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### Medical image processing apparatus, medical image processing method, and program

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#### Abstract

Provided are a medical image processing apparatus and a medical image processing method that effectively display an observation state indication related to the comprehensiveness of observation while suppressing a decrease in the visibility of an endoscopic image. The medical image processing apparatus is a medical image processing apparatus including a processor and a memory. The processor is configured to acquire a plurality of medical images in a time-series manner, make a determination of an observation state in units of a small area of a photographic subject on the basis of the medical images, cause the memory to store a result of the determination, and upon an observation state of the photographic subject being changed, cause a monitor to display an observation state indication of the photographic subject, the observation state indication being based on the result of the determination stored in the memory.

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## **Background/Summary**

CROSS-REFERENCE TO RELATED APPLICATIONS (1) The present application is a Continuation of PCT International Application No. PCT/JP2021/002354 filed on Jan. 25, 2021 claiming priority under 35 U.S.C § 119(a) to Japanese Patent Application No. 2020-010917 filed on Jan. 27, 2020. Each of the above applications is hereby expressly incorporated by reference, in its entirety, into the present application.

### **BACKGROUND OF THE INVENTION**

#### **1. Field of the Invention**

(1) The present invention relates to a medical image processing apparatus, a medical image processing method, and a program.

#### **2. Description of the Related Art**

(2) Hitherto, it has been demanded to comprehensively observe an area of an organ or the like as a target to be examined in an examination performed using an endoscope system.

(3) JP2018-50890A describes a technique aimed at preventing insufficient imaging in an examination using an endoscope system. In the technique described in JP2018-50890A, a map image depicting an imaged area and a not-yet-imaged area of a target organ to be imaged is displayed as a notification indication on a monitor.

### **SUMMARY OF THE INVENTION**

(4) Normally, an endoscopic image captured in real time during an examination is displayed in a main display region of a monitor of an endoscope system. Thus, in a case where a notification indication as that described in JP2018-50890A is displayed in the main display region, the notification indication is superimposed on the endoscopic image, and the visibility of the endoscopic image decreases. In a case where the notification indication is displayed in a sub display region of the monitor, the display region is small and thus the visibility of the notification

indication decreases. On the other hand, the notification indication may be provided on a sub-monitor different from a main monitor. However, this involves an issue that a user is unable to concentrate his/her attention on an endoscopic image displayed on the main monitor during an examination.

(5) The above-described JP2018-50890A does not refer to a display manner in which the visibility of an endoscopic image or the visibility of a notification indication (map image) is taken into consideration.

(6) The present invention has been made in view of these circumstances, and an object of the present invention is to provide a medical image processing apparatus, a medical image processing method, and a program that effectively display an observation state indication related to the comprehensiveness of observation while suppressing a decrease in the visibility of an endoscopic image.

(7) A medical image processing apparatus according to an aspect of the present invention for achieving the above-described object is a medical image processing apparatus including a processor and a memory. The processor is configured to acquire a plurality of medical images in a time-series manner, make a determination of an observation state in units of a small area of a photographic subject on the basis of the medical images, cause the memory to store a result of the determination, and upon an observation state of the photographic subject being changed, cause a monitor to display an observation state indication of the photographic subject, the observation state indication being based on the result of the determination stored in the memory.

(8) According to this aspect, upon the observation state of the photographic subject being changed, the observation state indication of the photographic subject is displayed on the monitor. Accordingly, as a result of displaying the observation state indication of the photographic subject at an appropriate timing, display can be effectively performed while an influence on observation of an endoscopic image is suppressed.

(9) Preferably, the processor is configured to cause the observation state indication displayed on the monitor to be hidden after a predetermined time elapses.

(10) Preferably, the medical image processing apparatus further includes a user operation acceptance unit, and the processor is configured to cause the observation state indication to be displayed or hidden on the basis of an instruction from the user operation acceptance unit.

(11) Preferably, the processor is configured to, in a case of determining an observation state of the small area, determine that observation is completed in a case where observation of the small area has been completed, and determine that observation is uncompleted in a case where observation of the small area has not been completed.

(12) Preferably, the processor is configured to cause the monitor to display the observation state indication by using text information.

(13) Preferably, the processor is configured to provide the text information with information regarding completion or incompleteness of observation of the unit of the small area of the photographic subject, and display, as the observation state indication, the text information provided with the information.

(14) Preferably, the processor is configured to cause the observation state indication to be displayed by using a photographic subject model schematically representing the photographic subject.

(15) Preferably, the processor is configured to provide the photographic subject model with information regarding completion or incompleteness of observation of the unit of the small area of the photographic subject, and display, as the observation state indication, the photographic subject model provided with the information.

(16) Preferably, the processor is configured to display, as the observation state indication, an indication indicating only completion of observation of the unit of the small area of the photographic subject or an indication indicating only incompleteness of observation of the unit of the small area of the photographic subject.

- (17) Preferably, the processor is configured to cause the monitor to display the medical images such that the observation state indication is superimposed on the medical images.
- (18) Preferably, the processor is configured to cause a monitor having a first display region and a second display region smaller than the first display region to display the observation state indication in the first display region and the second display region in a manner different between the first display region and the second display region.
- (19) Preferably, the processor is configured to cause the observation state indication to be constantly displayed in the second display region.
- (20) Preferably, the processor is configured to cause a monitor having the first display region and a third display region different from the second display region to display the medical images in the third display region.
- (21) A medical image processing method according to another aspect of the present invention is a medical image processing method for a medical image processing apparatus including a processor and a memory. The processor is configured to execute a medical image acquisition step of acquiring a plurality of medical images in a time-series manner, an observation state determination step of making a determination of an observation state in units of a small area of a photographic subject on the basis of the medical images, a storage step of causing the memory to store a result of the determination, and a display step of, upon an observation state of the photographic subject being changed, causing a monitor to display an observation state indication of the photographic subject, the observation state indication being based on the result of the determination stored in the memory.
- (22) A program according to another aspect of the present invention is a program that causes a medical image processing apparatus including a processor and a memory to execute a medical image processing method. The processor is configured to execute a medical image acquisition step of acquiring a plurality of medical images in a time-series manner, an observation state determination step of making a determination of an observation state in units of a small area of a photographic subject on the basis of the medical images, a storage step of causing the memory to store a result of the determination, and a display step of, upon an observation state of the photographic subject being changed, causing a monitor to display an observation state indication of the photographic subject, the observation state indication being based on the result of the determination stored in the memory.
- (23) According to the present invention, an observation state indication of a photographic subject is displayed on a monitor upon an observation state of the photographic subject being changed. Thus, as a result of displaying the observation state indication of the photographic subject at an appropriate timing, effective display can be performed while an influence on observation of an endoscopic image is suppressed.
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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

