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Okano

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(54) **BIOLOGICAL COMPONENT ESTIMATING APPARATUS, BIOLOGICAL COMPONENT ESTIMATING METHOD, AND COMPUTER PROGRAM PRODUCT**

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(51) **Int. Cl.**

G06K 9/00	(2006.01)
A61B 5/1455	(2006.01)
A61B 5/145	(2006.01)
A61B 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/1455*** (2013.01); ***A61B 5/14532*** (2013.01); *A61B 5/70* (2013.01); *A61B 5/742* (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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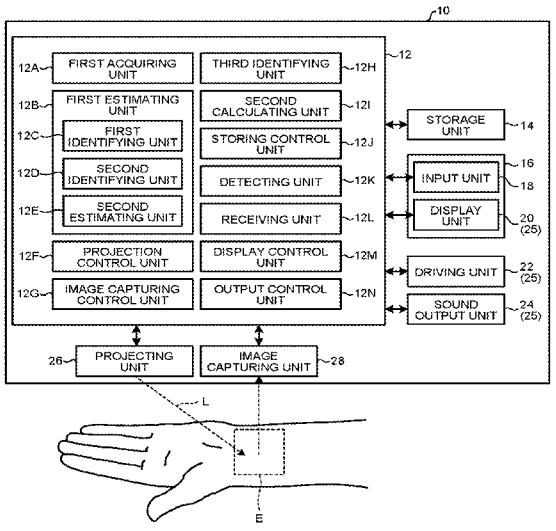
(74) *Attorney, Agent, or Firm* — Oblon, McClelland, Maier & Neustadt, L.L.P.

(57) **ABSTRACT**

According to an embodiment, a biological component estimating apparatus includes a first acquiring unit and a first estimating unit. The first acquiring unit acquires a scattering coefficient distribution image having each pixel specified with a scattering coefficient of a measurement target region of a biological body for light including a wavelength range in a near infrared range. The first estimating unit estimates an amount of change in a biological component based on the scattering coefficient distribution image.

12 Claims, 13 Drawing Sheets



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Thomas D. O'Sullivan, et al., "Diffuse optical imaging using spatially and temporally modulated light" Journal of Biomedical Optics, vol. 17(7), 2012, pp. 071311-1-071311-14.

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FIG.1

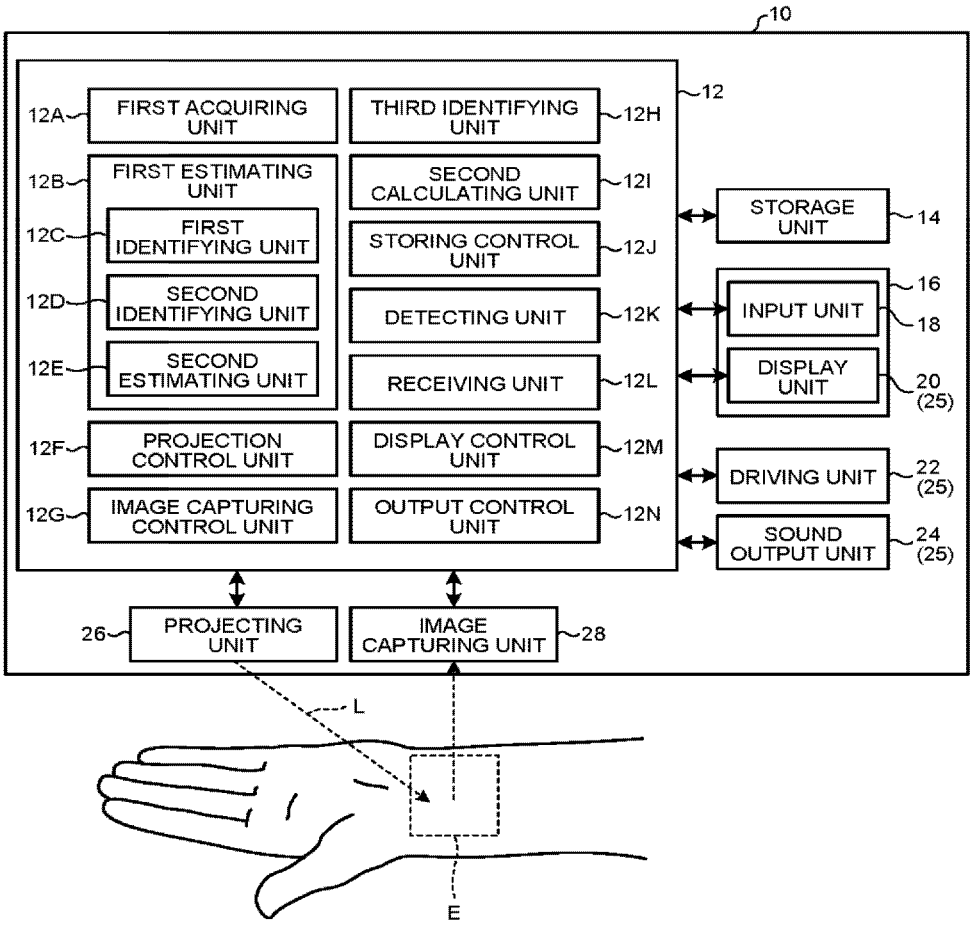

10
12
12A
FIRST ACQUIRING UNIT
THIRD IDENTIFYING UNIT
12H
12B
FIRST ESTIMATING UNIT
SECOND CALCULATING UNIT
12I
12C
FIRST IDENTIFYING UNIT
STORING CONTROL UNIT
12J
STORAGE UNIT
14
12D
SECOND IDENTIFYING UNIT
DETECTING UNIT
12K
16
INPUT UNIT
18
12E
SECOND ESTIMATING UNIT
RECEIVING UNIT
12L
DISPLAY UNIT
20 (25)
12F
PROJECTION CONTROL UNIT
DISPLAY CONTROL UNIT
12M
DRIVING UNIT
22 (25)
12G
IMAGE CAPTURING CONTROL UNIT
OUTPUT CONTROL UNIT
12N
SOUND OUTPUT UNIT
24 (25)
26
PROJECTING UNIT
IMAGE CAPTURING UNIT
28
L
E

