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IMAGE PROCESSING METHOD, IMAGE PROCESSING DEVICE, AND PROGRAM

Abstract

An image processing method, including: by a processor: acquiring a fundus image; performing a first enhancement processing on an image of at least a central region of the fundus image, and performing a second enhancement processing, which is different from the first enhancement processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and generating an enhanced image of the fundus image on the basis of a first image obtained as a result of the first enhancement processing having been performed and a second image obtained as a result of the second enhancement processing having been performed.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to an image processing method, an image processing device, and a program.

BACKGROUND ART

[0002] Japanese Patent Application Laid-Open (JP-A) No. 2008-229157 discloses an image processing technique that depicts blood vessel regions of a fundus image sharply. An image processing technique that sharpens fundus images is desired.

SUMMARY OF INVENTION

[0003] A first aspect of the technique of the present disclosure is an image processing method, including: by a processor: acquiring a fundus image; performing a first enhancement processing on an image of at least a central region of the fundus image, and performing a second enhancement processing, which is different from the first enhancement processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and generating an enhanced image of the fundus image on the basis of a first image obtained as a result of the first enhancement processing having been performed and a second image obtained as a result of the second enhancement processing having been performed.

[0004] A second aspect of the technique of the present disclosure is an image processing method, including: by a processor: acquiring a fundus image; performing a first sharpening processing using a first parameter on the fundus image, and performing a second sharpening processing using a second parameter, which is different from the first parameter, on the fundus image; and generating a sharpened fundus image on the basis of an image obtained as a result of the first sharpening processing and the second sharpening processing having been performed.

[0005] An image processing device of a third aspect of the technique of the present disclosure includes a processor, and a memory coupled to the processor, the processor being configured to: acquire a fundus image; perform a first enhancement processing on an image of at least a central region of the fundus image, and perform a second enhancement processing, which is different from the first enhancement processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and generate an enhanced image of the fundus image on the basis of a first image obtained as a result of the first enhancement processing having been executed and a second image obtained as a result of the second enhancement processing having been performed.

[0006] An image processing device of a fourth aspect of the technique of the present disclosure includes a processor, and a memory coupled to the processor, wherein the processor: acquires a fundus image; performs a first sharpening processing using a first parameter on the fundus image, and performs a second sharpening processing using a second parameter, which is different from the first parameter, on the fundus image; and generates a sharpened fundus image on the basis of an image obtained as a result of the first sharpening processing and the second sharpening processing having been performed.

[0007] A program of a fifth aspect of the technique of the present disclosure causes a computer to execute: acquiring a fundus image; performing a first enhancement processing on an image of at least a central region of the fundus image, and performing a second enhancement processing, which is different from the first enhancement processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and generating an enhanced image of the fundus image on the basis of a first image obtained as a result of the first enhancement processing having been performed and a second image obtained as a result of the second enhancement processing having been performed.

[0008] A program of a sixth aspect of the technique of the present disclosure causes a computer to execute: acquiring a fundus image; performing a first sharpening processing using a first parameter on the fundus image, and performing a second sharpening processing using a second parameter, which is different from the first parameter, on the fundus image; and generating a sharpened fundus image on the basis of an image obtained as a result of the first sharpening processing and the second sharpening processing having been performed.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. **1** a block drawing of an ophthalmic system **100**.

[0010] FIG. **2** is a schematic structural drawing illustrating the overall structure of an ophthalmic device **110**.

[0011] FIG. **3** is a block drawing of the structure of the electrical system of a server **140**.

[0012] FIG. **4** is a block drawing of functions of a CPU **262** of the server **140**.

[0013] FIG. **5** is a flowchart of image processings by the server **140**.

[0014] FIG. **6**A is a flowchart of the sharpening processing of step **504** of FIG. **5**.

[0015] FIG. **6**B is a flowchart of the analyzing processing of a sharpened image of step **506** of FIG. **5**.

[0016] FIG. **7** is a drawing illustrating UWF fundus image G**1** of the RGB color space.

[0017] FIG. **8**A is a drawing illustrating image G**11** of the L* component of an image in the L*a*b* color space that is obtained by conversion of the UWF fundus image G**1** of the RGB color space.

[0018] FIG. **8**B is a drawing illustrating a central region and a peripheral region of the fundus image.

[0019] FIG. **9** is a drawing illustrating first tile size Tc for CLAHE processing on an image of the central region of the image G**11** of the L* component, and second tile size Tp for CLAHE processing on an image of the peripheral region.

[0020] FIG. **10** is a drawing illustrating UWF fundus image G**2** of the RGB color space after sharpening processing.

[0021] FIG. **11** is a drawing illustrating an enhanced image in which lesion portions have been enhanced.

[0022] FIG. **12** is a drawing illustrating first fundus image display screen **1000**A.

[0023] FIG. **13** is a drawing illustrating second fundus image display screen **1000**B.

[0024] FIG. **14** is a drawing illustrating third fundus image display screen **1000**C.

[0025] FIG. **15** is a flowchart of a modified example of the sharpening processing of step **504** of FIG. **5**.

DESCRIPTION OF EMBODIMENTS

[0026] Embodiments of the present invention are described in detail hereinafter with reference to the drawings.

[0027] The structure of an ophthalmic system **100** is described with reference to FIG. **1**. As illustrated in FIG. **1**, the ophthalmic system **100** has an ophthalmic device **110**, an ocular axis length measuring instrument **120**, a managing server device (hereinafter called “server”) **140**, and an image display device (hereinafter called “viewer”) **150**. The ophthalmic device **110** acquires a fundus image. The ocular axis length measuring instrument **120** measures the ocular axis length of a patient. The server **140** stores the fundus image, which is acquired by the fundus of the patient being imaged by the ophthalmic device **110**, in correspondence with the ID of the patient. The viewer **150** displays medical information such as the fundus image acquired from the server **140**, and the like.

[0028] The ophthalmic device **110**, the ocular axis length measuring instrument **120**, the server **140** and the viewer **150** are connected to one another via a network **130**.

[0029] The structure of the ophthalmic device **110** is described next with reference to FIG. **2**.

[0030] For convenience of explanation, a scanning laser ophthalmoscope is called “SLO”. Further, optical coherence tomography is called “OCT”.

[0031] Note that the horizontal direction, in a case in which the ophthalmic device **110** is set on a horizontal surface, is the “X direction”, the direction orthogonal to the horizontal surface is the “Y direction”, and the direction that connects the center of the pupil of the anterior eye portion of an subject eye **12** and the center of the eyeball is the “Z direction”.

[0032] Accordingly, the X direction, the Y direction and the Z direction are orthogonal to one another.

[0033] The ophthalmic device **110** includes an imaging device **14** and a control device **16**. The imaging device **14** has a SLO unit **18**, an OCT unit **20** and an imaging optical system **19**, and acquires a fundus image of the fundus of the subject eye **12**. Hereinafter, the two-dimensional fundus image that is acquired by the SLO unit **18** is called a SLO image. Further, the tomographic image or the directly frontal image (en-face image) or the like of the retina that is created on the basis of the OCT data acquired by the OCT unit **20** is called an OCT image.

[0034] The control device **16** has a computer having a CPU (Central Processing Unit) **16**A, a RAM (Random Access Memory) **16**B, a ROM (Read Only Memory) **16**C, and an input/output port (I/O) **16**D.

[0035] The control device **16** has an input/display device **16**E that is connected to the CPU **16**A via the I/O port **16**D. The input/display device **16**E has a graphic user interface that displays the image of the subject eye **12** and receives various instructions from the user. A touch panel display is an example of the graphic user interface.