- (1) FIG. 1 is an external appearance diagram of an endoscope system;
- (2) FIG. 2 is a block diagram illustrating the configuration of a main part of the endoscope system;
- (3) FIG. 3 is a functional block diagram of an image processing unit in a medical image processing apparatus;
- (4) FIG. 4 is a diagram illustrating main information stored in a recording unit;
- (5) FIGS. 5A and 5B are diagrams illustrating configurations of a neural network;
- (6) FIG. 6 is a schematic diagram illustrating an example configuration of an intermediate layer;
- (7) FIG. 7 is a flowchart illustrating a medical image processing method;
- (8) FIG. 8 is a diagram illustrating an example of an observation state indication;

- (9) FIG. **9** is a diagram illustrating Modification 1 of an observation state indication;
- (10) FIG. **10** is a diagram illustrating Modification 2 of an observation state indication;
- (11) FIG. **11** is a diagram illustrating Modification 3 of an observation state indication;
- (12) FIG. **12** is a diagram illustrating Modification 4 of an observation state indication;
- (13) FIG. **13** is a diagram illustrating Modification 5 of an observation state indication;
- (14) FIG. **14** is a diagram illustrating Modification 6 of an observation state indication;
- (15) FIG. **15** is a diagram for describing an example of a monitor having a main display region and a sub display region;
- (16) FIG. **16** is a diagram for describing an example of the case of displaying different observation state indications in the main display region and the sub display region; and
- (17) FIG. **17** is a diagram for describing an example of the case of displaying different observation state indications in the main display region and the sub display region.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

(18) Hereinafter, preferred embodiments of a medical image processing apparatus, a medical image processing method, and a program according to the present invention will be described with reference to the attached drawings.

#### (19) Configuration of Endoscope System

(20) FIG. **1** is an external appearance diagram of an endoscope system **10**, and FIG. **2** is a block diagram illustrating the configuration of a main part of the endoscope system **10**. As illustrated in FIGS. **1** and **2**, the endoscope system **10** is constituted by an endoscope **100**, an endoscope processor apparatus **200**, a light source apparatus **300**, and a monitor **400**. The endoscope processor apparatus **200** has the medical image processing apparatus of the present invention mounted therein.

#### (21) Configuration of Endoscope

(22) The endoscope **100** includes a handheld operation section **102** and an insertion section **104** that communicates with the handheld operation section **102**. An operator (a user) operates the handheld operation section **102** while grasping it and inserts the insertion section **104** into a body of a subject (a living body) to perform observation. The handheld operation section **102** is provided with an air/water supply button **141**, a suction button **142**, a function button **143** to which various functions are allocated, and an imaging button **144** for receiving an imaging instruction operation (a still image, a moving image). The insertion section **104** is constituted by a soft part **112**, a bending part **114**, and a tip rigid part **116**, which are arranged in this order from the handheld operation section **102** side. That is, the bending part **114** is connected to a base end side of the tip rigid part **116**, and the soft part **112** is connected to a base end side of the bending part **114**. The handheld operation section **102** is connected to a base end side of the insertion section **104**. The user is able to change the orientation of the tip rigid part **116** in an up, down, left, or right direction by causing the bending part **114** to bend by operating the handheld operation section **102**. The tip rigid part **116** is provided with an imaging optical system **130**, an illumination unit **123**, a forceps port **126**, and so forth (see FIGS. **1** and **2**).

(23) During observation and treatment, an operation of an operation unit **208** (see FIG. **2**) enables white light and/or narrow-band light (one or more of red narrow-band light, green narrow-band light, blue narrow-band light, and violet narrow-band light) to be radiated from illumination lenses **123A** and **123B** of the illumination unit **123**. In addition, an operation of the air/water supply button **141** enables washing water to be ejected from a water supply nozzle that is not illustrated, so that an imaging lens **132** of the imaging optical system **130** and the illumination lenses **123A** and **123B** can be washed. The forceps port **126** opening in the tip rigid part **116** communicates with a pipe line that is not illustrated, so that a treatment tool that is not illustrated and is for extirpating a tumor or the like can be inserted into the pipe line and necessary treatment can be given to a subject by moving the treatment tool forward or backward as appropriate.

(24) As illustrated in FIG. **1** and FIG. **2**, the imaging lens **132** is disposed on a distal-end-side

surface **116A** of the tip rigid part **116**. An imaging element **134** of a complementary metal-oxide semiconductor (CMOS) type, a driving circuit **136**, and an analog front end (AFE) **138** are disposed behind the imaging lens **132**, and these elements output an image signal. The imaging element **134** is a color imaging element and includes a plurality of pixels constituted by a plurality of light-receiving elements arranged in a matrix (arranged two-dimensionally) in a specific pattern arrangement (Bayer arrangement, X-Trans (registered trademark) arrangement, honeycomb arrangement, or the like). Each pixel of the imaging element **134** includes a microlens, a red (R), green (G), or blue (B) color filter, and a photoelectric conversion unit (a photodiode or the like). The imaging optical system **130** is capable of generating a color image from pixel signals of three colors, red, green, and blue, and is also capable of generating an image from pixel signals of any one or two colors among red, green, and blue. The imaging element **134** may be of a charge coupled device (CCD) type. Each pixel of the imaging element **134** may further include a violet color filter corresponding to a violet light source **310V** and/or an infrared filter corresponding to an infrared light source.