FIG.2A

30

USER ID	MEASUREMENT ID	ACQUISITION TIMING	AMOUNT OF CHANGE IN BLOOD GLUCOSE LEVEL	TRACKING INFORMATION		
				REFERENCE TEMPLATE	FIRST PATTERN	RELATIVE POSITION
A	1	2015/3/01 09:00:00	2			
		2015/3/01 09:10:00	1			
		2015/3/01 09:20:00	4			
		2015/3/01 09:30:00	1			
	2	2015/3/01 10:10:00	10			
		2015/3/01 10:20:00	10			
		2015/3/01 10:30:00	10			
		2015/3/01 10:40:00	10			
		2015/3/01 10:50:00	3			
		2015/3/01 11:00:00	2			
...						

FIG.2B

FIRST TIME PERIOD	ABNORMAL AMOUNT OF CHANGE

32

FIG.2C

AMOUNT OF CHANGE IN BLOOD GLUCOSE LEVEL	AMOUNT OF CHANGE IN SCATTERING COEFFICIENT

34

FIG.3

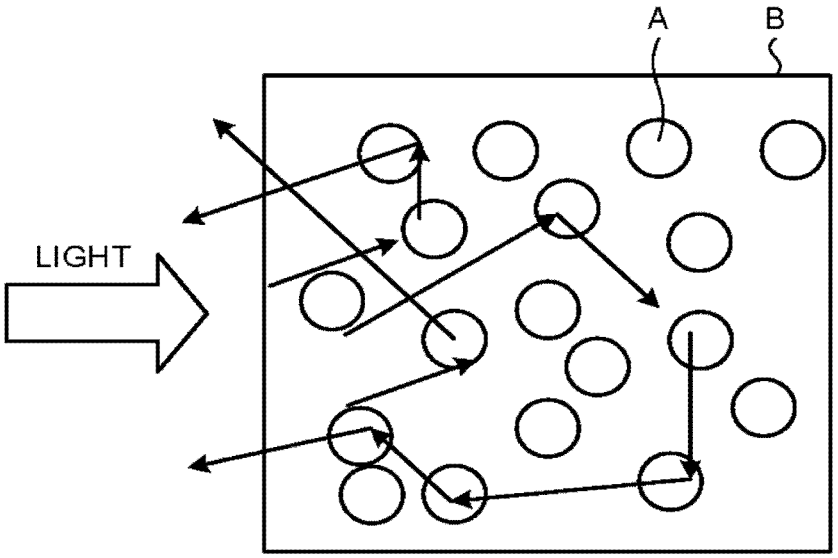


FIG.4A

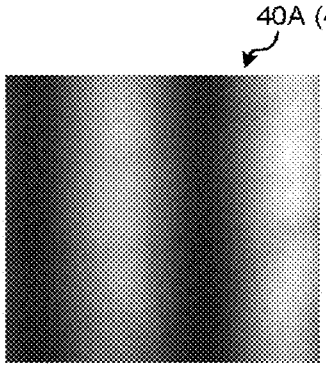


FIG.4B

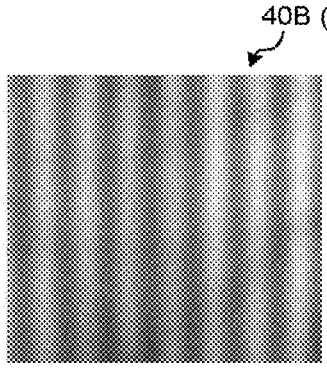


FIG.4C

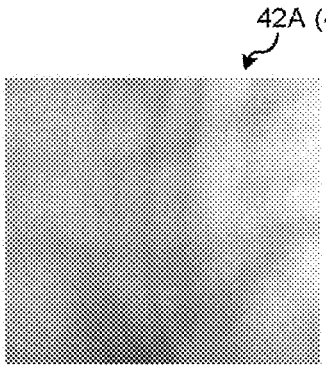


FIG.4D

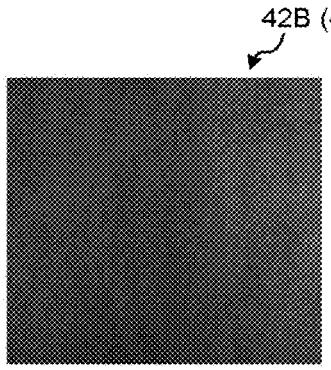


FIG.4E

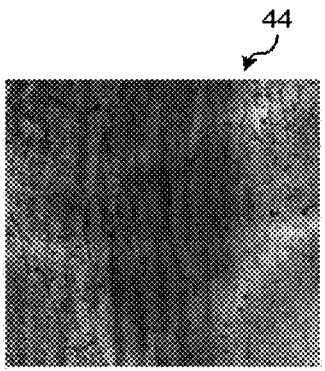


FIG.4F

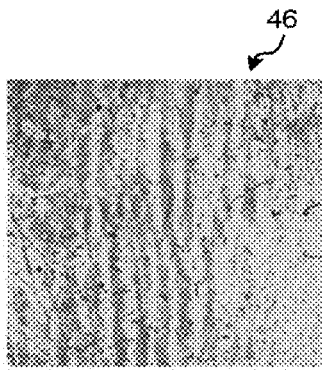


FIG.5

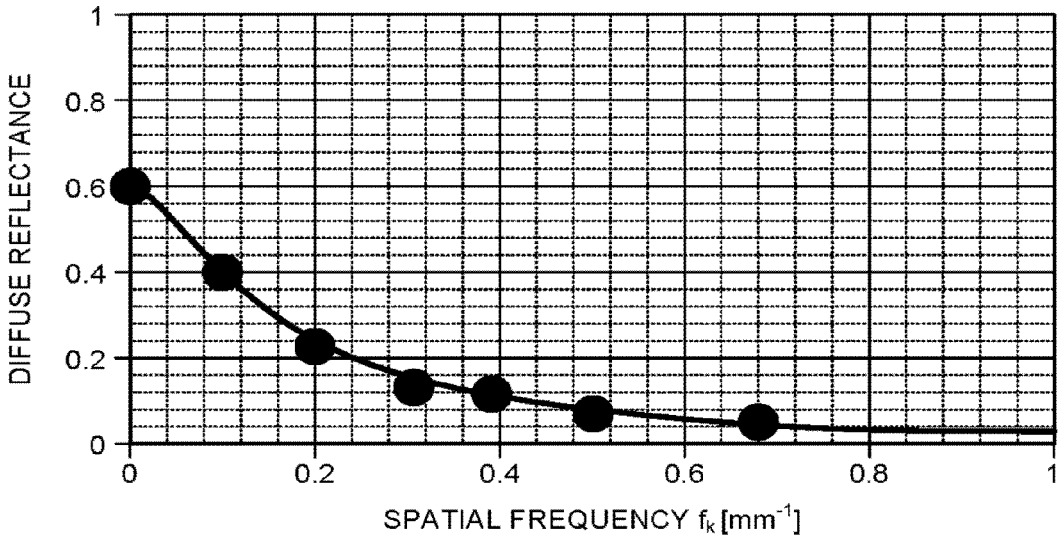

DIFFUSE REFLECTANCE
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
SPATIAL FREQUENCY f_k [mm^{-1}]