[0036] Further, the control device **16** has an image processing device **16**G that is connected to the I/O port **16**D. The image processing device **16**G generates an image of the subject eye **12** on the basis of data obtained by the imaging device **14**. The control device **16** has a communication interface (I/F) **16**F that is connected to the I/O port **16**D. The ophthalmic device **110** is connected to the ocular axis length measuring instrument **120**, the server **140** and the viewer **150** via the communication interface (I/F) **16**F and the network **130**.

[0037] As described above, in FIG. **2**, the control device **16** of the ophthalmic device **110** has the input/display device **16**E, but the technique of the present disclosure is not limited to this. For example, the control device **16** of the ophthalmic device **110** may not have the input/display device **16**E, and may have a separate input/display device that is physically independent of the ophthalmic device **110**. In this case, the display device has an image processing processor unit that operates under the control of the CPU **16**A of the control device **16**. The image processing processor unit may display the SLO image and the like on the basis of image signals that are outputted and instructed from the CPU **16**A.

[0038] The imaging device **14** operates under the control of the CPU **16**A of the control device **16**. The imaging device **14** includes the SLO unit **18**, the imaging optical system **19** and the OCT unit **20**. The imaging optical system **19** includes a first optical scanner **22**, a second optical scanner **24**, and a wide angle optical system **30**.

[0039] The first optical scanner **22** two-dimensionally scans, in the X direction and the Y direction, the light that exits from the SLO unit **18**. The second optical scanner **24** two-dimensionally scans, in the X direction and the Y direction, the light that exits from the OCT unit **20**. It suffices for the first optical scanner **22** and the second optical scanner **24** to be optical elements that can deflect light bundles, and, for example, polygon mirrors, galvano mirrors or the like can be used therefor. Further, the first optical scanner **22** and the second optical scanner **24** may be combinations of these.

[0040] The wide angle optical system **30** includes an objective optical system (not illustrated in FIG. **2**) having a shared optical system **28**, and a combining section **26** that combines the light from the SLO unit **18** and the light from the OCT unit **20**.

[0041] Note that the objective optical system of the shared optical system **28** may be a reflective optical system that uses a concave mirror such as an elliptical mirror or the like, or a refractive optical system using a wide angle lens or the like, or a reflective/refractive optical system that combines a concave mirror and a lens. By using a wide angle optical system that uses an elliptical mirror or a wide angle lens or the like, not only the central portion of the fundus at which the optic papilla and the macula *lutea* exist, but also the retina of the fundus peripheral portion at which the equator of the eyeball and the vorticose veins exist, can be imaged.

[0042] Cases of using a system that includes an elliptical mirror may be structured so as to use the system using an elliptical mirror that is disclosed in International Publication WO 2016/103484 or International Publication WO 2016/103489. The respective disclosures of International Publication WO 2016/103484 and International Publication WO 2016/103489 are, in their entireties, incorporated by reference into the present specification.

[0043] Observation in a wide field of view (FOV) **12**A at the fundus is realized by the wide angle optical system **30**. The FOV **12**A means the range in which imaging is possible by the imaging device **14**. The FOV **12**A can be expressed as the viewing angle. In the present embodiment, the viewing angle can be prescribed by the internal illumination angle and the external illumination angle. The external illumination angle is the illumination angle in which the illumination angle of the light bundle, which is illuminated from the ophthalmic device **110** toward the subject eye **12**, is prescribed by using pupil **27** as the reference. Further, the internal illumination angle is the illumination angle in which the illumination angle of the light bundle, which is illuminated toward the fundus, is prescribed by using eyeball center O as the reference. The external illumination angle and the internal illumination angle have a corresponding relationship. For example, in a case in which the external illumination angle is 120°, the internal illumination angle corresponds to approximately 160°. In the present embodiment, the internal illumination angle is made to be 200°.

[0044] 200° that is the internal illumination angle is an example of the “predetermined value” of the technique of the present disclosure.

[0045] Here the SLO fundus image that is obtained by carrying out imaging at an imaging field angle of 160° or more that is an internal illumination angle is called a UWF-SLO fundus image. Note that UW F is the abbreviation for ultra wide field.

[0046] A SLO system is realized by the control device **16**, the SLO unit **18** and the imaging optical system **19** that are illustrated in FIG. **2**. Because the SLO system has the wide angle optical system **30**, the SLO system can capture images of the fundus in the wide FOV **12**A.

[0047] The SLO unit **18** has plural light sources, e.g., a light source **40** of B light (blue color light), a light source **42** of G light (green color light), a light source **44** of R light (red color light), and a light source **46** of IR light (infrared light (e.g., near infrared light)), and has optical systems **48**, **50**, **52**, **54**, **56** that reflect or transmit the lights from the light sources **40**, **42**, **44**, **46** and guide the lights to a single optical path. The optical systems **48**, **50**, **56** are mirrors, and the optical systems **52**, **54** are beam splitters. The B light is reflected at the optical system **48**, and transmitted through the optical system **50**, and reflected at the optical system **54**. The G light is reflected at the optical systems **50**, **54**. The R light is transmitted through the optical systems **52**, **54**. The IR light is reflected by the optical systems **56**, **52**. The respective lights are guided to a single optical path.

[0048] The SLO unit **18** is structured so as to be able to switch the combination of light sources that emit laser lights of different wavelengths or the light sources that are made to emit light such

as a mode in which G light, R light and B light are emitted, a mode in which infrared light is emitted, and the like. In the example illustrated in FIG. **2**, the four light sources that are the light source **40** of B light (blue color light), the light source **42** of G light, the light source **44** of R light, and the light source **46** of IR light are provided, but the technique of the present disclosure is not limited to this. For example, the SLO unit **18** may further have a light source of white light, and may emit light in various modes such as a mode in which only white light is emitted, or the like.
[0049] The light that is incident on the imaging optical system **19** from the SLO unit **18** is scanned in the X direction and the Y direction by the first optical scanner **22**. The scanning light goes through the wide angle optical system **30** and the pupil **27**, and is illuminated onto the posterior eye portion of the subject eye **12**. The reflected light that is reflected by the fundus goes through the wide angle optical system **30** and the first optical scanner **22**, and is made incident on the SLO unit **18**.
[0050] The SLO unit **18** has a beam splitter **64** that, of the light from the posterior eye portion (e.g., the fundus) of the subject eye **12**, reflects B light and transmits lights other than B light, and a beam splitter **58** that, of the light that is transmitted through the beam splitter **64**, reflects G light and transmits lights other than G light. The SLO unit **18** has a beam splitter **60** that, of the light transmitted through the beam splitter **58**, reflects R light and transmits light other than R light. The SLO unit **18** has a beam splitter **62** that, of the light transmitted through the beam splitter **60**, reflects IR light.
[0051] The SLO unit **18** has plural light detecting elements in correspondence with the plural light sources. The SLO unit **18** has a B light detecting element **70** that detects the B light reflected by the beam splitter **64**, and a G light detecting element **72** that detects the G light reflected by the beam splitter **58**. The SLO unit **18** has an R light detecting element **74** that detects the R light reflected by the beam splitter **60**, and an IR light detecting element **76** that detects the IR light reflected by the beam splitter **62**.
[0052] In a case in which the light, which goes through the wide angle optical system **30** and the first optical scanner **22** and is made incident on the SLO unit **18** (the reflected light reflected by the fundus), is B light, the light is reflected at the beam splitter **64** and received by the B light detecting element **70**. In the case of G light, the above-described incident light is transmitted through the beam splitter **64**, reflected by the beam splitter **58**, and received by the G light detecting element **72**. In a case in which the above-described incident light is R light, the light is transmitted through the beam splitters **64**, **58**, is reflected by the beam splitter **60**, and is received by the R light detecting element **74**. In a case in which the above-described incident light is IR light, the light is transmitted through the beam splitters **64**, **58**, **60**, is reflected by the beam splitter **62**, and is received by the IR light detecting element **76**. The image processing device **16**G that operates under the control of the CPU **16**A generates UWF-SLO images by using the signals detected at the B light detecting element **70**, the G light detecting element **72**, the R light detecting element **74** and the IR light detecting element **76**.
[0053] The UWF-SLO images include a UWF-SLO image (G color fundus image) obtained by the fundus being imaged by G color, and a UWF-SLO image (R color fundus image) obtained by the fundus being imaged by R color. The UWF-SLO images include a UWF-SLO image (B color fundus image) obtained by the fundus being imaged by B color, and a UWF-SLO image (IR fundus image) obtained by the fundus being imaged by IR.
[0054] Further, the control device **16** controls the light sources **40**, **42**, **44** so as to emit light simultaneously. A G color fundus image, an R color fundus image and a B color fundus image whose respective positions correspond to one another are obtained due to the fundus of the subject eye **12** being imaged simultaneously by B light, G light and R light. An RGB color fundus image is obtained from the G color fundus image, the R color fundus image and the B color fundus image. Due to the control device **16** controlling the light sources **42**, **44** so as to emit light simultaneously, and the fundus of the subject eye **12** being imaged simultaneously by G light and R light, a G color