(25) An optical image of a subject is formed on a light-receiving surface (an imaging surface) of the imaging element **134** by the imaging lens **132**, converted into an electric signal, output to the endoscope processor apparatus **200** through a signal cable that is not illustrated, and converted into a video signal. Accordingly, an endoscopic image (medical image) of the subject is displayed on the monitor **400**, which is connected to the endoscope processor apparatus **200**.

(26) The illumination lenses **123A** and **123B** of the illumination unit **123** are provided next to the imaging lens **132** on the distal-end-side surface **116A** of the tip rigid part **116**. An emission end of a light guide **170**, which will be described below, is disposed behind the illumination lenses **123A** and **123B**. The light guide **170** extends through the insertion section **104**, the handheld operation section **102**, and a universal cable **106**, and an incidence end of the light guide **170** is located in a light guide connector **108**.

(27) A user performs imaging at a determined frame rate while inserting or removing the endoscope **100** having the above-described configuration into or from a living body as a subject, thereby being capable of sequentially capturing time-series endoscopic images of the inside of the living body.

(28) Configuration of Light Source Apparatus

(29) As illustrated in FIG. 2, the light source apparatus **300** is constituted by a light source **310** for illumination, a diaphragm **330**, a condenser lens **340**, a light source control unit **350**, and so forth, and causes observation light to enter the light guide **170**. The light source **310** includes a red light source **310R**, a green light source **310G**, a blue light source **310B**, and the violet light source **310V** that radiate red narrow-band light, green narrow-band light, blue narrow-band light, and violet narrow-band light, respectively, and is capable of radiating red narrow-band light, green narrow-band light, blue narrow-band light, and violet narrow-band light. The illuminance of observation light from the light source **310** is controlled by the light source control unit **350**, which is capable of changing (increasing or decreasing) the illuminance of observation light or stopping illumination as necessary.

(30) The light source **310** is capable of emitting red narrow-band light, green narrow-band light, blue narrow-band light, and violet narrow-band light in any combination. For example, the light source **310** is capable of simultaneously emitting red narrow-band light, green narrow-band light, blue narrow-band light, and violet narrow-band light to radiate white light (normal light) as observation light, and is also capable of emitting any one or two of red narrow-band light, green narrow-band light, blue narrow-band light, and violet narrow-band light to radiate narrow-band light (special light). The light source **310** may further include an infrared light source that radiates infrared light (an example of narrow-band light). Alternatively, with use of a light source that radiates white light and a filter that allows white light and each narrow-band light to pass therethrough, white light or narrow-band light may be radiated as observation light.

(31) Wavelength Range of Light Source

(32) The light source **310** may be a light source that generates light in a white range or light in a plurality of wavelength ranges as the light in the white range, or may be a light source that generates light in a specific wavelength range narrower than the white wavelength range. The specific wavelength range may be a blue range or green range in a visible range, or may be a red range in the visible range. In a case where the specific wavelength range is the blue range or green range in the visible range, the specific wavelength range may include a wavelength range of 390 nm or more and 450 nm or less or a wavelength range of 530 nm or more and 550 nm or less, and the light in the specific wavelength range may have a peak wavelength in the wavelength range of 390 nm or more and 450 nm or less or the wavelength range of 530 nm or more and 550 nm or less. In a case where the specific wavelength range is the red range in the visible range, the specific wavelength range may include a wavelength range of 585 nm or more and 615 nm or less or a wavelength range of 610 nm or more and 730 nm or less, and the light in the specific wavelength range may have a peak wavelength in the wavelength range of 585 nm or more and 615 nm or less or the wavelength range of 610 nm or more and 730 nm or less.

(33) The specific wavelength range may include a wavelength range in which a light absorption coefficient is different between oxyhemoglobin and deoxyhemoglobin, and the light in the specific wavelength range may have a peak wavelength in the wavelength range in which the light absorption coefficient is different between oxyhemoglobin and deoxyhemoglobin. In this case, the specific wavelength range may include a wavelength range of  $400\pm 10$  nm, a wavelength range of  $440\pm 10$  nm, a wavelength range of  $470\pm 10$  nm, or a wavelength range of 600 nm or more and 750 nm or less, and may have a peak wavelength in the wavelength range of  $400\pm 10$  nm, the wavelength range of  $440\pm 10$  nm, the wavelength range of  $470\pm 10$  nm, or the wavelength range of 600 nm or more and 750 nm or less.

(34) The wavelength range of the light generated by the light source **310** may include a wavelength range of 790 nm or more and 820 nm or less or a wavelength range of 905 nm or more and 970 nm or less, and the light generated by the light source **310** may have a peak wavelength in the wavelength range of 790 nm or more and 820 nm or less or the wavelength range of 905 nm or more and 970 nm or less.

(35) Alternatively, the light source **310** may include a light source that radiates excitation light whose peak is 390 nm or more and 470 nm or less. In this case, an endoscopic image having information about fluorescence emitted by a fluorescent substance in a subject (a living body) can be acquired. In the case of acquiring a fluorescence image, a pigment for a fluorescence method (fluorescein, acridine orange, or the like) may be used.

(36) It is preferable that the type of the light source **310** (a laser light source, a xenon light source, a light-emitting diode (LED) light source, or the like), the wavelength of the light source **310**, the presence or absence of a filter for the light source **310**, and so forth be determined in accordance with the type, area, purpose of observation, or the like of a photographic subject. It is also preferable that, during observation, the wavelengths of observation light be combined and/or switched in accordance with the type, area, purpose of observation, or the like of a photographic subject. In the case of switching the wavelength, for example, a disc-shaped filter (a rotary color filter) that is disposed in front of the light source and that is provided with a filter for transmitting or blocking light of a specific wavelength may be rotated to switch the wavelength of light to be radiated.

(37) The imaging element used to carry out the present invention is not limited to a color imaging element in which color filters are disposed for the individual pixels, such as the imaging element **134**, and may be a monochrome imaging element. In the case of using a monochrome imaging element, imaging can be performed in a frame sequential (color sequential) manner by sequentially switching the wavelength of observation light. For example, the wavelength of outgoing observation light may be sequentially switched among violet, blue, green, and red, or wide-band light (white light) may be radiated and the wavelength of outgoing observation light may be



switched by using a rotary color filter (red, green, blue, violet, and the like). Alternatively, one or a plurality of types of narrow-band light (green, blue, violet, and the like) may be radiated and the wavelength of outgoing observation light may be switched by using a rotary color filter (green, blue, violet, and the like). The narrow-band light may be infrared light of two or more different wavelengths (first narrow-band light and second narrow-band light).