FIG.6A

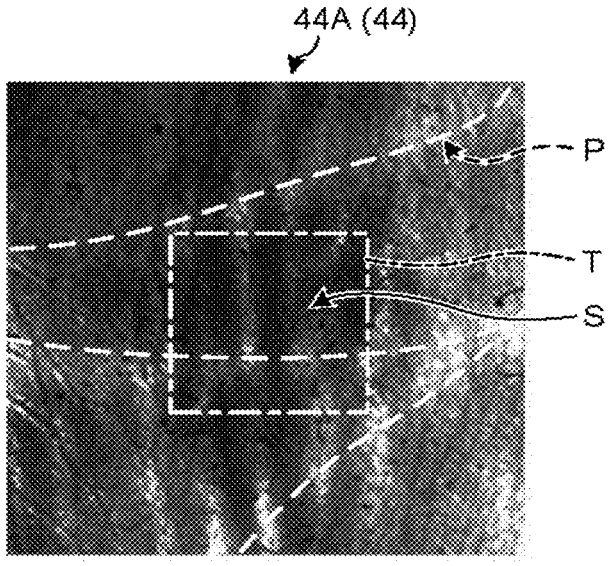


FIG.6B

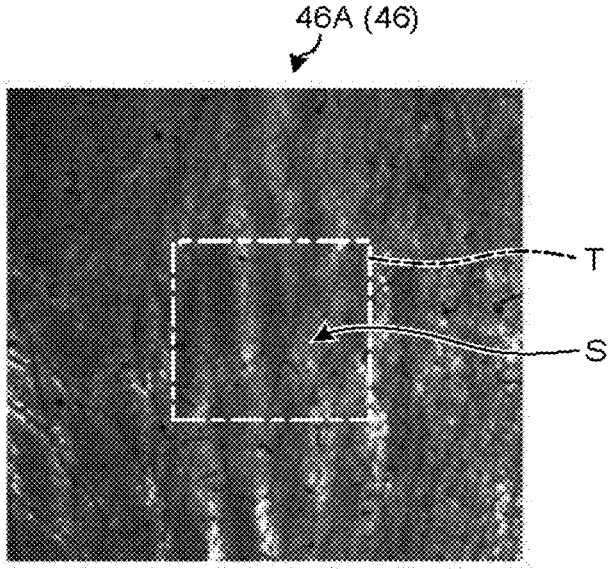


FIG.7A

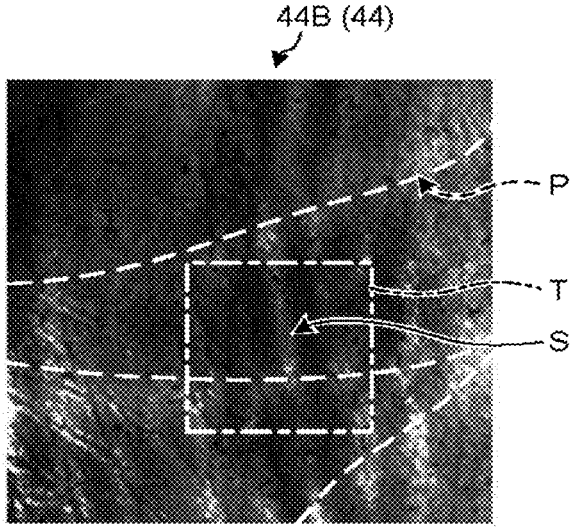


FIG.7B

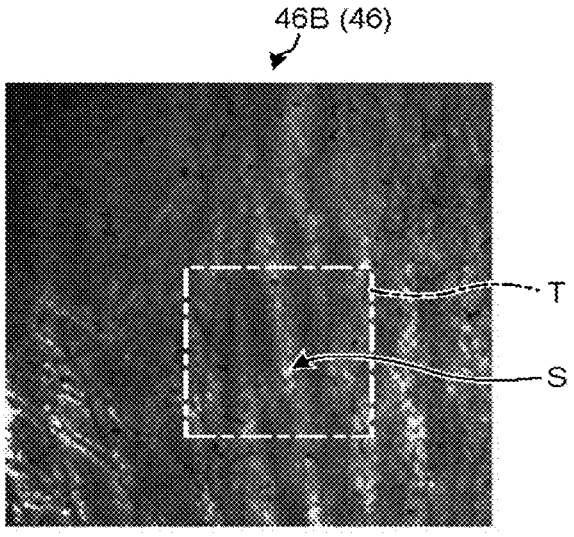


FIG.8

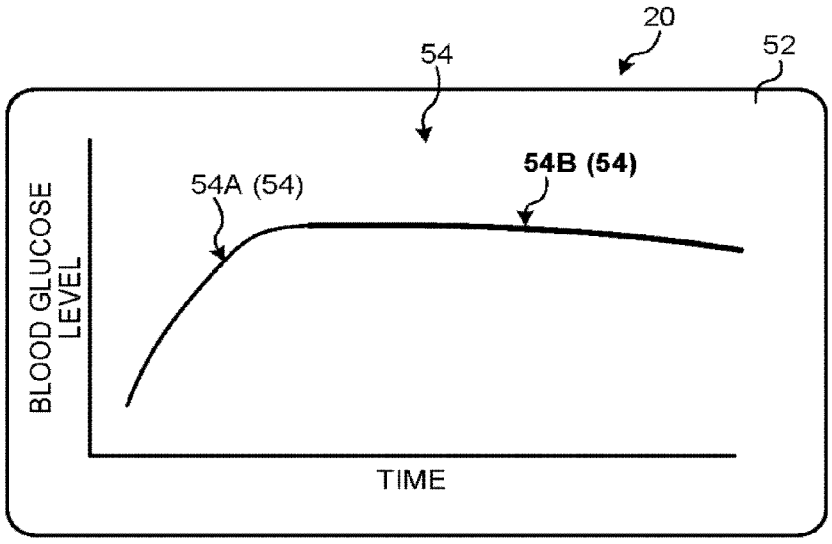

20
54
52
54A (54)
54B (54)
BLOOD GLUCOSE LEVEL
TIME

FIG.9

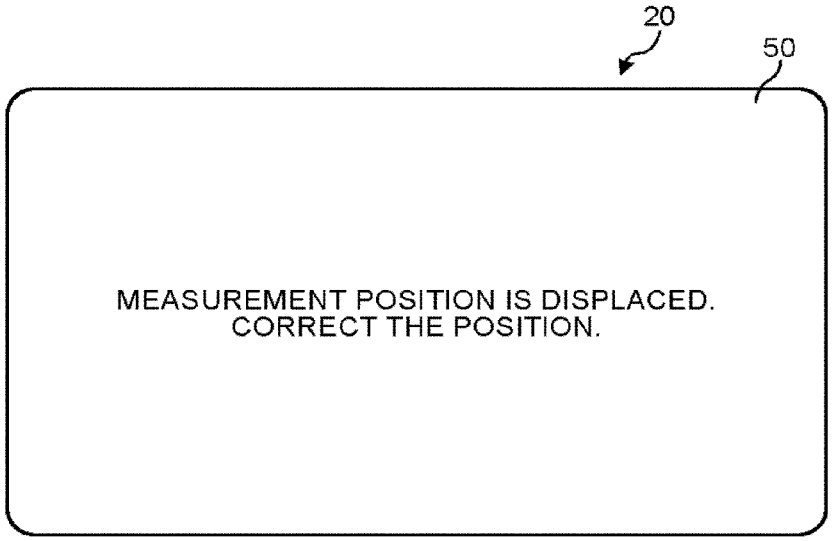

20
50
MEASUREMENT POSITION IS DISPLACED.
CORRECT THE POSITION.

