus may be an LSLO (Line Scanning Laser Ophthalmoscope) instead of an SLO. In that case, needless to say, the SLO scanner (X) becomes unnecessary.

**[0049]** Furthermore, although in the above embodiments, positional information is reflected in real time, the positional information may be reflected after the acquisition of an SLO image.

**[0050]** If templates are detected at more than two lo-

cations, rotation and magnification may be calculated by affine transformations or the like even during acquisition of the same fundus image and fed back to the OCT apparatus.

**[0051]** The present invention can also be implemented by software (program) which implements the functions of the above embodiments if the software (program) is supplied to a system or apparatus via a network or any of various storage media and a computer (or a CPU or MPU) of the system or apparatus then reads and executes the program.

**[0052]** 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 such modifications and equivalent structures and functions.

**[0053]** The present invention provides an ophthalmological apparatus capable of displaying a plurality of fundus tomographic images. A photographing apparatus includes a fundus imaging unit adapted to capture a fundus image of a subject's eye, a scanning unit adapted to scan a desired position of the fundus of the subject's eye to capture tomographic images of the subject's eye, a measuring unit adapted to measure movement amounts of the fundus of the subject's eye by performing pattern matching between a plurality of feature points in the acquired fundus image and feature points in another fundus image newly acquired at a different time, and a control unit adapted to control the scanning unit based on the measured movement amounts.

#### Claims

1. A photographing apparatus which measures movements of an eye to be inspected, comprising:

a scanning unit (105) adapted to scan measuring light to acquire tomographic images of the eye to be inspected;

a fundus image acquisition unit adapted to acquire a plurality of fundus images;

a recording unit (207);

a control unit (201, 203) adapted to extract a plurality of characteristic images (T1 to T4) in an initial fundus image (S) of the eye to be inspected,

the control unit being further adapted to record the plurality of characteristic images (T1 to T4) extracted from the initial fundus image (S) in the recording unit (207); and

a measuring unit (201) adapted to measure the movements of the eye to be inspected, by executing matching using each of the plurality of recorded characteristic images (T1 to T4) and each of a corresponding plurality of character-

istic images (T1-1 to T4-4) extracted from a further fundus image (S-1, S-2, S-3, S-4) of the eye to be inspected and acquired at a different time, the control unit (201, 203) being further adapted to control the scanning unit based on each of the movements of the eye to be inspected, **characterized in that** the measuring unit (201) is further adapted to measure the movements of the eye to be inspected according to an order in which the corresponding plurality of characteristic images (T1-1 to T4-4) is extracted while the fundus image acquisition unit is acquiring said further fundus image (S-1, S-2, S-3, S-4), the order being an order of increasing distance from a scan start position of said further fundus image (S-1, S-2, S-3, S-4).

- 2. The photographing apparatus according to claim 1, wherein after measuring the movements of the eye to be inspected, the measuring unit is adapted to calculate at least one of rotation and magnification of the eye to be inspected using the plurality of characteristic images.
- 3. The photographing apparatus according to claim 1 or 2, wherein an acquisition rate of the tomographic images is an integral multiple of an acquisition rate of the fundus images.
- 4. The photographing apparatus according to claim 3, wherein a number of characteristic images is set equal to a quotient of the acquisition rate of the tomographic images divided by the acquisition rate of the fundus images.
- 5. The photographing apparatus according to any one of claims 1-4, wherein the fundus image acquisition unit is an SLO or an LSLO.
- 6. The photographing apparatus according to any one of claims 1-5, wherein the scanning unit is a part of an OCT.
- 7. The photographing apparatus according to any one of claims 1-6, wherein the measuring unit is adapted to start processing when an image for one scan or a scanned image corresponding to a position of one of the characteristic images is acquired by the fundus image acquisition unit.
- 8. A control method for a photographing apparatus which measures movements of an eye to be inspected, the control method comprising:

extracting a plurality of characteristic images (T1 to T4) in an initial fundus image (S) of the eye to be inspected;

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recording the plurality of characteristic images (T1 to T4) extracted from the initial fundus image (S);  
measuring the movements of the eye to be inspected, by executing matching using each of the plurality of recorded characteristic images (T1 to T4) and each of a corresponding plurality of characteristic images (T1-1 to T4-4) extracted from a further fundus image (S-1, S-2, S-3, S-4) of the eye to be inspected and acquired at a different time; and  
controlling a scanning unit based on each of the movements of the eye to be inspected, where the scanning unit is adapted to scan measuring light to acquire tomographic images of the eye to be inspected, **characterized in that** the movements of the eye to be inspected are measured according to an order in which the corresponding plurality of characteristic images (T1-1 to T4-4) is extracted while acquiring said further fundus image (S-1, S-2, S-3, S-4), the order being an order of increasing distance from a scan start position of said further fundus image (S-1, S-2, S-3, S-4).

- 9. The control method according to claim 8, wherein after measuring the movements of the eye to be inspected, at least one of rotation and magnification of the eye to be inspected is calculated using the plurality of characteristic images.
- 10. The control method according to claim 8 or 9, wherein an acquisition rate of the tomographic images is an integral multiple of an acquisition rate of the fundus images.
- 11. A program which causes a photographing apparatus according to any one of claims 1-7 to execute the steps of the control method according to any one of claims 8 to 10.

**Patentansprüche**

- 1. Fotografiervorrichtung, die Bewegungen eines zu untersuchenden Auges misst, mit  
  
einer Abtasteinheit (105) zur Abtastung von Messlicht zum Beschaffen von Tomographiebildern des zu untersuchenden Auges, einer Fundusbildbeschaffungseinheit zur Beschaffung einer Vielzahl von Fundusbildern, einer Aufzeichnungseinheit (207), einer Steuereinheit (201, 203) zum Extrahieren einer Vielzahl charakteristischer Bilder (T1 bis T4) in einem Anfangsfundusbild (S) des zu untersuchenden Auges, wobei die Steuereinheit ferner zur Aufzeichnung