(38) As a result of connecting the light guide connector **108** (see FIGS. **1** and **2**) to the light source apparatus **300**, observation light radiated by the light source apparatus **300** is transmitted through the light guide **170** to the illumination lenses **123A** and **123B** and is radiated from the illumination lenses **123A** and **123B** to an observation range.

(39) Configuration of Endoscope Processor Apparatus

(40) The configuration of the endoscope processor apparatus **200** will be described with reference to FIG. **2**. In the endoscope processor apparatus **200**, an image input controller **202** receives an image signal output from the endoscope **100**, an image processing unit **204** performs necessary image processing thereon, and a video output unit **206** outputs a resulting image signal.

Accordingly, an endoscopic image is displayed on the monitor **400**. These processing operations are performed under control by a central processing unit (CPU) **210**. The CPU **210** functions as a processor of the medical image processing apparatus. A communication control unit **205** controls communication, for acquiring a medical image, with a hospital information system (HIS), a hospital local area network (LAN), and/or an external system or network that are not illustrated.

(41) Functions of Image Processing Unit

(42) The image processing unit **204** is capable of performing calculation of a feature quantity of an endoscopic image, processing of emphasizing or reducing a component of a specific frequency band, and processing of emphasizing or deemphasizing a specific target (a region of interest, blood vessels at a desired depth, or the like). The image processing unit **204** may include a special-light image acquiring unit (not illustrated) that acquires a special-light image having information about a specific wavelength range on the basis of a normal-light image that is acquired by radiating light in the white range or light in a plurality of wavelength ranges as the light in the white range. In this case, a signal in the specific wavelength range can be acquired through computation based on color information of RGB (R: red, G: green, B: blue) or CMY (C: cyan, M: magenta, Y: yellow) included in the normal-light image. In addition, the image processing unit **204** may include a feature quantity image generating unit (not illustrated) that generates a feature quantity image through computation based on at least one of a normal-light image that is acquired by radiating light in the white range or light in a plurality of wavelength ranges as the light in the white range or a special-light image that is acquired by radiating light in a specific wavelength range, and may acquire and display the feature quantity image as an endoscopic image. The above-described processing is performed under control by the CPU **210**.

(43) Furthermore, the image processing unit **204** has individual functions in the medical image processing apparatus as described below.

(44) FIG. **3** is a functional block diagram of the image processing unit **204** in the medical image processing apparatus. The image processing unit **204** includes a medical image acquiring unit **220**, an observation state determining unit **222**, and a display control unit **224**.

(45) Implementation of Functions by Various Types of Processors

(46) The functions of the above-described units of the image processing unit **204** can be implemented by using various types of processors and a recording medium. The various types of processors include, for example, a central processing unit (CPU) which is a general-purpose processor that executes software (program) to implement various functions. Also, the various types of processors include a graphics processing unit (GPU) which is a processor dedicated to image processing, and a programmable logic device (PLD) which is a processor whose circuit configuration is changeable after manufacturing, such as a field programmable gate array (FPGA). In the case of performing learning and recognition of images as in the present invention, the

configuration using a GPU is effective. Furthermore, the various types of processors include a dedicated electric circuit which is a processor having a circuit configuration designed exclusively for executing specific processing, such as an application specific integrated circuit (ASIC).

(47) The function of each unit may be implemented by one processor or may be implemented by a plurality of processors of the same type or different types (for example, a combination of a plurality of FPGAs, a combination of a CPU and an FPGA, or a combination of a CPU and a GPU). A plurality of functions may be implemented by one processor. A first example of implementing a plurality of functions by one processor is that a combination of one or more CPUs and software constitute one processor and the one processor implements the plurality of functions, as represented by a computer. A second example is that a processor that implements the functions of an entire system by one integrated circuit (IC) chip is used, as represented by a system on chip (SoC). In this way, various functions are configured as a hardware structure by using one or more of the above-described various types of processors. Furthermore, the hardware structure of the various types of processors is, more specifically, electric circuitry formed by combining circuit elements such as semiconductor elements. The electric circuitry may be electric circuitry that implements the above-described functions by using logical disjunction, logical conjunction, logical negation, exclusive disjunction, and logical operation as a combination thereof.

(48) When the above-described processor or electric circuitry executes the software (program), the code of the software to be executed that is readable by a computer (for example, the various types of processors or electric circuitry constituting the image processing unit **204**, and/or a combination thereof) is stored in a non-transitory recording medium, such as a read only memory (ROM) **211**, and the computer refers to the software. The software stored in the non-transitory recording medium includes a program for executing the medical image processing method for the medical image processing apparatus according to the present invention, and data to be used to execute the program. The code may be recorded on a non-transitory recording medium, such as a magneto-optical recording device of various types or a semiconductor memory, instead of the ROM **211**. In the processing using the software, a random access memory (RAM) **212** may be used as a transitory storage region, for example, and data stored in an electrically erasable and programmable read only memory (EEPROM) that is not illustrated can be referred to, for example. A recording unit **207** may be used as a “non-transitory recording medium”.

(49) The read only memory (ROM) **211** is a nonvolatile storage element (a non-transitory recording medium) and stores a computer-readable code of a program that causes the CPU **210** and/or the image processing unit **204** to execute various image processing methods. The random access memory (RAM) **212** is a storage element for temporary storage in various processing operations and can be used as a buffer when acquiring an image. An audio processing unit **209** outputs audio and sound from a speaker **209A** under control by the CPU **210**.

(50) The operation unit **208** can be constituted by devices such as a keyboard and a mouse that are not illustrated. A user is able to provide an instruction to execute processing or designate a condition necessary for the execution via the operation unit **208**.