FIG.10

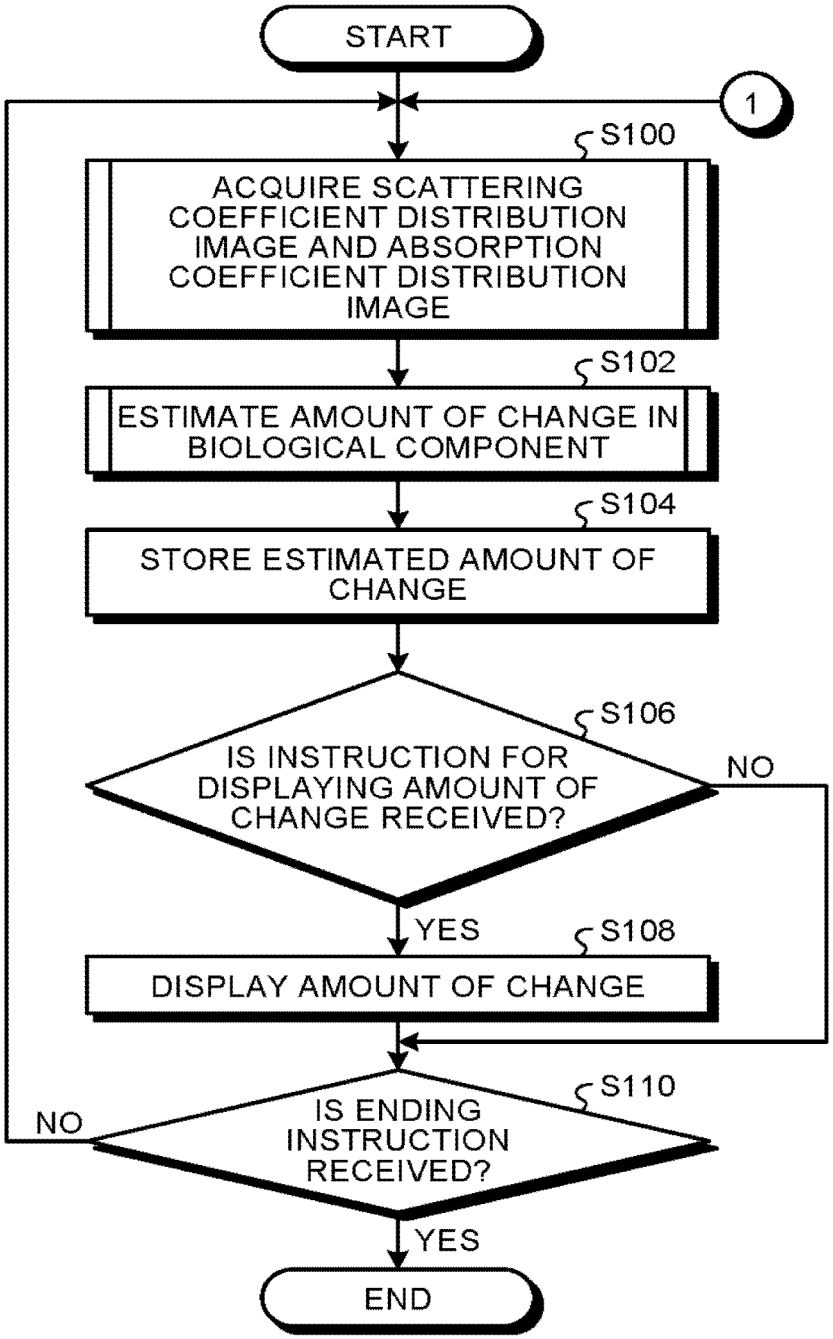

START
1
S100
ACQUIRE SCATTERING COEFFICIENT DISTRIBUTION IMAGE AND ABSORPTION COEFFICIENT DISTRIBUTION IMAGE
S102
ESTIMATE AMOUNT OF CHANGE IN BIOLOGICAL COMPONENT
S104
STORE ESTIMATED AMOUNT OF CHANGE
S106
IS INSTRUCTION FOR DISPLAYING AMOUNT OF CHANGE RECEIVED?
NO
YES
S108
DISPLAY AMOUNT OF CHANGE
S110
IS ENDING INSTRUCTION RECEIVED?
NO
YES
END