- der Vielzahl der aus dem Anfangsfundusbild (S) extrahierten charakteristischen Bilder (T1 bis T4) in der Aufzeichnungseinheit (207) eingerichtet ist, und
- einer Messeinheit (201) zur Messung der Bewegungen des zu untersuchenden Auges durch Ausführen eines Übereinstimmungsvergleichs unter Verwendung jedes der Vielzahl der aufgezeichneten charakteristischen Bilder (T1 bis T4) und jedes einer entsprechenden Vielzahl charakteristischer Bilder (T1-1 bis T4-4), die aus einem weiteren Fundusbild (S-1, S-2, S-3, S-4) des zu untersuchenden Auges extrahiert und zu einer anderen Zeit beschafft werden, wobei die Steuereinheit (201, 203) ferner zur Steuerung der Abtasteinheit beruhend auf jeder der Bewegungen des zu untersuchenden Auges eingerichtet ist,
- dadurch gekennzeichnet, dass** die Messeinheit (201) ferner zur Messung der Bewegungen des zu untersuchenden Auges gemäß einer Reihenfolge eingerichtet ist, in der die entsprechende Vielzahl charakteristischer Bilder (T1-1 bis T4-4) extrahiert wird, während die Fundusbildbeschaffungseinheit das weitere Fundusbild (S-1, S-2, S-3, S-4) beschafft, wobei die Reihenfolge eine Reihenfolge ansteigender Entfernung von einem Abtaststartpunkt des weiteren Fundusbildes (S-1, S-2, S-3, S-4) ist.
2. Fotografiervorrichtung nach Anspruch 1, wobei nach Messung der Bewegungen des zu untersuchenden Auges die Messeinheit zum Berechnen einer Rotation und/oder Vergrößerung des zu untersuchenden Auges unter Verwendung der Vielzahl charakteristischer Bilder eingerichtet ist.
  3. Fotografiervorrichtung nach Anspruch 1 oder 2, wobei eine Beschaffungsrate der Tomographiebilder ein ganzzahliges Vielfaches einer Beschaffungsrate der Fundusbilder ist.
  4. Fotografiervorrichtung nach Anspruch 3, wobei eine Anzahl charakteristischer Bilder gleich einem Quotienten der Beschaffungsrate der Tomographiebilder geteilt durch die Beschaffungsrate der Fundusbilder ist.
  5. Fotografiervorrichtung nach einem der Ansprüche 1 bis 4, wobei die Fundusbildbeschaffungseinheit eine SLO- oder eine LSLO-Einrichtung ist.
  6. Fotografiervorrichtung nach einem der Ansprüche 1 bis 5, wobei die Abtasteinheit ein Teil einer OCT-Einrichtung ist.
  7. Fotografiervorrichtung nach einem der Ansprüche 1 bis 6, wobei die Messeinheit zum Starten einer Ver-
- arbeitung eingerichtet ist, wenn ein Bild für eine Abtastung oder ein abgetastetes Bild, das einer Position eines der charakteristischen Bilder entspricht, durch die Fundusbildbeschaffungseinheit beschafft wird.
8. Steuerverfahren für eine Fotografiervorrichtung, die Bewegungen eines zu untersuchenden Auges misst, mit
    - Extrahieren einer Vielzahl charakteristischer Bilder (T1 bis T4) in einem Anfangsfundusbild (S) des zu untersuchenden Auges,
    - Aufzeichnen der Vielzahl der aus dem Anfangsfundusbild (S) extrahierten charakteristischen Bilder (T1 bis T4),
    - Messen der Bewegungen des zu untersuchenden Auges durch Ausführen eines Übereinstimmungsvergleichs unter Verwendung jedes der Vielzahl aufgezeichneter charakteristischer Bilder (T1 bis T4) und jedes einer entsprechenden Vielzahl charakteristischer Bilder (T1-1 bis T4-4), die aus einem weiteren Fundusbild (S-1, S-2, S-3, S-4) des zu untersuchenden Auges extrahiert und zu einer anderen Zeit beschafft werden, und
    - Steuern einer Abtasteinheit beruhend auf jeder der Bewegungen des zu untersuchenden Auges, wobei die Abtasteinheit zur Abtastung von Messlicht zum Beschaffen von Tomografiebildern des zu untersuchenden Auges eingerichtet ist,
    - dadurch gekennzeichnet, dass** die Bewegungen des zu untersuchenden Auges gemäß einer Reihenfolge gemessen werden, in der die entsprechende Vielzahl charakteristischer Bilder (T1-1 bis T4-4) extrahiert wird, während das weitere Fundusbild (S-1, S-2, S-3, S-4) beschafft wird, wobei die Reihenfolge eine Reihenfolge einer ansteigender Entfernung von einem Abtaststartpunkt des weiteren Fundusbildes (S-1, S-2, S-3, S-4) ist.
  9. Steuerverfahren nach Anspruch 8, wobei nach Messung der Bewegungen des zu untersuchenden Auges eine Rotation und/oder Vergrößerung des zu untersuchenden Auges unter Verwendung der Vielzahl charakteristischer Bilder berechnet wird/werden.
  10. Steuerverfahren nach Anspruch 8 oder 9, wobei eine Beschaffungsrate der Tomografiebilder ein ganzzahliges Vielfaches einer Beschaffungsrate der Fundusbilder ist.
  11. Programm, das eine Fotografiervorrichtung nach einem der Ansprüche 1 bis 7 zur Ausführung der Schritte des Steuerverfahrens nach einem der Ansprüche 8 bis 10 veranlasst.

## Revendications

1. Appareil photographique qui mesure les mouvements d'un oeil à examiner, comprenant :

une unité de balayage (105) adaptée pour balayer une lumière de mesure pour acquérir des images tomographiques de l'oeil à examiner ;  
une unité d'acquisition d'images de fond adaptée pour acquérir une pluralité d'images de fond ;

une unité d'enregistrement (207) ;

une unité de commande (201, 203) adaptée pour extraire une pluralité d'images caractéristiques (T1 à T4) dans une image initiale de fond (S) de l'oeil à examiner,

l'unité de commande étant en outre adaptée pour enregistrer la pluralité d'images caractéristiques (T1 à T4) extraites de l'image initiale de fond (S) dans l'unité d'enregistrement (207) ; et une unité de mesure (201) adaptée pour mesurer les mouvements de l'oeil à examiner, en exécutant une mise en correspondance en utilisant chacune de la pluralité d'images caractéristiques enregistrées (T1 à T4) et chacune d'une pluralité correspondante d'images caractéristiques (T1-1 à T4-4) extraites d'une image de fond supplémentaire (S-1, S-2, S-3, S-4) de l'oeil à examiner et acquises à un moment différent, l'unité de commande (201, 203) étant en outre adaptée pour commander l'unité de balayage sur la base de chacun des mouvements de l'oeil à examiner,

**caractérisé en ce que :**

l'unité de mesure (201) est en outre adaptée pour mesurer les mouvements de l'oeil à examiner selon un ordre dans lequel la pluralité correspondante d'images caractéristiques (T1-1 à T4-4) est extraite pendant que l'unité d'acquisition d'images de fond acquiert ladite image de fond supplémentaire (S-1, S-2, S-3, S-4), l'ordre étant un ordre de distance croissante depuis une position de début de balayage de ladite image de fond supplémentaire (S-1, S-2, S-3, S-4).