(51) Information Stored in Recording Unit

(52) FIG. **4** is a diagram illustrating main information stored in the recording unit **207**. The recording unit (memory) **207** stores a medical image (endoscopic image) **260**, a determination result **262** of the observation state determining unit **222**, and so forth. The recording unit **207** also stores information about a series of small areas to be observed in an examination performed using the endoscope system **10**. The small areas of a photographic subject herein are, for example, individual portions of an organ. Specifically, in the case of performing an examination of observing all the portions of the stomach, the small areas are the cardia, fundus, angulus, gastric body (upper portion, middle portion, lower portion), antrum, anterior wall, posterior wall, greater curvature, and lesser curvature.

(53) Recognizing Unit Using Neural Network

(54) The observation state determining unit **222** in the above-described image processing unit **204** includes a recognizer. The recognizer is constituted by using a trained model (a model trained by using an image set constituted by captured images of a living body), such as a neural network, and is capable of recognizing small areas of a photographic subject. The observation state determining unit **222** determines, in units of a small area, whether observation of the small area has been completed, on the basis of the position of the small area recognized by the recognizer, the number of endoscopic images in which the small area has been recognized, or the like. Hereinafter, a description will be given of the configuration of the recognizer included in the observation state determining unit **222** in the case of using a convolutional neural network (CNN) as a neural network.

(55) Example of Configuration of Recognizer

(56) FIGS. **5A** and **5B** are diagrams illustrating configurations of a CNN **232** (neural network). In the example illustrated in FIG. **5A**, the CNN **232** has an input layer **232A**, an intermediate layer **232B**, and an output layer **232C**. The input layer **232A** receives an endoscopic image acquired by the medical image acquiring unit **220** and outputs a feature quantity. The intermediate layer **232B** includes convolutional layers **234** and pooling layers **235**, and receives the feature quantity output from the input layer **232A** and calculates another feature quantity. These layers have a structure in which a plurality of “nodes” are connected by “edges”. Weighting coefficients applied to an input image are associated with the nodes and edges and are stored in a weighting coefficient storage unit that is not illustrated. The values of the weighting coefficients change as learning progresses.

(57) Processing in Intermediate Layer

(58) The intermediate layer **232B** calculates a feature quantity through convolutional operation and pooling processing. The convolutional operation performed in the convolutional layer **234** is processing of acquiring a feature map through convolutional operation using a filter, and plays a role in feature extraction such as edge extraction from an image. As a result of the convolutional operation using a filter, one-channel (one) “feature map” is created for one filter. The size of the “feature map” is reduced as convolution is performed in each layer in the case of being scaled down by convolution. The pooling processing performed in the pooling layer **235** is processing of reducing (or enlarging) the feature map output through the convolutional operation to create a new feature map, and plays a role in giving robustness so that the extracted feature is not affected by parallel movement or the like. The intermediate layer **232B** can be constituted by one or a plurality of layers that perform these processing operations. The CNN **232** may be configured without a pooling layer **235**.

(59) The CNN **232** may include a fully connected layer **236** as in the example illustrated in FIG. **5B**. The layer configuration of the CNN **232** is not limited to the configuration in which the convolutional layers **234** and the pooling layers **235** are alternately arranged, and may include a plurality of consecutive convolutional layers **234** or pooling layers **235** (for example, convolutional layers **234**).

(60) FIG. **6** is a schematic diagram illustrating an example configuration of the intermediate layer **232B** of the CNN **232** illustrated in FIGS. **5A** and **5B**. In the first convolutional layer of the intermediate layer **232B**, convolutional operation of an image set constituted by a plurality of endoscopic images and a filter F.sub.1 is performed. The image set is constituted by N (N-channel) images each having an image size in which the height is represented by H and the width is represented by W. In the case of inputting normal-light images, the images constituting an image set are three-channel images of red (R), green (G), and blue (B). The filter F.sub.1 convoluted with this image set has a filter size of  $5 \times 5 \times N$  in the case of the filter having size 5 ( $5 \times 5$ ), for example, because the image set has N channels (N images). As a result of convolutional operation using the filter F.sub.1, one-channel (one) “feature map” is created for one filter F.sub.1. A filter F.sub.2 used in the second convolutional layer has a filter size of  $3 \times 3 \times M$  in the case of the filter having size 3 ( $3 \times 3$ ), for example.

(61) As in the first convolutional layer, in the second to n-th convolutional layers, convolutional operations using filters F.sub.2 to F.sub.n are performed, respectively. The size of the “feature map” in the n-th convolutional layer is smaller than the size of the “feature map” in the second convolutional layer because scaling-down is performed in the convolutional layers or pooling layers in the preceding stages.

(62) In the layers of the intermediate layer **232B**, lower-order feature extraction (extraction of edges or the like) is performed in a convolutional layer near the input side, and higher-order feature extraction (extraction of features about the shape, structure, and the like of a recognition target) is performed near the output side.

(63) The intermediate layer **232B** may include a layer for performing batch normalization in addition to the convolutional layers **234** and the pooling layers **235**. Batch normalization processing is the processing of normalizing a data distribution in units of mini batches for performing learning, and plays a role in quickly performing learning, reducing dependency on an initial value, suppressing overtraining, and so forth.

(64) The output layer **232C** outputs the feature quantity calculated by the intermediate layer **232B** in a form appropriate for recognition. The output layer **232C** may include a fully connected layer.

(65) Individual Processes of Medical Image Processing Method

(66) Next, a medical image processing method using the medical image processing apparatus will be described.

(67) FIG. 7 is a flowchart illustrating a medical image processing method. Hereinafter, individual steps will be described with reference to FIG. 7. Hereinafter, a description will be given of the case of observing area **1**, area **2**, and area **3**, which are small areas, in units of areas, for examining organ A as a photographic subject.

(68) Medical Image Acquisition Step

(69) The medical image acquiring unit **220** sequentially acquires a plurality of medical images of organ A in a time-series manner (step **S10**). The recording unit **207** stores a record indicating that observation of area **1**, area **2**, and area **3** of organ A is to be performed, and stores, in an initial state, a record indicating that observation of area **1**, area **2**, and area **3** has not been completed.