FIG.11

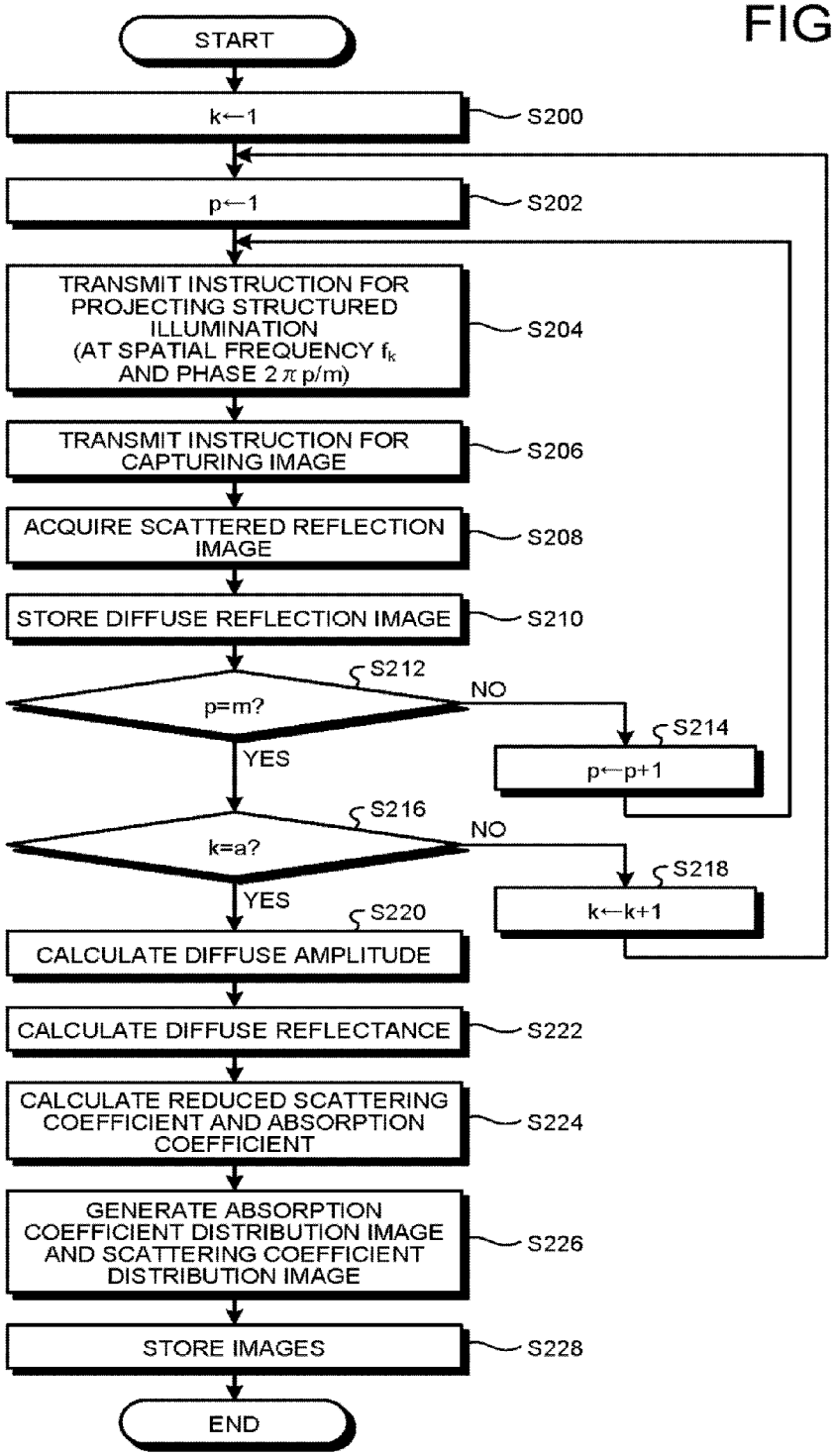

START
k←1
S200
p←1
S202
TRANSMIT INSTRUCTION FOR PROJECTING STRUCTURED ILLUMINATION (AT SPATIAL FREQUENCY f_k AND PHASE $2\pi p/m$)
S204
TRANSMIT INSTRUCTION FOR CAPTURING IMAGE
S206
ACQUIRE SCATTERED REFLECTION IMAGE
S208
STORE DIFFUSE REFLECTION IMAGE
S210
S212
p=m?
NO
S214
p←p+1
YES
S216
k=a?
NO
S218
k←k+1
YES
S220
CALCULATE DIFFUSE AMPLITUDE
CALCULATE DIFFUSE REFLECTANCE
S222
CALCULATE REDUCED SCATTERING COEFFICIENT AND ABSORPTION COEFFICIENT
S224
GENERATE ABSORPTION COEFFICIENT DISTRIBUTION IMAGE AND SCATTERING COEFFICIENT DISTRIBUTION IMAGE
S226
STORE IMAGES
S228
END