fundus image and an R color fundus image whose respective positions correspond to one another are obtained. An RG color fundus image is obtained from the G color fundus image and the R color fundus image.
[0055] In this way, specifically, there are a B color fundus image, a G color fundus image, an R color fundus image, an IR fundus image, an RGB color fundus image, and an RG color fundus image as the UWF-SLO images. The respective image data of the UWF-SLO images are, together with information of the patient that is inputted via the input/display device **16**E, transmitted from the ophthalmic device **110** via the communication interface (I/F) **16**F to the server **140**. The respective image data of the UWF-SLO images and the information of the patient are stored in correspondence in a storage device **254**. Note that examples of the information of the patient are the patient ID, name, age, visual acuity, designation of right eye/left eye and the like. An operator inputs the patient information via the input/display device **16**E.
[0056] An OCT system is realized by the control device **16**, the OCT unit **20** and the imaging optical system **19** that are illustrated in FIG. **2**. Because the OCT system has the wide angle optical system **30**, the OCT system can capture an image of the fundus in the wide FOV **12**A, in the same way as the above-described capturing of a SLO fundus image. The OCT unit **20** includes a light source **20**A, a sensor (detecting element) **20**B, a first optical coupler **20**C, a reference optical system **20**D, a collimator lens **20**E and a second optical coupler **20**F.
[0057] The light that exits from the light source **20**A is split at the first optical coupler **20**C. One divisional light is made into parallel light at the collimator lens **20**E as measurement light, and thereafter, is made incident on the imaging optical system **19**. The measurement light is scanned in the X direction and the Y direction by the second optical scanner **24**. The scanning light goes through the wide angle optical system **30** and the pupil **27**, and is illuminated onto the fundus. The measurement light that is reflected by the fundus goes through the wide angle optical system **30** and the second optical scanner **24** and is made incident on the OCT unit **20**, and, via the collimator lens **20**E and the first optical coupler **20**C, is incident on the second optical coupler **20**F.
[0058] The other light, which exits from the light source **20**A and is split-off at the first optical coupler **20**C, is incident on the reference optical system **20**D as reference light, and goes through the reference optical system **20**D and is incident on the second optical coupler **20**F.
[0059] These lights that are made incident on the second optical coupler **20**F, i.e., the measurement light reflected at the fundus and the reference light, are made to interfere at the second optical coupler **20**F, and interference light is generated. The interference light is received at the sensor **20**B. On the basis of the OCT data detected at the sensor **20**B, the image processing device **16**G, which operates under the control of the CPU **16**A, generates an OCT image that is a tomographic image or an en-face image or the like.
[0060] Here, the OCT fundus image, which is obtained by imaging at an imaging field angle of 160° or more that is an internal illumination angle, is called a UWF-OCT image.
[0061] The image data of the UWF-OCT image is, together with the information of the patient, transmitted from the ophthalmic device **110** via the communication interface (I/F) **16**F to the server **140**. The image data of the UWF-OCT image and the patient information are stored in the storage device **254** in correspondence with one another.
[0062] Note that, in the present embodiment, an example is given in which the light source **20**A is SS-OCT (Swept-Source OCT), but the light source **20**A may be any of various types of OCT systems such as SD-OCT (Spectral-Domain OCT), TD-OCT (Time-Domain OCT) or the like.
[0063] The ocular axis length measuring instrument **120** is described next. The ocular axis length measuring instrument **120** has two modes that are a first mode and a second mode that measure the ocular axis length that is the length of the subject eye **12** in the ocular axis direction. In the first mode, light from an unillustrated light source is guided to the subject eye **12**, and thereafter, interference light of the reflected light from the fundus and the reflected light from the cornea is received, and the ocular axis length is measured on the basis of the interference signal that

expresses the received interference light. The second mode is a mode in which the ocular axis length is measured by using unillustrated ultrasonic waves.

[0064] The ocular axis length measuring instrument **120** transmits the ocular axis length measured by the first mode or the second mode to the server **140**. The ocular axis length may be measured by the first mode and the second mode, and, in this case, the average of the ocular axis lengths measured by the both modes is transmitted to the server **140** as the ocular axis length. The server **140** stores the ocular axis length of the patient in correspondence with the patient ID.

[0065] The structure of the electrical system of the server **140** is described next with reference to FIG. **3**. As illustrated in FIG. **3**, the server **140** has a computer main body **252**. The computer main body **252** has a CPU **262**, a RAM **266**, a ROM **264** and an input/output (I/O) port **268** that are connected to one another by a bus **270**. The storage device **254**, a display **256**, a mouse **255**M, a keyboard **255**K and a communication interface (I/F) **258** are connected to the input/output (I/O) port **268**. The storage device **254** is structured by a non-volatile memory for example. The input/output (I/O) port **268** is connected to the network **130** via the communication interface (I/F) **258**. Accordingly, the server **140** can communicate with the ophthalmic device **110** and the viewer **150**. An image processing program that is described later is stored in the storage device **254**. Note that the image processing program may be stored in the ROM **264**.

[0066] The image processing program is an example of the “program” of the technique of the present disclosure. The storage device **254** and the ROM **264** are examples of the “memory” and the “computer-readable storage medium” of the technique of the present disclosure. The CPU **262** is an example of the “processor” of the present disclosure.

[0067] A processing section **208** (refer to FIG. **5** as well), which is described later, of the server **140** stores the respective data that are received from the ophthalmic device **110** in the storage device **254**. Specifically, the processing section **208** stores the respective image data of the UWF-SLO images and the image data of the UWF-OCT image, and patient information (as described above, the patient ID and the like), in correspondence with one another in the storage device **254**. Further, in a case in which there is a lesion at the subject eye of the patient, or in a case in which surgery has been carried out on a lesion portion, information relating to the lesion is inputted via the input/display device **16**E of the ophthalmic device **110**, and is transmitted to the server **140**. The information of the lesion is stored in the storage device **254** in correspondence with the information of the patient. Information of the position of the lesion portion, the name of the lesion, the name of the surgery and the date and time of the surgery in a case in which the lesion portion has been operated on, and the like are information of the lesion.

[0068] The viewer **150** has a computer, which is equipped with a CPU, a RAM, a ROM and the like, and has a display. An image processing program is installed in the ROM. On the basis of instructions of the user, the computer controls the display such that medical information, such as the fundus image acquired from the server **140** and the like, are displayed on the display.

[0069] Various functions, which are realized by the CPU **262** of the server **140** executing the image processing program, are described next with reference to FIG. **4**. The image processing program has a display control function, image processing functions (a sharpening processing function, a fundus structure analyzing function), and a processing function. Due to the CPU **262** executing the image processing program that has these respective functions, as illustrated in FIG. **4**, the CPU **262** functions as a display control section **204**, an image processing section **206** (a sharpening processing section **2060**, a fundus structure analyzing section **2062**), and the processing section **208**.