(70) Observation State Determination Step

(71) The observation state determining unit **222** determines, on the basis of the acquired medical images, the observation states of area **1**, area **2**, and area **3** of organ A (step **S11**). The observation state determining unit **222** recognizes area **1**, area **2**, or area **3** in the medical images. The observation state determining unit **222** then determines the observation states of area **1**, area **2**, and area **3** on the basis of a result of the recognition. For example, if area **1** has been recognized at the centers of ten chronologically consecutive medical images, the observation state determining unit **222** determines that observation of area **1** has been completed.

(72) Storage Step

(73) The recording unit **207** stores a result of the determination made by the observation state determining unit **222** (step **S12**). At start of the examination (initial state), a record indicating that observation of area **1**, area **2**, and area **3** has not been completed is stored. If the observation state determining unit **222** determines that observation of the individual areas has been completed, the record is updated to indicate that observation has been completed.

(74) Display Step

(75) The display control unit **224** determines whether a change has occurred in the observation state of the photographic subject (step **S13**). Upon determining that a change has occurred in the observation state of the photographic subject, the display control unit **224** causes the monitor **400** to display an observation state indication **501** of the photographic subject (step **S14**). Here, “upon the observation state of the photographic subject being changed” is a case where a change in the observation state has been stored in the recording unit **207** in a plurality of small area units that are stored in the recording unit **207** and that are to be observed. An example of the case is a case where

the recording unit **207** stores a record indicating that observation of area **1**, area **2**, and area **3** has not been completed, then the observation state determining unit **222** determines that observation of area **1** has been completed, and then the observation state of area **1** has been changed to completion of observation in the recording unit **207**. The observation state indication **501** of the photographic subject is an indication for notifying a user of the observation states of small area units constituting the photographic subject as an observation target. By viewing the observation state indication **501**, the user is able to determine whether he/she is comprehensively observing small areas of the observation target.

(76) FIG. **8** is a diagram illustrating an example of the observation state indication **501** of organ A displayed on the monitor **400**.

(77) In the case illustrated in FIG. **8**, an endoscopic image **503** is displayed on the entire screen of the monitor **400**. Upon the record in the recording unit **207** being updated from a record indicating that observation of area **3** has not been completed to a record indicating that observation of area **3** has been completed, the display control unit **224** causes the monitor **400** to display the observation state indication **501** such that the observation state indication **501** is superimposed on the endoscopic image **503**. The observation state indication **501** is a list indication having text information indicating an area for which observation has been completed and an area for which observation has not been completed. In the observation state indication **501**, area **1** and area **3** for which observation has been completed are shown below “Completed”, and area **2** for which observation has not been completed is shown below “Uncompleted”.

(78) Referring back to FIG. **7**, the display control unit **224** then continues displaying the observation state indication **501** until a predetermined display time elapses. The display time can be set by a user as appropriate. Preferably, the observation state indication **501** is hidden upon the observation state being checked by the user so that the endoscopic image **503** can be observed. Thus, it is preferable that the display time be set on the basis of a time within which the user is able to check the observation state. For example, the display time can be set to 10 seconds or 30 seconds. After that, the display control unit **224** hides the observation state indication **501** after the predetermined time has elapsed (step **S15**).

(79) After that, the medical image acquiring unit **220** determines whether observation of all the small area units has been finished (step **S16**). Because observation of area **2** has not been completed, medical images are further acquired (step **S10**).

(80) As described above, in the present invention, in the case of observing area **1**, area **2**, and area **3**, which are small areas of organ A, the observation state indication **501** is provided upon the observation state of organ A being changed. Accordingly, as a result of providing the observation state indication **501** when it is necessary and hiding the observation state indication **501** in other cases, display can be effectively performed while an influence on observation of an endoscopic image is suppressed.

(81) Modifications of Observation State Indication

(82) In the example described in FIG. **8**, a description has been given of the case of displaying the observation state indication **501** in which text information indicates an area for which observation has been completed and an area for which observation has not been completed. However, the example of the observation state indication **501** is not limited thereto. The display manner of the observation state indication **501** is not particularly limited as long as a user can be notified of an observation state of a photographic subject as an observation target by using text or a figure. Hereinafter, specific examples of the observation state indication **501** will be described.

(83) FIG. **9** is a diagram illustrating Modification 1 of the observation state indication **501**. The present modification is the observation state indication **501** using text information. The observation state indication **501** of the present modification indicates only an area for which observation has not been completed. Specifically, in a case where observation of area **2** has not been completed, text information indicating area **2** is shown below “Uncompleted”.

(84) In this way, as a result of providing the monitor **400** with the observation state indication **501** having only a small area for which observation has not been completed, the user is able to clearly recognize the small area for which observation has not been completed, and comprehensive observation can be realized. In the example in FIG. **9**, a description has been given of an example of displaying, in the observation state indication **501**, a small area for which observation has not been completed. However, a small area for which observation has been completed may be displayed in the observation state indication **501**. In this case, the user is able to clearly recognize the small area for which observation has been completed.

(85) FIG. **10** is a diagram illustrating Modification 2 of the observation state indication **501**. The present modification is the observation state indication **501** using text information. In the observation state indication **501** of the present modification, all small areas (areas **1** to **5**) constituting a photographic subject as an observation target are displayed in a list view. In the observation state indication **501**, an area for which observation has been completed and an area for which observation has not been completed are displayed using characters of different colors. Specifically, in the observation state indication **501**, areas **3** and **5** are displayed using characters of the same color because the observation thereof has not been completed, and areas **1**, **2**, and **4** are displayed using characters of the same color because the observation thereof has been completed. In this way, all the small areas are displayed in a list view, and text is provided with, in units of small areas, information indicating that observation has been completed or information indicating that observation has not been completed. Thus, the user is able to comprehensively recognize an area for which observation has been completed or has not been completed.