FIG.12

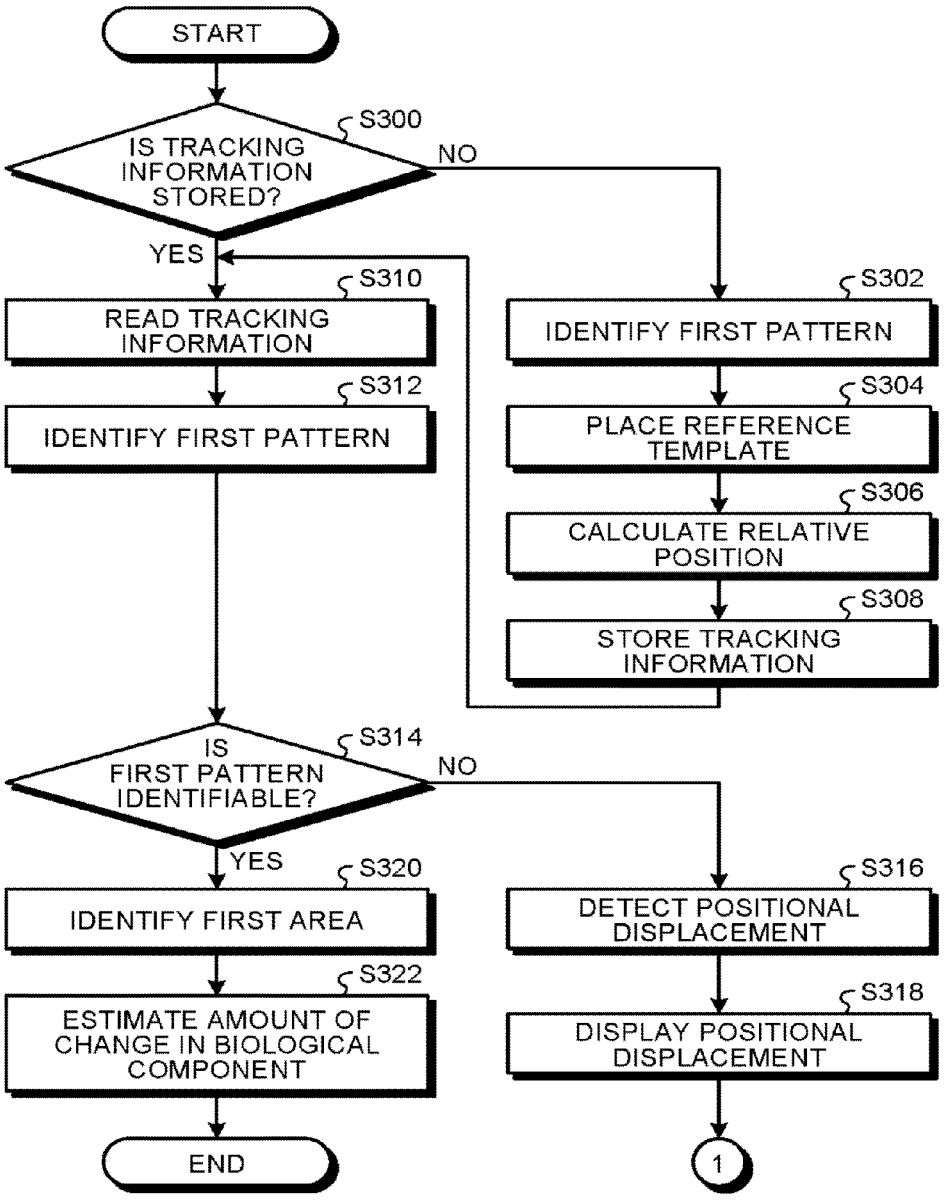

START
S300
IS TRACKING INFORMATION STORED?
NO
YES
S310
READ TRACKING INFORMATION
S312
IDENTIFY FIRST PATTERN
S302
IDENTIFY FIRST PATTERN
S304
PLACE REFERENCE TEMPLATE
S306
CALCULATE RELATIVE POSITION
S308
STORE TRACKING INFORMATION
S314
IS FIRST PATTERN IDENTIFIABLE?
NO
YES
S320
IDENTIFY FIRST AREA
S322
ESTIMATE AMOUNT OF CHANGE IN BIOLOGICAL COMPONENT
END
S316
DETECT POSITIONAL DISPLACEMENT
S318
DISPLAY POSITIONAL DISPLACEMENT
1

FIG.13

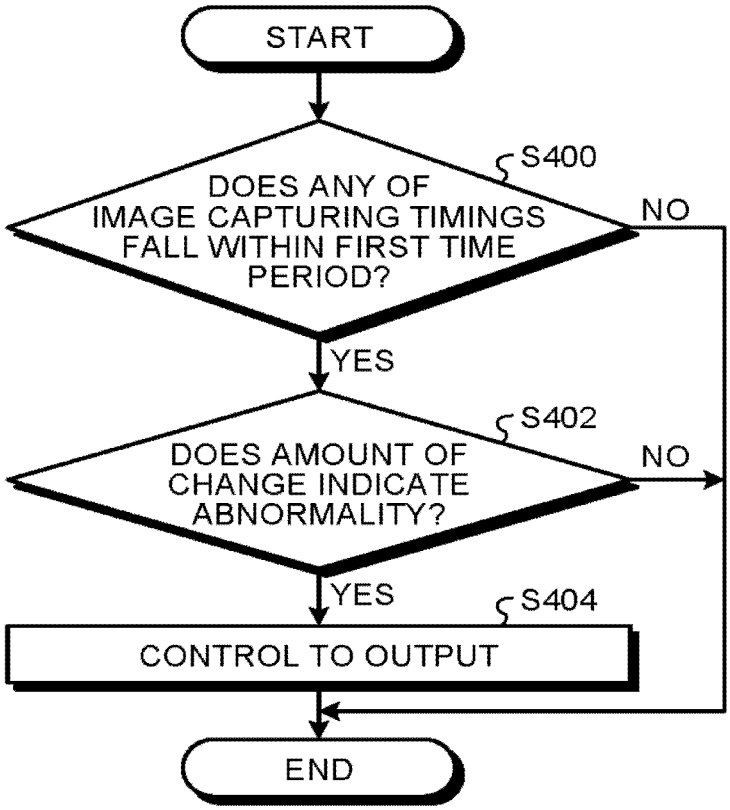
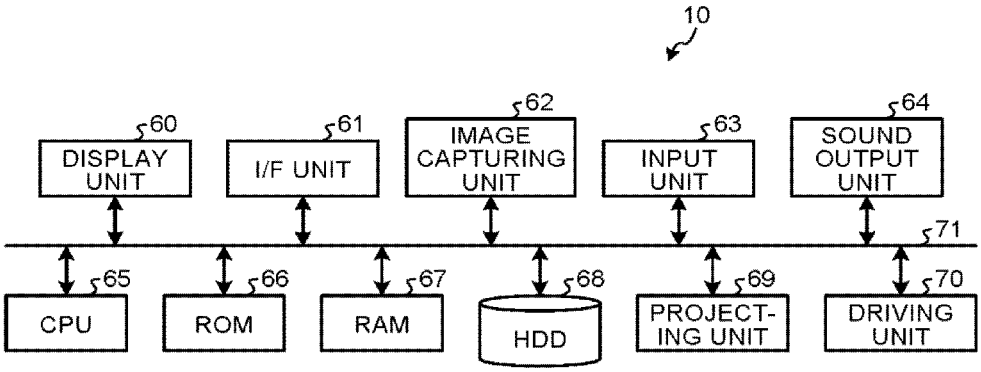

START
S400
DOES ANY OF IMAGE CAPTURING TIMINGS FALL WITHIN FIRST TIME PERIOD?
NO
YES
S402
DOES AMOUNT OF CHANGE INDICATE ABNORMALITY?
NO
YES
S404
CONTROL TO OUTPUT
END

FIG.14


10
60
DISPLAY UNIT
61
I/F UNIT
62
IMAGE CAPTURING UNIT
63
INPUT UNIT
64
SOUND OUTPUT UNIT
71
65
CPU
66
ROM
67
RAM
68
HDD
69
PROJECT-ING UNIT
70
DRIVING UNIT

BIOLOGICAL COMPONENT ESTIMATING APPARATUS, BIOLOGICAL COMPONENT ESTIMATING METHOD, AND COMPUTER PROGRAM PRODUCT

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2015-058581, filed on Mar. 20, 2015; the entire contents of which are incorporated herein by reference.