[0070] Next, the image processing by the server **140** is described in detail by using FIG. **5**. Due to the CPU **262** of the server **140** executing the image processing program, the image processing illustrated in the flowchart of FIG. **5** is realized. This image processing starts in a case in which a patient ID is inputted, and an unillustrated start button displayed on the display **256** is operated.

[0071] In step **502**, as illustrated in FIG. **7**, the processing section **208** acquires UWF fundus image

G**1**, which is stored in correspondence with the patient ID, from the storage device **254**. The UWF fundus image G**1** is the RGB color fundus image among the UWF-SLO images, and is a UWF fundus image in the RGB color space, and is the original UWF fundus image that has not been subjected to image processing.

[0072] In step **504**, the sharpening processing section **2060** executes sharpening processing that is described in detail later. In step **506**, the fundus structure analyzing section **2062** analyzes the sharpened image that is described in detail later.

[0073] In step **508**, the processing section **208** generates image identifying flags, and sets image identifying flags for the original UWF fundus image (the UWF fundus image G**1** (see FIG. **7**)) and a post-sharpening-processing UWF fundus image. Specifically, the processing section **208** associates flag=0 with the original UWF fundus image. The processing section **208** associates flag=1 with the post-sharpening-processing UWF fundus image (the sharpened image).

[0074] In step **510**, the processing section **208** stores the original UWF fundus image in correspondence with flag=0, and the sharpened image in correspondence with flag=1, in the storage device **254**.

[0075] In step **512**, the processing section **208** stores, in the storage device **254**, data of the results of analysis that are obtained by the analysis executed by the fundus structure analyzing section **2062** on the post-sharpening-processing UW F fundus image.

[0076] In step **514**, the processing section **208** outputs (transmits) the original UWF fundus image that is in a state of being associated with flag=0, and the post-sharpening-processing UWF fundus image that is in a state of being associated with flag=1, and analysis data to the viewer **150** via the communication interface **258**.

[0077] Next, the sharpening processing of step **504** is executed with reference to FIG. **6**A.

[0078] In step **602**, the sharpening processing section **2060** converts the UW F fundus image G**1** (see FIG. **7**) of the RGB color space into images in the L*a*b* color space. Due thereto, an image G**11** of the L* component (see FIG. **8**A), an image of the a* component, and an image of the b* component are obtained.

[0079] The L*a*b* color space is an example of the “color space having three components that are a brightness component that expresses lightness, and a first color component and a second color component that are components of two different shades” of the technique of the present disclosure. The image G**11** of the L* component (see FIG. **8**A), the image of the a* component, and the image of the b* component respectively are fundus images, and therefore, a color space fundus image, which has three components that are brightness and two different shades, is acquired by the processing of step **602**.

[0080] Namely, the RGB fundus image of the three primary color space (RGB) is converted into the Lab space fundus image of the complementary color space (L*a*b*), and the sharpening processing of step **504** is executed.

[0081] The complementary color space (L*a*b*) is also called the CIELAB color space or the “CIE 1976 L a*b* color space”.

[0082] Further, the RGB fundus image may be converted into the CIELUV color space (or the “CIE 1976 L*u*v* color space”) that is another color space.

[0083] In order for the user to more effectively perceive the effects of the sharpening, it is better to carry out sharpening processing in the complementary color space (L*a*b*) in which perceived differences in color are converted into quantitative differences, and this is because the user (the observer (e.g., an ophthalmologist) who is viewing the image) can more effectively perceive the effects of sharpening. Namely, it is better to separate the image into a brightness component and color components that are perceptually independent in the complementary color space (L*a*b*), and to carry out sharpening processing independently on the respective components, than to carry out processing on the respective R, G, B color components in the RGB color space. Accordingly, an image in which the perceived differences can be experienced effectively can be generated by sharpening processing in the complementary color space (L*a*b*). Accordingly, it is preferable that the sharpening processing of the technique of the present disclosure be carried out with the image having been converted into the complementary color space (L*a*b*).

[0084] In step **604**, the sharpening processing section **2060** extracts an image of a circular region of a predetermined radius whose center is the center of the image in the L a*b* color space, from each image in the L a*b* color space, as an image of the central region. Here, the central region is the region that includes the optic disc and the macula in the fundus image, and is the posterior pole portion of the fundus. The peripheral region is the region at the outer side of the central region, and is the equator and the peripheral portion of the fundus. Specifically, as illustrated in FIG. **8**B, the region, which is surrounded by the dotted-line circle and includes optic disc DD and macula MM, is central region CR, and the outer side of this dotted-line circle is the peripheral region.

[0085] Note that the central position of an image in the L*a*b* color space is the position at which the fundus of the subject eye **12** and the optical axis intersect.

[0086] In step **606**, the sharpening processing section **2060** sets a first parameter as the parameter for CLA HE processing that is executed on the image of the central region.

[0087] Here, CLAHE (Contrast Limited Adaptive Histogram Equalization) processing is processing in which an image is divided into plural regions, and histogram equalization is carried out locally per divisional region, and, at the borders of the respective regions, interpolation processing such as bilinear interpolation or the like is carried out, thereby adjusting the contrast of the image.

[0088] Tile size is a parameter in CLAHE Processing. CLAHE processing is executed locally on an image (an image in the L a*b* color space). Specifically, the image is divided into plural, quadrangular regions, and CLA HE processing is executed on each of the divisional regions. Each of these regions is called a tile, and the size of the tile is called the tile size.

[0089] In the present embodiment, in step **606**, the sharpening processing section **2060** sets first tile size Tc as the tile size as illustrated in FIG. **9**. Although described in detail later, the sharpening processing section **2060** sets a second tile size Tp for the image of the peripheral region that is at the periphery of the central region. For the second tile size Tp that is used in CLAHE processing of the peripheral region, it is good for the length of one side of the tile (assuming that the tile is square) to be 1.4 times, and, in terms of surface area, to be 2 times the first tile size Tc that is used in CLA HE processing of the central region. Namely, the size of the first tile size Tc is smaller than the second tile size Tp. This is because, in order to capture an image of the fundus that is spherical, the peripheral region has distortion with respect to the central region.

[0090] In the original UWF fundus image G**1** (FIG. **7**) that is obtained by imaging in an imaging field angle of 160° or more that is an internal illumination angle as described above, distortion of the image is greater at the peripheral region than at the central region. In other words, the surface area of the actual fundus, which corresponds to a portion of the same predetermined surface area in the original UWF fundus image G**1**, is greater at the peripheral region than at the central region.

[0091] Thus, in the present embodiment, the second tile size Tp is made to be a size that is greater than the first tile size Tc.

[0092] Specifically, Tp=n.sup.2Tc, given that the surface area of the actual fundus that corresponds to a portion of the central region in the original UWF fundus image G**1** is Sc, and that the surface area of the actual fundus that corresponds to a portion of the peripheral region in the original UWF fundus image G**1** is Sp, and that Sp=n.sup.2Sc.

[0093] Accordingly, the degree of enhancement by CLA HE processing with respect to the respective L*a*b* components of the image of the peripheral region, is made to be greater than the degree of enhancement by CLA HE processing with respect to the respective L*a* b* components of the image of the central region.

[0094] In step **608**, the sharpening processing section **2060** executes CLA HE processing by using the first parameter, on the respective L*a*b* components of the image of the central region.