2. Appareil photographique selon la revendication 1, dans lequel, après avoir mesuré les mouvements de l'oeil à examiner, l'unité de mesure est adaptée pour calculer au moins l'un d'une rotation et d'un agrandissement de l'oeil à examiner en utilisant la pluralité d'images caractéristiques.
3. Appareil photographique selon la revendication 1 ou 2, dans lequel une vitesse d'acquisition des images tomographiques est un multiple entier d'une vitesse d'acquisition des images de fond.

4. Appareil photographique selon la revendication 3, dans lequel un certain nombre d'images caractéristiques est défini comme étant égal à un quotient de la vitesse d'acquisition des images tomographiques divisée par la vitesse d'acquisition des images de fond.

5. Appareil photographique selon l'une quelconque des revendications 1 à 4, dans lequel l'unité d'acquisition d'images de fond est un SLO ou un LSLO.

6. Appareil photographique selon l'une quelconque des revendications 1 à 5, dans lequel l'unité de balayage fait partie d'une OCT.

7. Appareil photographique selon l'une quelconque des revendications 1 à 6, dans lequel l'unité de mesure est adaptée pour commencer le traitement lorsqu'une image pour un balayage ou une image balayée correspondant à une position de l'une des images caractéristiques est acquise par l'unité d'acquisition d'images de fond.

8. Procédé de commande pour un appareil photographique qui mesure les mouvements d'un oeil à examiner, le procédé de commande comprenant le fait :

d'extraire une pluralité d'images caractéristiques (T1 à T4) dans une image initiale de fond (S) de l'oeil à examiner ;

d'enregistrer la pluralité d'images caractéristiques (T1 à T4) extraites de l'image initiale de fond (S) ;

de mesurer les mouvements de l'oeil à examiner, en exécutant une mise en correspondance en utilisant chacune de la pluralité d'images caractéristiques enregistrées (T1 à T4) et chacune d'une pluralité correspondante d'images caractéristiques (T1-1 à T4-4) extraites d'une image de fond supplémentaire (S-1, S-2, S-3, S-4) de l'oeil à examiner et acquises à un autre moment ;

de commander une unité de balayage sur la base de chacun des mouvements de l'oeil à examiner, où l'unité de balayage est adaptée pour balayer une lumière de mesure pour acquérir des images tomographiques de l'oeil à examiner,

**caractérisé en ce que** les mouvements de l'oeil à examiner sont mesurés selon un ordre dans lequel la pluralité correspondante d'images caractéristiques (T1-1 à T4-4) est extraite lors de l'acquisition de ladite image de fond supplémentaire (S-1, S-2, S-3, S-4), l'ordre étant un ordre de distance croissante depuis une position de début de balayage de ladite image de fond supplémentaire (S-1, S-2, S-3, S-4).

9. Procédé de commande selon la revendication 8, dans lequel, après avoir mesuré les mouvements de l'oeil à examiner, au moins l'un d'une rotation et d'un agrandissement de l'oeil à examiner est calculé en utilisant la pluralité d'images caractéristiques. 5
10. Procédé de commande selon la revendication 8 ou 9, dans lequel une vitesse d'acquisition des images tomographiques est un multiple entier d'une vitesse d'acquisition des images de fond. 10
11. Programme qui amène un appareil photographique selon l'une quelconque des revendications 1 à 7 à exécuter les étapes du procédé de commande selon l'une quelconque des revendications 8 à 10. 15