(86) FIG. **11** is a diagram illustrating Modification 3 of the observation state indication **501**. The present modification is the observation state indication **501** using text information. In the observation state indication **501** of the present modification, all small areas (areas **1** to **5**) constituting a photographic subject as an observation target are displayed in a list view. In the observation state indication **501**, a circle and a cross are displayed beside an area for which observation has been completed and an area for which observation has not been completed, respectively. Specifically, in the observation state indication **501**, areas **3** and **5** are given a cross because the observation thereof has not been completed, and areas **1**, **2**, and **4** are given a circle because the observation thereof has been completed. In this way, all the small areas are displayed in a list view, and information indicating that observation has been completed or information indicating that observation has not been completed is displayed beside text in units of small areas. Thus, the user is able to comprehensively recognize an area for which observation has been completed or has not been completed.

(87) FIG. **12** is a diagram illustrating Modification 4 of the observation state indication **501**. The present modification is the observation state indication **501** using text information. In the observation state indication **501** of the present modification, a percentage of incompleteness of observation is indicated as the observation state indication **501**. The percentage of incompleteness of observation herein means a percentage of small areas for which observation has not been completed among a plurality of small areas to be observed. The percentage may be calculated on the basis of the number of small areas or the area of small areas. In the example illustrated in FIG. **12**, the percentage is indicated in a text form. Alternatively, the percentage may be indicated using a figure, such as a bar indicating the percentage. In this way, as a result of indicating the percentage of incompleteness of observation, the user is able to clearly recognize the area for which observation has not been completed.

(88) FIG. **13** is a diagram illustrating Modification 5 of the observation state indication **501**. The present modification is the observation state indication **501** using a photographic subject model **M** schematically representing a photographic subject. The photographic subject model **M** is a figure schematically illustrating the stomach, which is a photographic subject as an observation target. In the photographic subject model **M**, in small area units, an area **513** for which observation has been

completed and an area **511** for which observation has not been completed are given different colors. In this way, as a result of providing the photographic subject model **M** with information indicating that observation has been completed and observation has not been completed, the user is able to recognize, in the photographic subject, the position of a small area for which observation has been completed and the position of a small area for which observation has not been completed. In the example illustrated in FIG. **13**, information indicating that observation has been completed and observation has not been completed is provided by using different colors for areas of the photographic subject model **M**, but the present invention is not limited to this example. For example, information about completion of observation and incompleteness of observation may be provided to the photographic subject model **M** by changing the density of a color.

(89) FIG. **14** is a diagram illustrating Modification 6 of the observation state indication **501**. The present modification is the observation state indication **501** using a photographic subject model **M** schematically representing a photographic subject. In the present modification, in the photographic subject model **M**, only a small area for which observation has been completed is shown. Upon observation of all the small areas being completed, the entire photographic subject model **M** (stomach) is displayed. In this way, as a result of providing the photographic subject model **M** with information indicating that observation has been completed and observation has not been completed, the user is able to recognize, in the photographic subject, the position of a small area for which observation has been completed and the position of a small area for which observation has not been completed. In FIG. **13** and FIG. **14**, a sectional view of the stomach as a photographic subject is used as the photographic subject model **M**, but the present invention is not limited thereto. For example, the photographic subject model **M** may be a development view of the stomach as a photographic subject.

(90) Modifications of Monitor

(91) In the description given above, an example of the monitor **400** having only a main display region has been described, but the present invention is not limited thereto. Hereinafter, modifications of the monitor will be described.

(92) FIG. **15** is a diagram for describing an example of a monitor **401** having a main display region and a sub display region.

(93) As illustrated in FIG. **15**, the monitor **401** has a main display region **402** and a sub display region **404**. In the main display region **402**, the endoscopic image **503** captured by the endoscope **100** is displayed in real time. The sub display region **404** is set to be smaller than the main display region **402**, and information such as an imaging condition, a date, and patient information is displayed therein. In FIG. **15**, illustration of these pieces of information displayed in the sub display region **404** is omitted. In the monitor **401**, the observation state indication **501** is provided in the main display region **402** and the sub display region **404**. In the main display region **402**, the observation state indication **501** is displayed upon the observation state of a photographic subject being changed, and display is finished after a display time elapses, as described above. FIG. **15** illustrates a case where the observation state indication **501** is hidden in the main display region **402**.

(94) In the sub display region **404**, an observation state indication **501B** is constantly displayed. The sub display region **404** has a small display area. Thus, the observation state indication **501B** is smaller than an observation state indication **501A** displayed in the main display region **402**, but serves as support for performing comprehensive observation. The same observation state indication or different observation state indications may be displayed in the main display region **402** and the sub display region **404**.

(95) FIG. **16** and FIG. **17** are diagrams for describing examples of the case of displaying different observation state indications in the main display region and the sub display region.

(96) In the example illustrated in FIG. **16**, the observation state indication **501A**, having details indicating small areas that are listed, is provided in the main display region **402**. In the sub display

region **404**, the observation state indication **501B** of the photographic subject model M is displayed.

(97) In the example illustrated in FIG. **17**, the observation state indication **501A**, having details indicating small areas that are listed, is provided in the main display region **402**. In the sub display region **404**, the observation state indication **501B** indicating a percentage of incompleteness of observation is displayed.

(98) As illustrated in FIG. **16** and FIG. **17**, in the main display region **402**, the observation state indication **501A**, which makes it possible to grasp the observation states of small area units in detail and which indicates small areas in a list view, is displayed upon the observation state of the photographic subject being changed. Accordingly, the user is able to grasp the detailed observation state of the photographic subject when the number of small areas for which observation has been completed increases. In the sub display region **404**, the observation state indication **501B**, which indicates the photographic subject model M or a percentage of incompleteness of observation, is constantly displayed. Accordingly, the user is able to grasp an overview of the observation state of the photographic subject even in a case where the observation state indication **501A** is not displayed in the main display region **402**. In the above-described example, a description has been given of the monitor **401** having the main display region (first display region) **402** and the sub display region (second display region) **404**. Alternatively, for example, the observation state indication **501** may be displayed on a monitor having a third display region. Alternatively, the observation state indication **501** may be provided on a plurality of monitors.

(99) Other Examples

(100) In the above description, a description has been given of the manner of providing the observation state indication **501** for the period of a predetermined display time. However, the manner of hiding the once displayed observation state indication **501** is not limited thereto.