[0095] In step **610**, the sharpening processing section **2060** extracts the image of the region other than the central region, from the images of the L*a*b* color space, as the image of the peripheral region.
[0096] In step **612**, the sharpening processing section **2060** sets a second parameter as the parameter of the CLA HE processing that is to be executed on the image of the peripheral region. In the present embodiment, the sharpening processing section **2060** sets the second tile size Tp, whose size is greater than the first tile size Tc, as the tile size.
[0097] In step **614**, the sharpening processing section **2060** executes CLA HE processing by using the second parameter, on the images of the peripheral regions of the respective L* a*b* components of the image of the peripheral region.
[0098] In step **616**, the sharpening processing section **2060** combines the respective components of the respective images of the central region and the peripheral region. In step **618**, the sharpening processing section **2060** combines the respective images of the central region and the peripheral region whose respective components have been combined. Due thereto, a sharpened UW F fundus image of the L*a*b* color space is obtained.
[0099] In step **620**, the sharpening processing section **2060** converts the sharpened UW F fundus image of the L*a*b* color space into image G**2** of the RGB color space, as illustrated in FIG. **10**.
[0100] In the image G**2** of the RGB color space (FIG. **10**), the blood vessels are sharper than in the original UWF fundus image G**1** (FIG. **7**), and the blood vessels, which were difficult to see in the original UWF fundus image G**1**, can be seen. Further, lesion portions, such as hemorrhages, white spots, retinal detachment, and the like also are sharp.
[0101] Next, the analyzing processing of the sharpened image of step **506** is described with reference to FIG. **6**B.
[0102] In step **652**, the fundus structure analyzing section **2062** judges whether or not information of a lesion has been registered in correspondence with the ID of the patient who is the current subject.
[0103] In a case in which information of a lesion has not been registered in correspondence with the ID of the patient who is the current subject, the analyzing processing ends.
[0104] In a case in which information of a lesion has been registered in correspondence with the ID of the patient who is the current subject, the fundus structure analyzing section **2062** generates an enhanced image in which the lesion region is enhanced, and stores the enhanced image in the storage device **254** as analysis data.
[0105] As described above, in step **508** of FIG. **5**, analysis data also is outputted (transmitted) to the viewer **150**. Therefore, the image, which is illustrated in FIG. **11** and in which lesion portions are enhanced, is displayed at the viewer **150**. Due thereto, the lesion portions are made visible.
[0106] For example, first, in a case in which there is a lesion portion at the vitreous body, and that lesion portion is being operated on, as illustrated in FIG. **11**, the fundus structure analyzing section **2062** generates an enhanced image in which the color of the retina blood vessels of surgical site **702** is changed or the retina blood vessels before the surgery are superposed.
[0107] The viewer **150** displays the enhanced image in accordance with the instructions of the ophthalmologist at the time of examining the subject eye. The viewer **150** displays the retina blood vessels of the surgical site **702** while changing the color thereof, or while superposing the retina blood vessels of the surgical site **702** and the retina blood vessels before surgery. Due thereto, the positional offset between the retina blood vessels of the surgical site **702** and the retina blood vessels before surgery can be confirmed. The viewer **150** may display only the retina blood vessels after surgery the surgical site **702**, or may display only the retina blood vessels before surgery of the surgical site **702**, or may display these alternately.
[0108] Second, in a case in which there is a retinal detachment lesion, the fundus structure analyzing section **2062** creates an enhanced image in which a red frame is superposed on place **708** of the retinal detachment.

[0109] The viewer **150** displays the enhanced image in accordance with the instructions of the ophthalmologist at the time of examining the subject eye. In this case, the viewer **150** may display the place **708** of the retinal detachment so as to flash, or may display the place **708** so as to flash inversely, or may display the position and the size thereof.
[0110] Third, in a case in which there is the lesion of dot hemorrhages, the fundus structure analyzing section **2062** creates an enhanced image in which the color of place **706** of the dot hemorrhages is changed or in which, instead of or together with changing the color, the number of places of dot hemorrhages is superposed.
[0111] The viewer **150** displays the enhanced image in accordance with the instructions of the ophthalmologist at the time of examining the subject eye. In this case, the viewer **150** may display the place **706** of the dot hemorrhages so as to flash, or may display the place **706** so as to flash inversely, or may display the counted value of the number thereof. In a case in which the vicinity of the place **706** of the dot hemorrhages is clicked-on, the viewer **150** may display a magnifying glass button M, and, when the magnifying glass button is pushed, the viewer **150** may display the place **706** of the dot hemorrhages in an enlarged manner.
[0112] Fourth, in a case in which there are white spot lesions, the fundus structure analyzing section **2062** creates an enhanced image in which the color of places **704**A, **704**B of the white spots is changed or in which, instead of or together with changing the color, the number of white spots is superposed.
[0113] The viewer **150** displays the enhanced image in accordance with the instructions of the ophthalmologist at the time of examining the subject eye. In this case, the viewer **150** may display the places **704**A, **704**B of the white spots so as to flash, or may display the places **704**A, **704**B so as to flash inversely.
[0114] At the time of examining the subject eye of the patient, the ophthalmologist inputs the patient ID to the viewer **150**. The viewer **150** instructs the server **140** to transmits image data and the like of the subject eye corresponding to the patient ID. The server **140** transmits the patient name, the age of the patient, the visual acuity of the patient, information as to whether the eye is the left eye or the right eye, the ocular axis length, the date of imaging, and the image data, which correspond to the patient ID, to the viewer **150** together with the patient ID.
[0115] The viewer **150**, which receives the patient ID, the patient name, the age of the patient, the visual acuity of the patient, information as to whether the eye is the left eye or the right eye, the ocular axis length, the date of imaging and the image data, displays a first fundus image display screen **1000**A that is illustrated in FIG. **12** on the display.
[0116] As illustrated in FIG. **12**, the first fundus image display screen **1000**A has a patient information display box **1002** and a first fundus image information display box **1004**A.
[0117] The patient information display box **1002** has respective display fields **1012** through **1022** for displaying the patient ID, the patient name, the age of the patient, the visual acuity of the patient, information as to whether the eye is the left eye or the right eye, and the ocular axis length, and a screen switching button **1024**. The received patient ID, patient name, age of the patient, visual acuity of the patient, information as to whether the eye is the left eye or the right eye, and ocular axis length are displayed in the display fields **1012** through **1022**.
[0118] The first fundus image information display box **1004**A has an imaging date display box **1030**, an original UWF fundus image display box **1032**A, a post-sharpening-processing UWF fundus image display box **1032**B, an information display box **1034**, and select buttons **1036**A through **1036**D.
[0119] The imaging date (Y Y Y/MM/DD) is displayed in the imaging date display box **1030**. Comments and memos at the time of examination by the user (the ophthalmologist) are displayed as text in the information display box **1034**.
[0120] The original UWF fundus image G**1** (FIG. **7**) is displayed in the original UW F fundus image display box **1032**A. The post-sharpening-processing UWF fundus image G**2** (FIG. **10**) is

displayed in the post-sharpening-processing UWF fundus image display box **1032**B.

[0121] Mode **1**, which is selected by the select button **1036**A, is a mode for camera-like correction of fundus image shades. The mode for camera-like correction of fundus image shades is a mode that changes the shades of the post-sharpening-processing UW F fundus image G**2**, which is displayed in the post-sharpening-processing UWF fundus image display box **1032**B, to the shades of an image that is obtained by imaging by the fundus camera.

[0122] Mode **2** that is selected by the select button **1036**B is a haze removal processing mode. The haze removal processing mode is a mode of processing (haze removal processing) that removes haze (e.g., fogging or the like) from the post-sharpening-processing UWF fundus image G**2**. Haze removal processing is disclosed in the following thesis and patent document and the like.

(Thesis)

[0123] He, Kaiming. "Single Image Haze Removal Using Dark Channel Prior." Thesis, The Chinese University of Hong Kong, 2011.