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FIG. 1

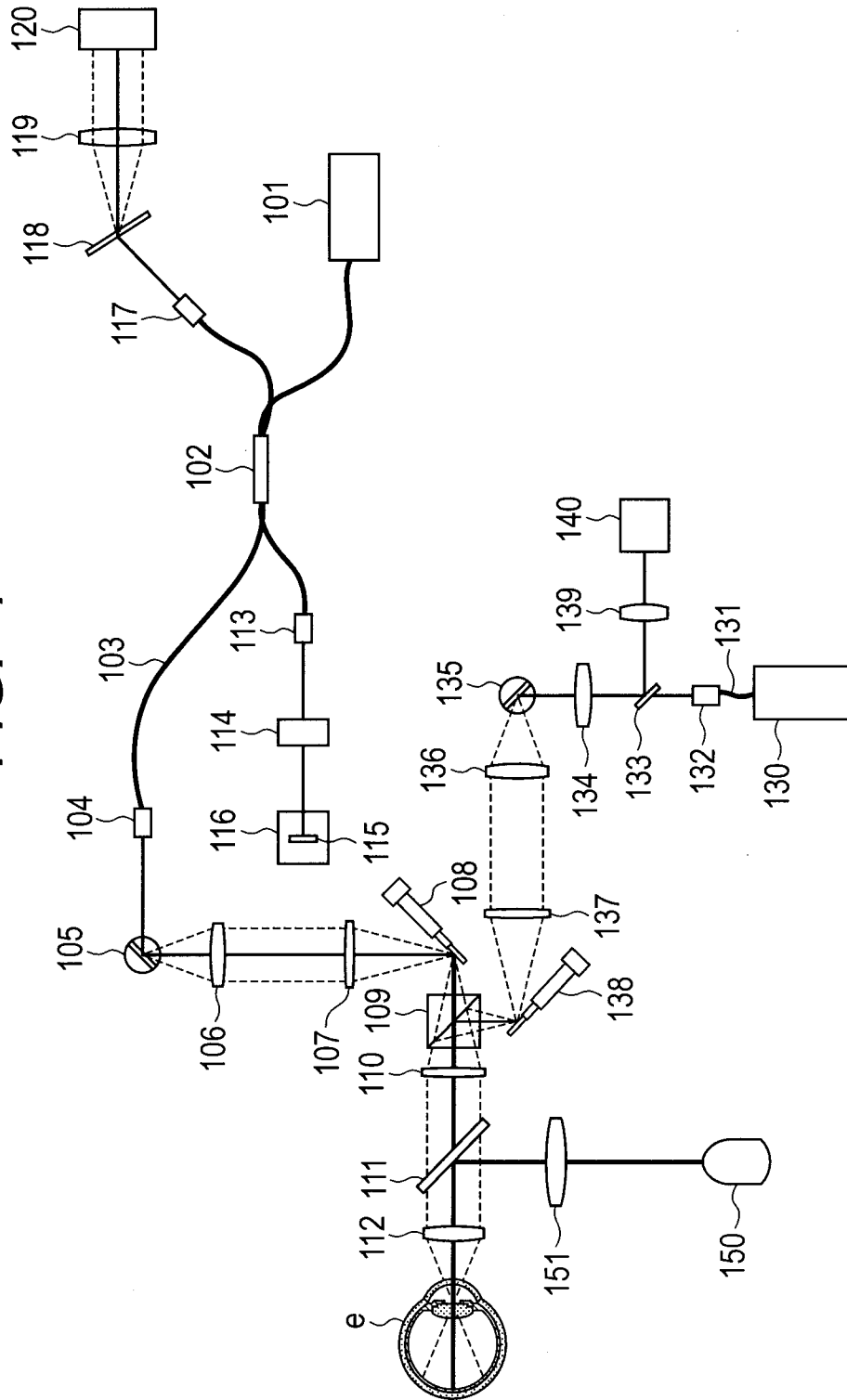


FIG. 2

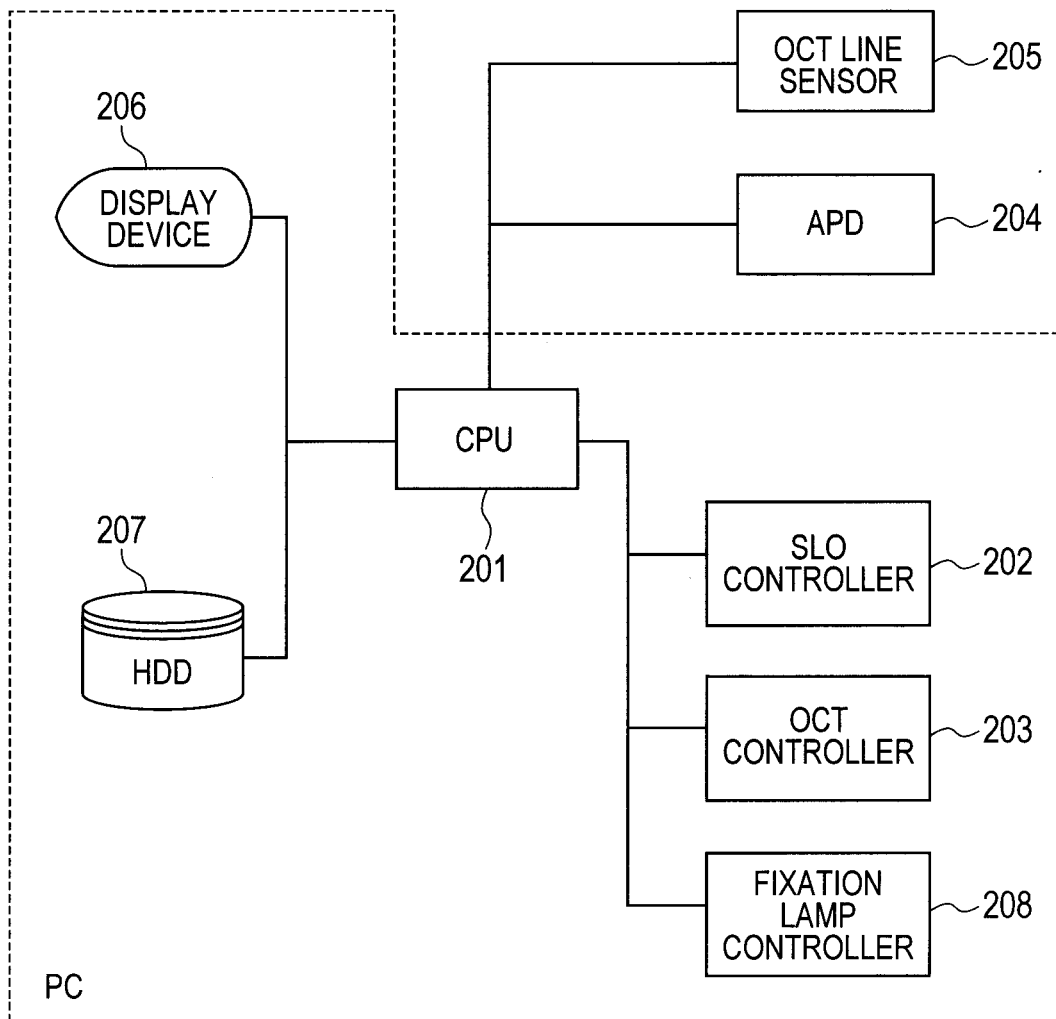


FIG. 3

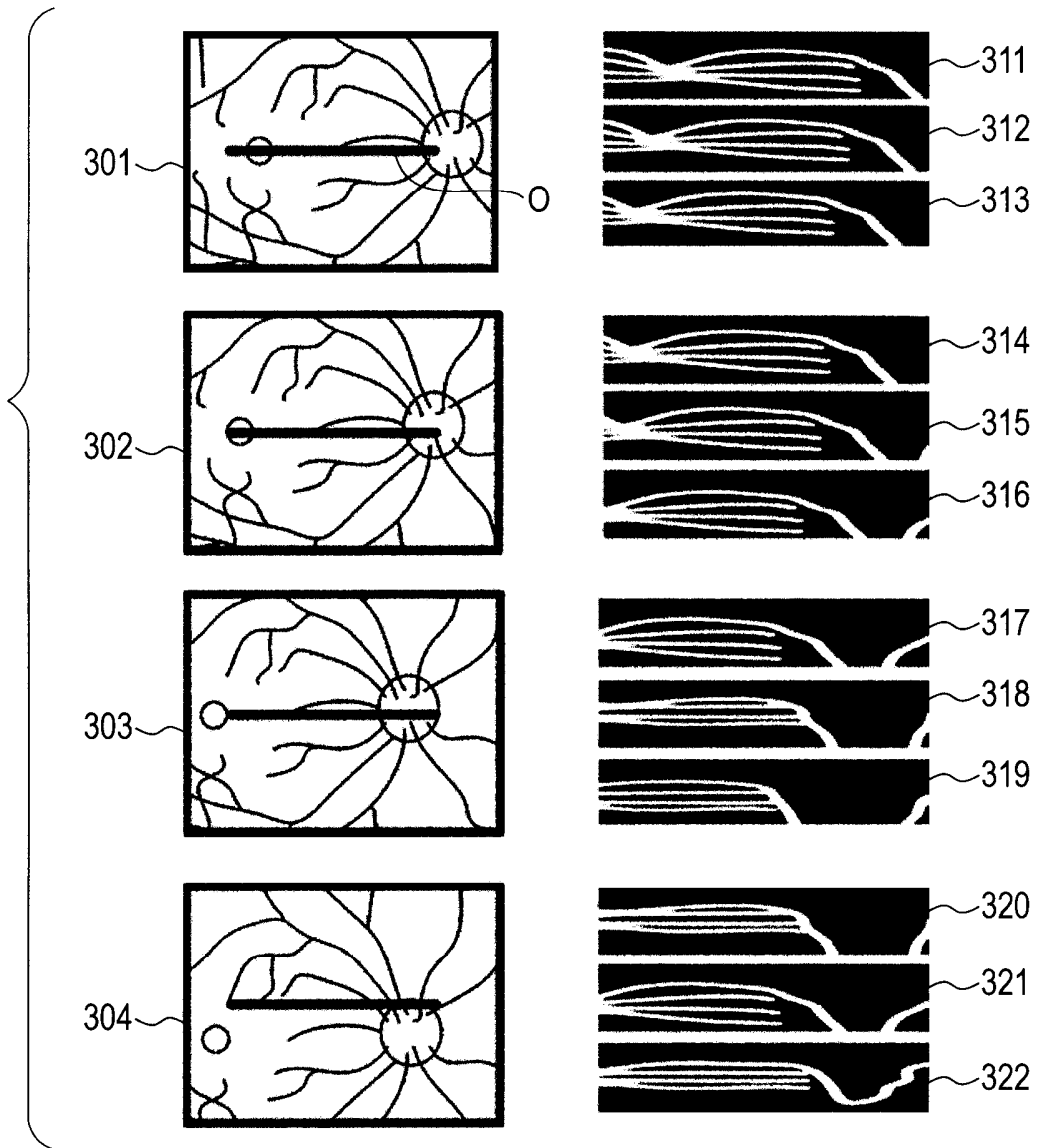


FIG. 4