(101) For example, the display control unit **224** may hide the observation state indication **501** on the basis of an instruction input by a user via the handheld operation section **102** (user operation acceptance unit) (see FIG. **1**). Furthermore, the display control unit **224** may display again the once hidden observation state indication **501** on the basis of an instruction input by a user via the handheld operation section **102** (user operation acceptance unit). In this way, as a result of controlling displaying and hiding of the observation state indication **501** by the user using the handheld operation section **102**, the user is able to check the observation state indication at a desired timing.

(102) Examples of the present invention have been described above. The present invention is not limited to the above-described embodiment, and various modifications can be made without deviating from the spirit of the present invention.

#### REFERENCE SIGNS LIST

(103) **10** endoscope system **100** endoscope **102** handheld operation section **104** insertion section **106** universal cable **108** light guide connector **112** soft part **114** bending part **116** tip rigid part **116A** distal-end-side surface **123** illumination unit **123A** illumination lens **123B** illumination lens **126** forceps port **130** imaging optical system **132** imaging lens **134** imaging element **136** driving circuit **141** air/water supply button **142** suction button **143** function button **144** imaging button **170** light guide **200** endoscope processor apparatus **202** image input controller **204** image processing unit **205** communication control unit **206** video output unit **207** recording unit **208** operation unit **209** audio processing unit **209A** speaker **210** CPU **211** ROM **212** RAM **220** medical image acquiring unit **222** observation state determining unit **224** display control unit **232A** input layer **232B** intermediate layer **232C** output layer **234** convolutional layer **235** pooling layer **236** fully connected layer **300** light source apparatus **310** light source **310B** blue light source **310G** green light source **310R** red light source **310V** violet light source **330** diaphragm **340** condenser lens **350** light source control unit **400** monitor



## Claims

1. A medical image processing apparatus comprising one or more processors and one or more memories, the one or more processors being configured to: acquire a plurality of medical images in a time-series manner; make a determination of an observation state of each of a plurality of predetermined areas in an organ of a photographic subject positioned differently from each other, using the plurality of medical images, to determine that the observation state is observation-completed in a case where observation is completed and determine that the observation state is observation-uncompleted in a case where observation is uncompleted; display, on a monitor, a notification that the observation state of each of the plurality of predetermined areas of the photographic subject is observation-uncompleted or observation-completed, on the basis of a result of the determination; cause the one or more memories to store the result of the determination; and update, in a case where the observation state of any one of the plurality of areas of the photographic subject changes from observation-uncompleted to observation-completed, a display on the monitor to inform that the observation state of the one area is the observation-completed.
2. The medical image processing apparatus according to claim 1, wherein the processor is configured to cause an observation state indication displayed on the monitor to be hidden after a predetermined time elapses.
3. The medical image processing apparatus according to claim 1, further comprising a user operation acceptance unit, wherein the processor is configured to cause an observation state indication to be displayed or hidden on the basis of an instruction from the user operation acceptance unit.
4. The medical image processing apparatus according to claim 1, wherein the processor is configured to, in a case of determining an observation state in units of a small area of the photographic subject on the basis of the medical images, determine that observation is completed in a case where observation of the small area has been completed, and determine that observation is uncompleted in a case where observation of the small area has not been completed.
5. The medical image processing apparatus according to claim 1, wherein the processor is configured to cause the monitor to display an observation state indication by using text information.
6. The medical image processing apparatus according to claim 5, wherein the processor is configured to provide the text information with information regarding completion or incompleteness of observation of units of a small area of the photographic subject, and cause the monitor to display, as the observation state indication, the text information provided with the information.
7. The medical image processing apparatus according to claim 1, wherein the processor is configured to cause an observation state indication to be displayed by using a photographic subject model schematically representing the photographic subject.
8. The medical image processing apparatus according to claim 7, wherein the processor is configured to provide the photographic subject model with information regarding completion or incompleteness of observation of units of a small area of the photographic subject, and cause the monitor to display, as the observation state indication, the photographic subject model provided with the information.
9. The medical image processing apparatus according to claim 1, wherein the processor is configured to cause the monitor to display, as an observation state indication, an indication indicating only completion of observation of units of a small area of the photographic subject or an indication indicating only incompleteness of observation of the unit of the small area of the photographic subject.
10. The medical image processing apparatus according to claim 1, wherein the processor is configured to cause the monitor to display the medical images such that an observation state

indication is superimposed on the medical images.

11. The medical image processing apparatus according to claim 1, wherein the processor is configured to cause a monitor having a first display region and a second display region smaller than the first display region to display an observation state indication in the first display region and the second display region in a manner different between the first display region and the second display region.

12. The medical image processing apparatus according to claim 11, wherein the processor is configured to cause the observation state indication to be constantly displayed in the second display region.

13. The medical image processing apparatus according to claim 11, wherein the processor is configured to cause a monitor having the first display region and a third display region different from the second display region to display the medical images in the third display region.

14. The medical image processing apparatus according to claim 1, wherein the one or more processors are configured to make the determination of the observations state with a trained model which are learned to recognize each of the plurality of the areas.

15. A medical image processing method for a medical image processing apparatus comprising one or more processors and one or more memories, the one or more processors being configured to execute: a medical image acquisition step of acquiring a plurality of medical images in a time-series manner; an observation state determination step of making a determination of an observation state of each of a plurality of predetermined areas in an organ of a photographic subject positioned differently from each other, using the plurality of medical images, to determine that the observation state is observation-completed in a case where observation is completed and determine that the observation state is observation-uncompleted in a case where observation is uncompleted; a display step of displaying, on a monitor, a notification that the observation state of each of the plurality of predetermined areas of the photographic subject is observation-uncompleted or observation-completed, on the basis of a result of the determination; a storage step of causing the one or more memories to store the result of the determination; and an update step of updating, in a case where the observation state of any one of the plurality of areas of the photographic subject changes from observation-uncompleted to observation-completed, a display on the monitor to inform that the observation state of the one area is the observation-completed.

16. A non-transitory computer-readable tangible recording medium storing a program which causes, when read by a computer, the computer to execute the medical image processing method according to claim 15.

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