(Patent Document)

[0124] Japanese Patent No. 6225255

[0125] Mode **3** that is selected by the select button **1036**C is a pachychoroid (choroidal thickening) confirming mode. The pachychoroid confirming mode is a mode in which, in the post-sharpening-processing UW F fundus image G**2** that is displayed in the post-sharpening-processing UWF fundus image display box **1032**B, the proportion of the red component is enhanced more than the proportions of the other color (green, blue) components. For example, if the select button **1036**C of mode **3** is operated in a case in which the red, green, blue components are equal in the post-sharpening-processing UW F fundus image G**2**, the proportion of the red component is made to be 80%, and the respective proportions of the other color (green, blue) components are made to be 10%, or the like. When the proportion of the red component is enhanced more than the proportions of the other color (green, blue) components in the post-sharpening-processing UWF fundus image G**2**, the red color light passes through the retina and reaches the choroid, and therefore, the blood vessel portions of the choroid are enhanced more than the blood vessels of the retina. Due thereto, the state of pachychoroid (choroidal thickening) can be confirmed.

[0126] The object of the image processing that is carried out in order to confirm the state of pachychoroid (choroidal thickening) in this way may be, instead of the post-sharpening-processing UWF fundus image G**2**, the UWF fundus image G**1** in the RGB color space (see FIG. **7**) as follows. Specifically, first, information of the red (R) component of the UWF fundus image G**1**, which is based on the R light that passes through the retina and reaches the choroid, includes information of the blood vessels of the retina and the choroid respectively. Information of the green (G) component of the UWF fundus image G**1**, which is based on the G light that only reaches as far as the retina, does not include information of the blood vessels of the choroid, and includes information of the blood vessels of the retina. The blood vessels of the choroid are extracted from the above-described information of the red (R) component and the above-described information of the green (G) component. Then, separately from the image processing of FIG. **5**, the processing section **208** of the server **140** extracts the blood vessels of the choroid from the UWF fundus image G**1** of the RGB color space (see FIG. **7**), and stores them in the storage device **254**. In a case in which the select button **1036**C for mode **3** is operated, the viewer **150** receives information of the choroid blood vessels from the server **140**, and superposes them on the post-sharpening-processing UWF fundus image G**2** that is displayed in the post-sharpening-processing UWF fundus image display box **1032**B.

[0127] Mode **4** that is selected by the select button **1036**D is a vitreous body surgical results confirming mode. The vitreous body surgical results confirming mode is a mode that enhances the proportion of the green component more than the proportions of the components of the other color (red, blue) components in the post-sharpening-processing UWF fundus image G**2** that is displayed in the post-sharpening-processing UW F fundus image display box **1032**B. For example, if the select button **1036**D of mode **4** is operated in a case in which the red, green, blue components are equal in the post-sharpening-processing UWF fundus image G**2**, the proportion of the green component is made to be 80%, and the respective proportions of the other color (red, blue) components are made to be 10%, or the like. When the proportion of the green color component is enhanced more than the proportions of the other color (red, blue) components in the post-sharpening-processing UW F fundus image G**2**, because the green color light does not pass through the retina and does not reach the choroid, only the blood vessels of the retina are enhanced. Due thereto, the post-surgical state of blood vessels of the retina, which is the object of vitreous body surgery, can be confirmed.

[0128] In a case in which the select button **1036**A through **1036**D is operated, the viewer **150** executes the above-described processing that corresponds to the mode, on the post-sharpening-processing UW F fundus image G**2** that is displayed in the post-sharpening-processing UWF fundus image display box **1032**B. The viewer **150** displays, in the UWF fundus image display box **1032**B, the post-sharpening-processing UW F fundus image that has been subjected to the above-described processing corresponding to the mode.

[0129] The technique of the present disclosure is not limited to the above-described processings, which correspond to the modes, being executed by the viewer **150** in this way. For example, first, the viewer **150** may instruct the server **140** to carry out processing corresponding to the mode, and the server **140** may execute that processing. The server **140** transmits the post-sharpening-processing UW F fundus image that has been subjected to that processing to the viewer **150**, and the viewer **150** displays the post-sharpening-processing UWF fundus image that has been subjected to that processing in the UWF fundus image display box **1032**B.

[0130] Moreover, other than the viewer **150** and the server **140**, a separate imaging processing device that is further connected to the network **130** may execute the processings corresponding to the modes.

[0131] Note that the post-sharpening-processing UWF fundus image, which has been subjected to the above-described processing corresponding to the mode, may be displayed together with the post-sharpening-processing UWF fundus image G**2**.

[0132] In a case in which the screen switching button **1024** of FIG. **12** is operated, the viewer **150** displays, on the display, a second fundus image display screen **1000**B that is illustrated in FIG. **13**.

[0133] Because the first fundus image display screen **1000**A and the second fundus image display screen **1000**B have substantially similar contents, the same portions are denoted by the same reference numerals, and description thereof is omitted, and only the different portions are described.

[0134] Instead of the original UWF fundus image display box **1032**A and the post-sharpening-processing UWF fundus image display box **1032**B, the second fundus image display screen **1000**B has an original UWF fundus image portion displaying box **1032**C and a post-sharpening-processing UWF fundus image portion displaying box **1032**D.

[0135] The size of the image display box, in which the original UWF fundus image portion displaying box **1032**C and the post-sharpening-processing UWF fundus image portion displaying box **1032**D are combined, is the same as the sizes of the UWF fundus image display box **1032**A and the UWF fundus image display box **1032**B of FIG. **12**.

[0136] A slide bar **1032**E is provided at the border between the original UWF fundus image portion displaying box **1032**C and the post-sharpening-processing UWF fundus image portion displaying box **1032**D.

[0137] As indicated by arrow **1032**F, the slide bar **1032**E can move toward the original UWF fundus image portion displaying box **1032**C side (leftward in FIG. **13**) and toward the post-sharpening-processing UWF fundus image portion displaying box **1032**D side (rightward in FIG. **13**).

[0138] In a case in which the slide bar **1032**E is moved leftward in FIG. **13**, the range of the UWF fundus image portion displaying box **1032**C becomes narrow, and the range of the UWF fundus image portion displaying box **1032**D becomes wide. In a case in which the slide bar **1032**E is moved rightward in FIG. **13**, the range of the UWF fundus image portion displaying box **1032**C becomes wide, and the range of the UWF fundus image portion displaying box **1032**D becomes narrow.

[0139] In a case in which the screen switching button **1024** of FIG. **13** is operated, the viewer **150** displays, on the display, a second fundus image display screen **1000**C that is illustrated in FIG. **14**.

[0140] Because the second fundus image display screen **1000**B and the third fundus image display screen **1000**C have substantially similar contents, the same portions are denoted by the same reference numerals, and description thereof is omitted, and only the different portions are described.

[0141] Instead of the original UWF fundus image portion displaying box **1032**C and the post-sharpening-processing UWF fundus image portion displaying box **1032**D of FIG. **13**, the third fundus image display screen **1000**C has a display-together box **1032**G.

[0142] In the display-together box **1032**G, the post-sharpening-processing UW F fundus image G**2** is displayed in portion **1032**G**2** excluding the frame. In portion **1032**G**1** that is separated by the frame, the portion of the original UWF fundus image that corresponds to the portion separated by the frame is displayed.

[0143] At the frame itself, for example, if portions that are other than the corners of the frame is clicked on, the display-together box **1032**G can move. If a corner of the frame is dragged, the size of the frame also can be enlarged or reduced.

[0144] In this way, the post-sharpening-processing UWF fundus image G**2** is disposed in the portion **1032**G**2** that is other than the frame, and the corresponding portion of the original UWF fundus image is displayed in the portion **1032**G **1** that is separated by the frame. Accordingly, the ophthalmologist can, while confirming the post-sharpening-processing UWF fundus image G**2** overall, confirm, at a portion thereof, the contents before the image processing.

[0145] Note that, for example, in a case in which any portion of the display-together box **1032**G is clicked-on, or in a case in which an invert button is provided and the invert button is operated, a portion of the original UWF fundus image is displayed in the portion **1032**G**2** other than the frame, and the post-sharpening-processing UWF fundus image G**2**, which corresponds to the portion separated by the frame, is displayed in the portion **1032**G**1** separated by the frame.