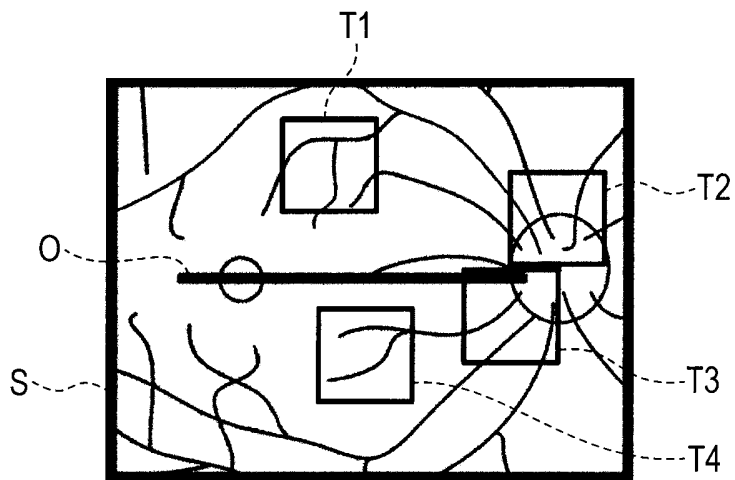


FIG. 5

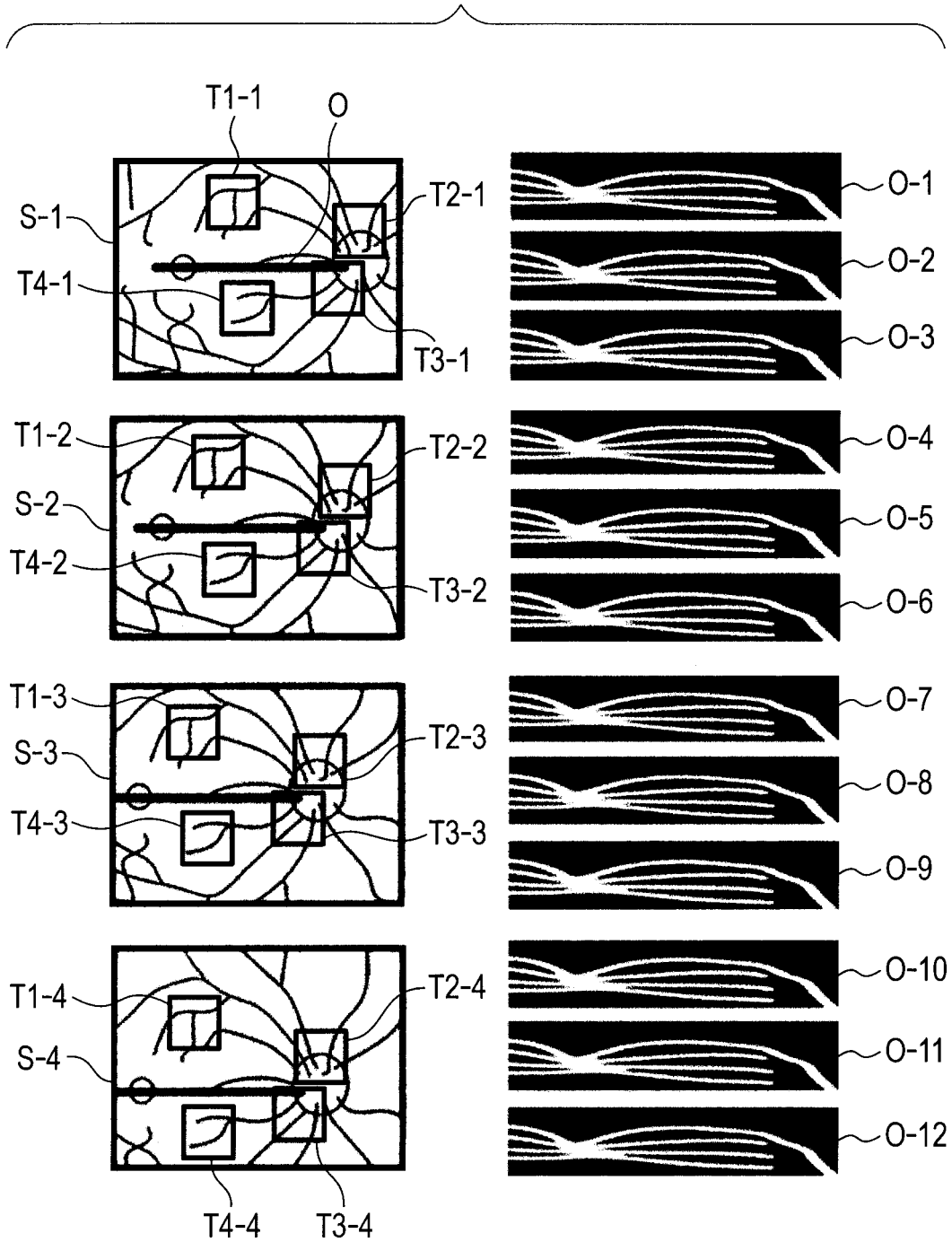


FIG. 6

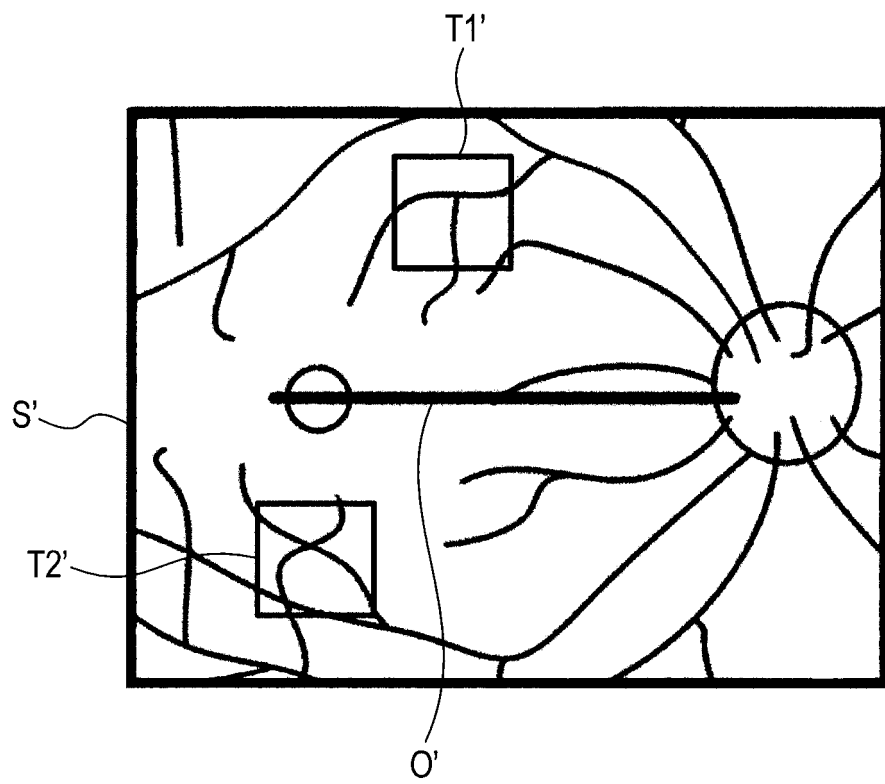


FIG. 7

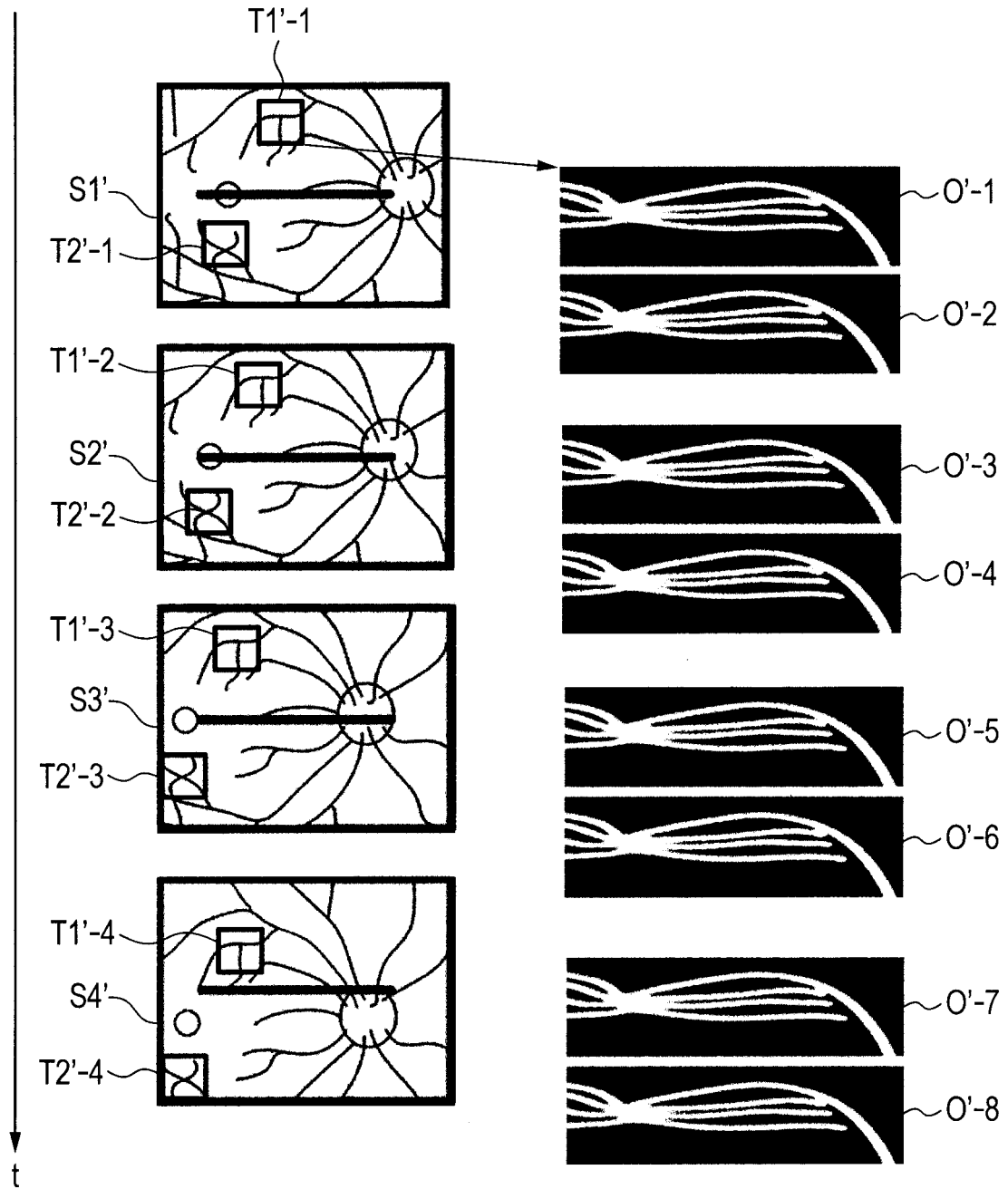


FIG. 8