[0146] As described above, in the technique of the present disclosure, the sharpening processing section **2060** executes CLA HE processing, by using parameters corresponding to respective regions, on the respective L*a* b* components of the images of the central region and the peripheral region. Specifically, the sharpening processing section **2060** executes CLAHE processing on the respective L*a*b* components of the image of the central region at the first tile size Tc, and on the respective L*a*b* components of the image of the peripheral region at the second tile size Tp.

[0147] In the original UWF fundus image G**1** (FIG. **7**) that is obtained by imaging in an imaging field angle of 160° or more that is an internal illumination angle as described above, distortion of the image is greater at the peripheral region than at the central region. In other words, the surface area of the actual fundus, which corresponds to a portion of the same predetermined surface area in the original UWF fundus image G**1**, is greater at the peripheral region than at the central region.

[0148] Thus, in the present embodiment, the second tile size Tp is made to be a size that is greater than the first tile size Tc.

[0149] Specifically, Tp=n.sup.2Tc, given that the surface area of the actual fundus that corresponds to a portion of the central region in the original UWF fundus image G**1** is Sc, and that the surface area of the actual fundus that corresponds to a portion of the peripheral region in the original UWF fundus image G**1** is Sp, and that Sp=n.sup.2Sc.

[0150] Accordingly, the degree of enhancement by CLA HE processing with respect to the respective L*a*b* components of the image of the peripheral region, is made to be greater than the degree of enhancement by CLAHE processing with respect to the respective L*a*b* components of the image of the central region.

[0151] In this way, in the present embodiment, CLA HE processing is executed by using parameters corresponding to the central region and the peripheral region. Therefore, as compared with a case in which CLA HE processing is executed equally by using a fixed parameter for the respective regions, the thicknesses of the blood vessels that are enhanced at the respective regions can be standardized, and, due thereto, the contrast of the image at the respective regions can be standardized, and the image can be sharpened.

[0152] By the way, in the technique of the present disclosure, the sharpening processing section **2060** may execute sharpening processing on the UWF fundus image of the RGB color space. However, in the present embodiment, the sharpening processing section **2060** converts the UWF fundus image of the RGB color space into images of the L* a*b* color space, and executes sharpening processing on the respective images of the L*a*b* color space.

[0153] In sharpening processing on a UWF fundus image of the RGB color space, sharpening processing is executed only with respect to the lightness (brightness).

[0154] However, in sharpening processing on an image in the L*a*b* color space, the sharpening processing section **2060** executes sharpening processing not only on the L* value (lightness), but also on the hue and saturation for redness and greenness as a*, and for yellowness and blueness as b*. Accordingly, the luminance, hue and saturation are enhanced. Accordingly, the UWF fundus image can be made even more sharp.

[0155] A modified example of the sharpening processing of step **504** of FIG. **5** is described next with reference to FIG. **15**.

[0156] In the sharpening processing of the above-described embodiment (see FIG. **6**A), the sharpening processing section **2060** extracts the image of the central region and the image of the peripheral region from the fundus image, and executes CLA HE processing on the extracted image of the peripheral region and the extracted image of the central region, such that the degree of enhancement is made greater for the former than for the latter.

[0157] The technique of the present disclosure is not limited to this. For example, the sharpening processing section **2060** executes CLA HE processing in which the degrees of enhancement are different, respectively on the image G**11** of the L* component (see FIG. **8**A), the image of the a* component, and the image of the b* component, and generates a first image and a second image for each component, and combines the first image and the second image in a predetermined combining ratio. Specifically, the sharpening processing section **2060** combines the first image and the second image of each component such that, the further that pixel is positioned away from the center toward the periphery, the greater the proportion of the second image than the proportion of the first image. More specifically, processing is carried out as follows.

[0158] In step **602**, the sharpening processing section **2060** converts the UW F fundus image G**1** of the RGB color space (see FIG. **7**) into images of the L*a*b* color space. Due thereto, the L* component image G**11** (see FIG. **8**A), the a* component image, and the b* component image are obtained.

[0159] In step **607**, the sharpening processing section **2060** sets a first parameter for the image of the central region, as a parameter of the CLA HE processing. Note that the first parameter is the same as the first parameter of step **606** of FIG. **6**A.

[0160] In step **609**, the sharpening processing section **2060** generates a first processed image for each of the components, by executing CLA HE processing on the respective components of the entire image of the L*a*b* color space by using the first parameter.

[0161] In step **613**, the sharpening processing section **2060** sets a second parameter for the image of the peripheral region, as a parameter of the CLA HE processing. Note that the second parameter is the same as the second parameter of step **612** of FIG. **6**A.

[0162] In step **615**, the sharpening processing section **2060** generates a second processed image for each of the components, by executing CLA HE processing on the respective components of the entire image of the L*a* b* color space by using the second parameter.

[0163] In step **617**, the sharpening processing section **2060** carries out combining such that, for each pixel of the first processed image and the second processed image for each component of the image of the L*a*b* color space, the further away the pixel is positioned from the center toward the periphery, the greater the proportion of the second processed image than the proportion of the first processed image.

[0164] For example, at the center, first processed image: second processed image=1:0, and, at the outermost periphery, first processed image: second processed image=0:1. The further the position from the center toward the outermost periphery, the more that the proportion of the first processed image becomes less than 1 and the proportion of the second processed image becomes greater than 0.

[0165] In step **619**, the sharpening processing section **2060** converts the respective components of the image of the L*a*b* color space, in which the first processed image and the second processed image have been combined, into an image of the RGB color space.

[0166] As described above, in the modified example illustrated in FIG. **15**, for each of the components, the first image and the second image are combined in a predetermined combining ratio, and the sharpening processing section **2060** combines the first image and the second image of each component such that the further the position of the pixel from the center toward the periphery, the greater the proportion of the second image than the proportion of the first image.

[0167] The technique of the present disclosure is not limited to this, and the sharpening processing section **2060** may combine the first image and the second image of each component such that, at the central region, the proportion of the first image is greater than the proportion of the second image, and, at the peripheral region, the proportion of the second image is greater than the proportion of the first image.

[0168] In the above-described respective examples, tile size is used as the parameter of the CLAHE processing. However, the technique of the present disclosure is not limited to this, and the stretch factor can be used.

[0169] Here, the stretch factor is a limiting value that is a factor that determines the degree of enhancement of the light/dark contrast with respect to the image.

[0170] The stretch factors are made to be values corresponding to the respective regions that are the central region and the peripheral region. Specifically, the stretch factors are made to be a first stretch factor for the central region, and a second stretch factor for the peripheral region. The second stretch factor is greater than the first stretch factor. Because the effects of aberration are greater the further from the central region toward the peripheral region, the UWF fundus image G**1** appears as if the sharpness thereof deteriorates the further from the central region toward the peripheral region. Thus, in order to make the contrast enhancement greater the further toward the peripheral region, the second stretch factor is made to be greater than the first stretch factor.

[0171] In the above-described respective examples, CLA HE processing is used as the sharpening processing. However, the technique of the present disclosure is not limited to this, and, for example, unsharp masking (frequency processing) may be used.

[0172] Further, a contrast enhancing processing that is different than CLA HE processing, e.g., deconvolution, histogram equalization, haze removal, shade correction, de-noising or the like, or processings that combine these may be used.

[0173] In unsharp masking, a sharpening parameter is used.

[0174] The sharpening parameter is a coefficient that determines the degree of enhancement of the light/dark contrast with respect to the image.