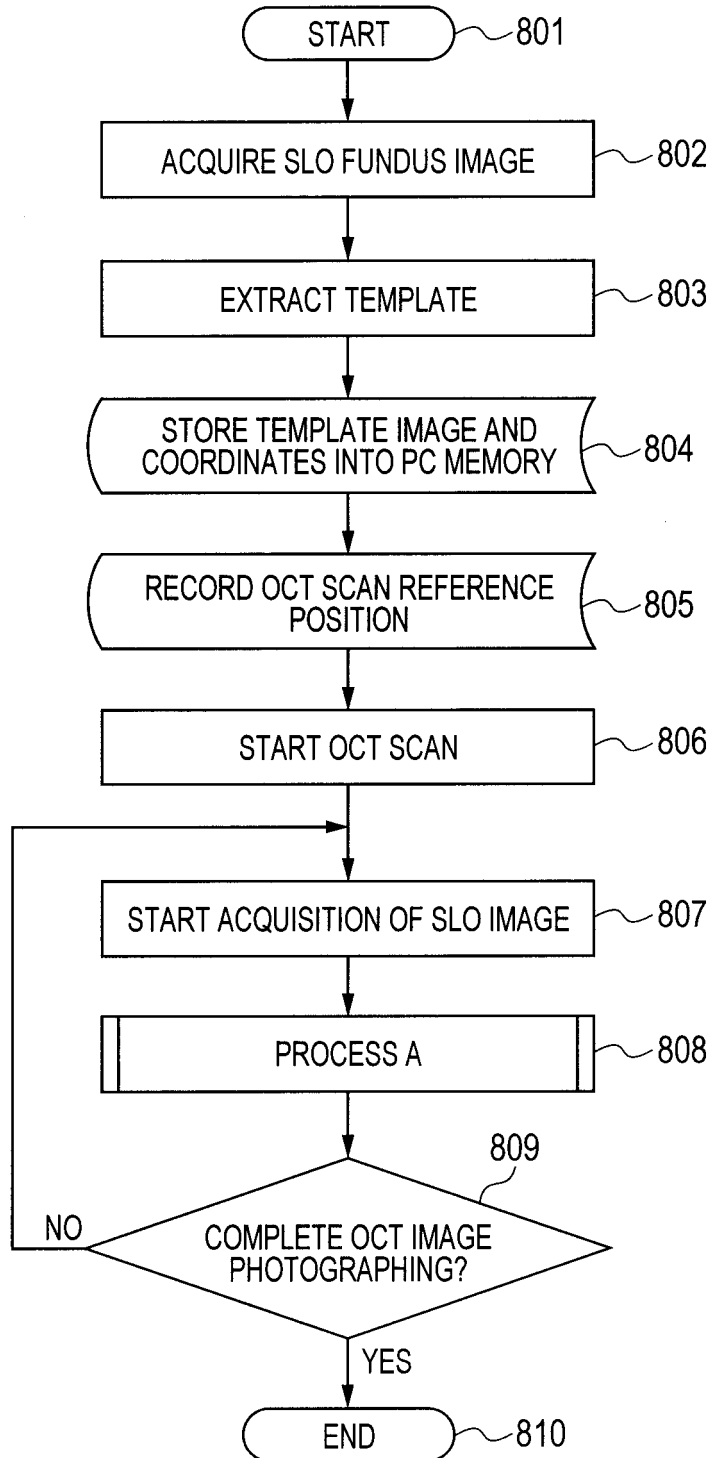


FIG. 9

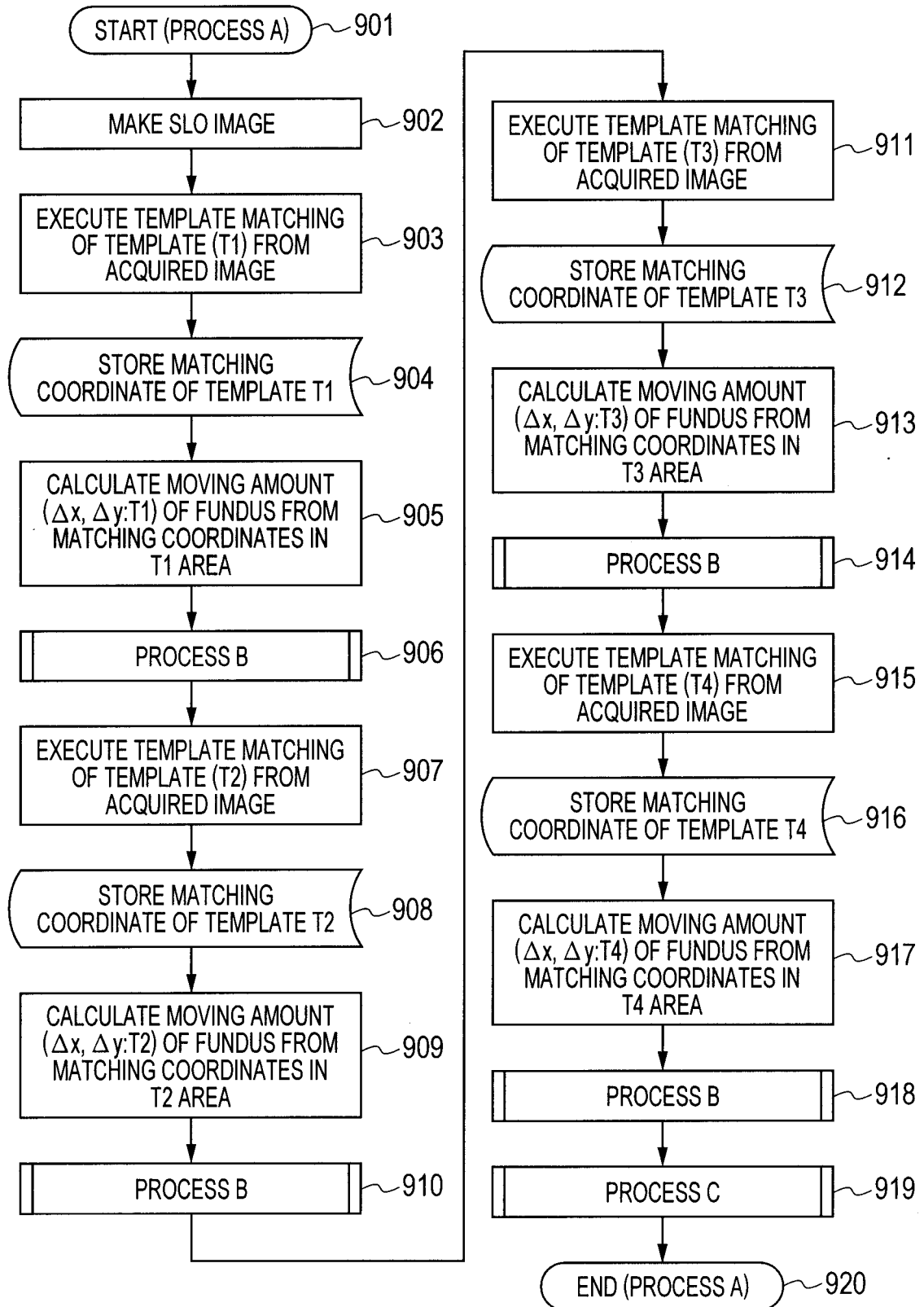


FIG. 10

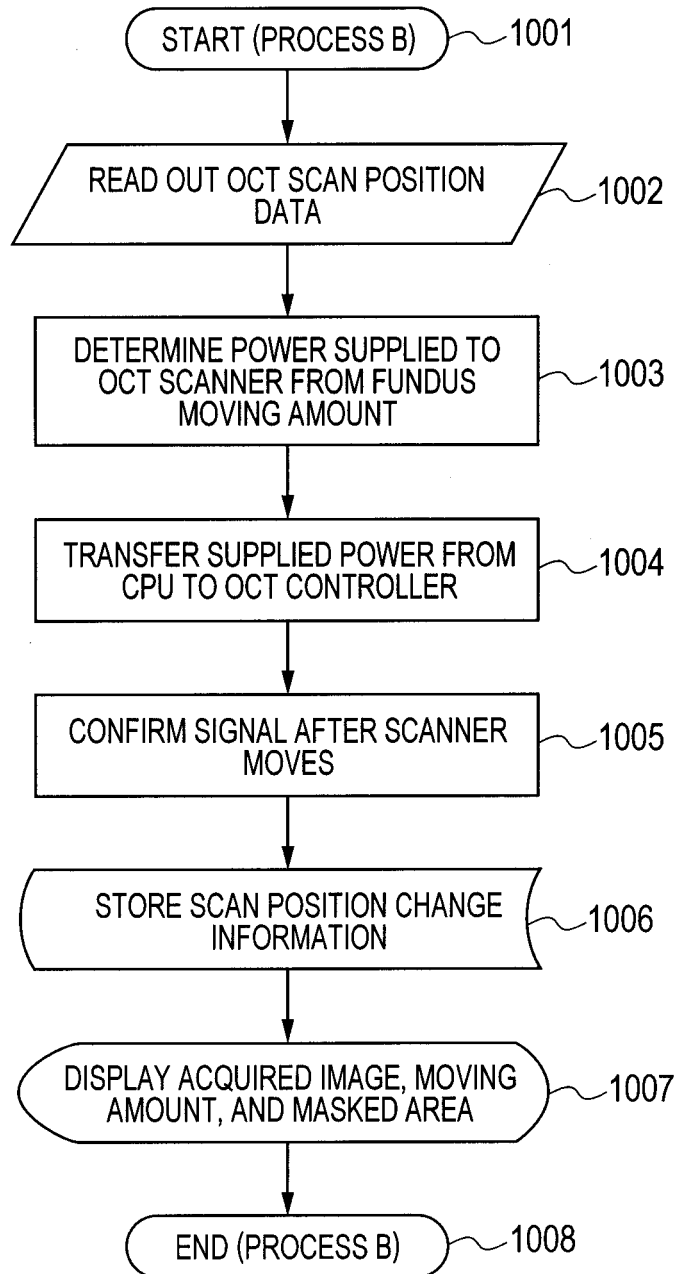
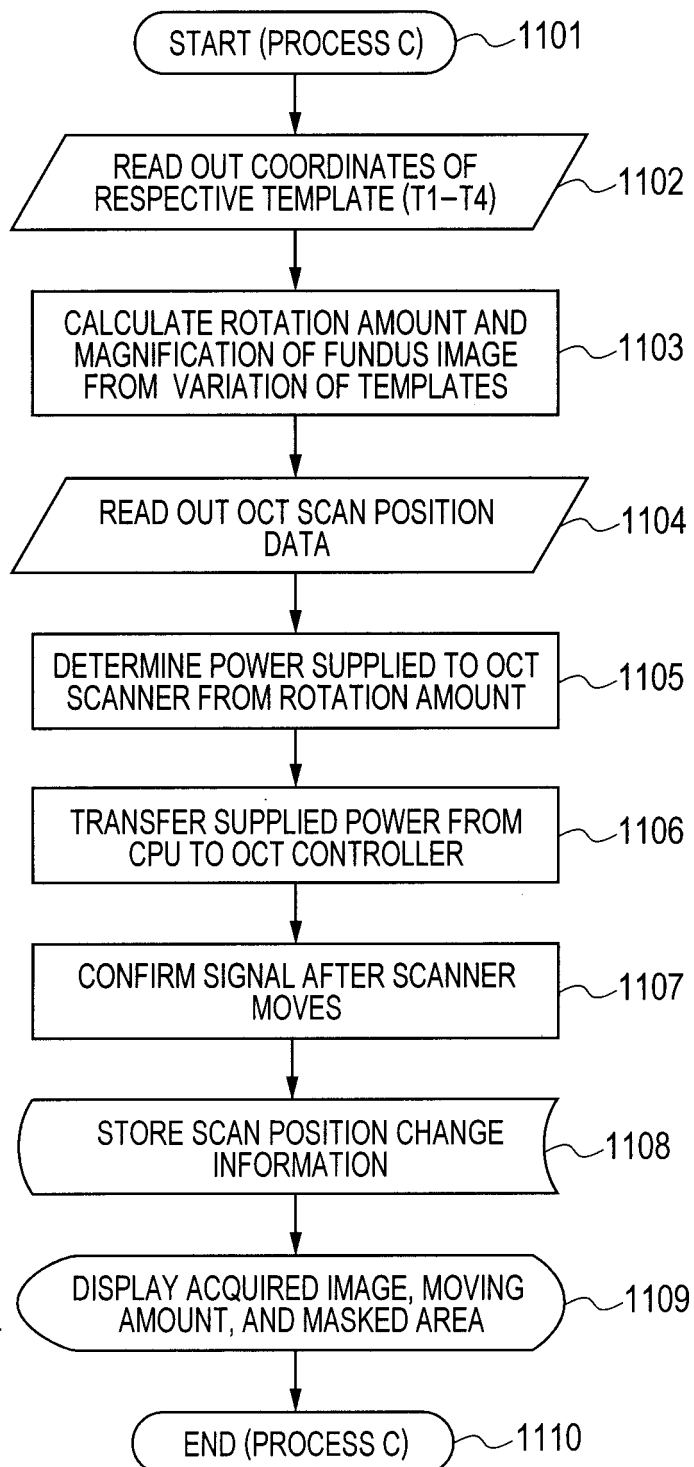


FIG. 11



**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 2004512125 A [0004] [0006] [0008]
- EP 1882445 A2 [0005] [0007] [0009]
- JP 2008029467 A [0005] [0007] [0009]
- EP 2382914 A1 [0010]

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摘要(译)

本发明提供一种能够显示多个眼底断层图像的眼科设备。一种摄影设备，包括：眼底成像单元，适于捕获被检眼的眼底图像；扫描单元，适于扫描被检眼的眼底的期望位置，以捕获被检眼的断层图像；测量单元，适于测量通过在获取的眼底图像中的多个特征点与在不同时间新获取的另一个眼底图像中的特征点之间进行模式匹配，以及适于基于控制扫描单元控制扫描单元的控制单元，对象眼底的移动量测量的运动量。