[0175] Unsharp masking is processing that enhances the high-frequency components of the image. By intentionally smoothing the original image (blurring the image), and creating a difference image

of the original image, sharp components of the original image are created.
[0176] Sharpening of the original image is carried out by adding this difference image to the original image. The constant that determines the proportion by which the difference image is added to the original image is the unsharpening parameter.
[0177] In a case in which unsharp masking is employed, in step **606** of FIG. **6**A, the sharpening processing section **2060** sets a first sharpening parameter as the sharpening parameter of the unsharp masking on the image of the central region. In step **608**, the sharpening processing section **2060** executes unsharp masking on the respective L*a* b* components of the image of the central region by using the first sharpening parameter. In step **612**, the sharpening processing section **2060** sets a second sharpening parameter as the sharpening parameter of the unsharp masking on the image of the peripheral region. In step **608**, the sharpening processing section **2060** executes unsharp masking on the respective L*a*b* components of the image of the peripheral region by using the second sharpening parameter. The second sharpening parameter is greater than the first sharpening parameter. Because the effects of aberration are greater at the peripheral region than at the central region, the second sharpening parameter is made to be greater than the first sharpening parameter in order to make the effects of aberration at the peripheral region smaller than the central region.
[0178] Moreover, the sharpening processing section **2060** may execute both CLAHE processing and unsharp masking as sharpening processings. In this case, the parameters of at least one of the CLA HE processing and the unsharp masking may be values corresponding to the respective regions that are the central region and the peripheral region.
[0179] For example, the parameters of both the CLA HE processing and the unsharp masking may be made to be values corresponding to the respective regions that are the central region and the peripheral region, or the parameters of the CLA HE processing may be made to be uniform at the central region and the peripheral region and, in the unsharp masking, the parameters may be made to be values corresponding to the respective regions that are the central region and the peripheral region. Specifically, for example, the tile sizes of the CLA HE processing are made to be constant (a tile size between the tile size Tc and the tile size Tp) at the central region and the peripheral region, and, in the unsharp masking, a first sharpening parameter is set for the central region, and a second sharpening parameter is set for the peripheral region. It is easier for the peripheral region to become blurred than the central region (the image blurs due to the effects of aberration of the optical system that images the fundus, or aberration due to the entry angle of the light beam into the pupil of the eyeball being large or the like, or the like). Therefore, is preferable to make the second sharpening parameter larger than the first sharpening parameter, and to make is such that even more of the sharp components are added.
[0180] Moreover, a contrast enhancing processing or the like other than CLAHE processing may be executed in place of at least one of, or together with the at least one of, CLAHE processing and unsharp masking. In this contrast enhancing processing other than CLAHE processing, the extent of enhancing is made to be greater at the peripheral region than at the central region, in accordance with the respective regions that are the central region and the peripheral region.
[0181] In the above-described examples, the regions having different parameters in the sharpening processing are the two regions that are the central region and the peripheral region, but the technique of the present disclosure is not limited to this, and there may be three or more plural regions. Specifically, the sharpening processing section **2060** may execute sharpening processing by using parameters that are larger the further from the center, at three or more plural regions.
[0182] In the above-described examples, the UWF fundus image G**1** is transmitted to the server **140** from the ophthalmic device **110** that has a SLO system. However, the technique of the present disclosure is not limited to this. For example, a fundus camera may be connected to the network **130**, and a fundus image of a smaller field angle than the ophthalmic device **110** that has a SLO system may also be transmitted from this fundus camera to the server **140**. In this case, the

ophthalmic device **110** transmits the UWF fundus image G**1** to the server **140** in correspondence with a flag expressing that this is a UW F fundus image, and the fundus camera transmits a fundus image in correspondence with a flag expressing that this is not a UWF fundus image. On the basis of the flag expressing that this is a UWF fundus image and the flag expressing that this is not a UWF fundus image, the server **140** judges whether or not the image, which is the object of processing and corresponds to the patient ID, is a UWF fundus image. In a case in which the server **140** judges that the image that is the object of processing is a UWF fundus image, the server **140** executes the image processing of FIG. **5**.

[0183] Note that the ophthalmic device **110** may transmit the UWF fundus image G**1** to the server **140** in correspondence with a flag expressing that this is a UWF fundus image, and the fundus camera may transmit the fundus image without correspondence to a flag.

[0184] Conversely, [0185] the ophthalmic device **110** may transmit the UWF fundus image G**1** to the server **140** without correspondence to a flag, and the fundus camera may transmit the fundus image in correspondence with a flag expressing that this is not a UWF fundus image.

[0186] In the above-described example, the image processing of FIG. **5** is executed by the server **140**, but the technique of the present disclosure is not limited to this. For example, the image processing of FIG. **5** may be executed by the ophthalmic device **110** or the viewer **150**, or a different image processing device may be further connected to the network **130**, and this image processing device may execute the image processing.

[0187] The above-described respective examples illustrate, as examples, cases in which the image processing is realized by software structures using a computer. However, the technique of the present disclosure is not limited to this. For example, instead of software structures using a computer, the image processing may be executed by only a hardware structure such as an FPGA (Field-Programmable Gate Array) or an A SIC (Application Specific Integrated Circuit) or the like. Some of the processings of the image processing may be executed by software structures, and the remaining processings may be executed by hardware structures.

[0188] In this way, the technique of the present disclosure includes cases in which image processing is realized by software structures using a computer, and cases in which image processing is realized by structures that are not software structures using a computer. Therefore, the technique of the present disclosure includes the following first technique and second technique.

[0189] An image processing device including: [0190] an acquiring section that acquires a fundus image; [0191] an executing section that executes a first enhancing processing on an image of at least a central region of the fundus image, and executes a second enhancing processing, which is different than the first enhancing processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and [0192] a generating section that generates an enhanced image of the fundus image on the basis of a first image obtained due to the first enhancing processing having been executed and a second image obtained due to the second enhancing processing having been executed.

[0193] Note that the sharpening processing section **2060** of the above-described embodiments is an example of the “acquiring section”, “executing section” and “generating section” of the above-described first technique.

[0194] The following second technique is proposed from the disclosed contents described above.

[0195] An image processing method including: [0196] an acquiring section acquiring a fundus image; [0197] an executing section executing a first enhancing processing on an image of at least a central region of the fundus image, and executing a second enhancing processing, which is different than the first enhancing processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and [0198] a generating section generating an enhanced image of the fundus image on the basis of a first image obtained due to the first enhancing processing having been executed and a second image obtained due to the second enhancing processing having been executed.

[0199] The following third technique is proposed from the disclosed contents described above.
[0200] A computer program product for image processing, wherein [0201] the computer program product has a computer-readable storage medium that itself is not a transitory signal, [0202] a program is stored on the computer-readable storage medium, and [0203] the program causes a computer to execute: [0204] acquiring a fundus image; [0205] executing a first enhancing processing on an image of at least a central region of the fundus image, and executing a second enhancing processing, which is different than the first enhancing processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and [0206] generating an enhanced image of the fundus image on the basis of a first image obtained due to the first enhancing processing having been executed and a second image obtained due to the second enhancing processing having been executed.
[0207] The above-described image processings are merely examples. Accordingly, it goes without saying that unnecessary steps may be deleted, new steps may be added or the order of processings may be rearranged, within a scope that does not depart from the gist.
[0208] All publications, patent applications, and technical standards mentioned in the present specification are incorporated by reference into the present specification to the same extent as if such individual publication, patent application, or technical standard was specifically and individually indicated to be incorporated by reference.

Claims

1. An image processing method, comprising: by a processor; acquiring a fundus image; performing a first enhancement processing on an image of at least a central region of the fundus image, and performing a second enhancement processing, which is different from the first enhancement processing, on an image of at least a peripheral region of the fundus image that is at a periphery of the central region; and generating an enhanced image of the fundus image on the basis of a first image obtained as a result of the first enhancement processing having been performed and a second image obtained as a result of the second enhancement processing having been performed.
2-22. (canceled)