FIELD

An embodiment described herein relates generally to a biological component estimating apparatus, a biological component estimating method, and a computer program product.

BACKGROUND

For patients with diabetes or abnormal glucose tolerance, monitoring of the blood glucose level is indispensable. A representative method among the known methods for monitoring a blood glucose level is a method using a blood sample obtained from a biological body. The method involves reacting glucose in the blood sample with an enzyme such as glucose oxidase (GOD) or glucose dehydrogenase (GDH), for example. This process generates electrons corresponding to the amount of glucose in the blood. With this known method, a voltage is applied to the blood so as to use the resultant current level for monitoring the blood glucose level.

The amount of a biological component such as blood glucose may change successively in the biological body. In order to measure the amount of change in the biological component, it has been conventionally necessary to draw blood from the subject repeatedly by needling. From the viewpoint of pain reduction and infection prevention, for example, there has been a demand for a non-invasive approach for measuring a change in the blood glucose level. Known non-invasive approaches for measuring a change in the blood glucose level include a technology for estimating the blood glucose level using the absorbance spectrum of skin, and a technology for estimating the blood glucose level using a tomographic image obtained with optical coherence tomography (OCT).

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating a functional configuration of a biological component estimating apparatus;

FIGS. **2**A, **2**B, and **2**C are schematics for illustrating exemplary data structures of first information, second information, and third information, respectively;

FIG. **3** is a schematic for explaining a scattering coefficient of a biological body for light;

FIGS. **4**A to **4**F are schematics for explaining generation of a scattering coefficient distribution image and an absorption coefficient distribution image;

FIG. **5** is a chart illustrating a relation between a spatial frequency and a diffuse reflectance;

FIGS. **6**A and **6**B are schematics illustrating an exemplary absorption coefficient distribution image and scattering coefficient distribution image, respectively;

FIGS. **7**A and **7**B are schematics illustrating an example of a displacement of a measurement target region;

FIG. **8** is a schematic illustrating an exemplary display screen;

FIG. **9** is a schematic illustrating another exemplary display screen;

FIG. **10** is a flowchart illustrating a biological component estimating process;

FIG. **11** is a flowchart illustrating the process at Step S**100** in FIG. **10**;

FIG. **12** is a flowchart illustrating the process at Step S**102** in FIG. **10**;

FIG. **13** is a flowchart illustrating an interruption process; and

FIG. **14** is a block diagram illustrating an exemplary hardware configuration.

DETAILED DESCRIPTION

According to an embodiment, a biological component estimating apparatus includes a first acquiring unit and a first estimating unit. The first acquiring unit acquires a scattering coefficient distribution image having each pixel specified with a scattering coefficient of a measurement target region of a biological body for light including a wavelength range in a near infrared range. The first estimating unit estimates an amount of change in a biological component based on the scattering coefficient distribution image.

An embodiment will now be explained in detail with reference to the appended drawings.

FIG. **1** is an exemplary block diagram illustrating a functional configuration of a biological component estimating apparatus **10** according to the present embodiment.

The biological component estimating apparatus **10** is an apparatus for estimating the amount of change in a biological component in a biological body. Examples of the biological body include humans and animals other than the humans. The biological component represents a component included in the biological body. Specifically, the biological component is a component of a blood sample. Examples of the biological component include blood sugar (specifically, glucose) and water.

In the description below, as an example, the biological component estimating apparatus **10** is explained to estimate the amount of change in a blood glucose level, as an example of the amount of change in a biological component. However, the amount of change in a biological component estimated by the biological component estimating apparatus **10** may be any biological component, without limitation to the amount of change in the blood glucose level.

In the present embodiment, the biological component estimating apparatus **10** estimates the amount of change in the blood glucose level from a measurement target region E of the biological body. The measurement target region E is a certain region of the skin of the biological body.

The biological component estimating apparatus **10** includes a control unit **12**, a storage unit **14**, an input unit **18**, a display unit **20**, a driving unit **22**, a sound output unit **24**, a projecting unit **26**, and an image capturing unit **28**.

The storage unit **14**, the input unit **18**, the display unit **20**, the driving unit **22**, the sound output unit **24**, the projecting unit **26**, and the image capturing unit **28** are connected to the control unit **12** in such a manner that data and signals can be exchanged.

Explained in the present embodiment is an example in which the biological component estimating apparatus **10** is an integration of the control unit **12**, the storage unit **14**, the

input unit **18**, the display unit **20**, the driving unit **22**, the sound output unit **24**, the projecting unit **26**, and the image capturing unit **28**. It is, however, also possible to allow at least one of the control unit **12**, the storage unit **14**, the input unit **18**, the display unit **20**, the driving unit **22**, the sound output unit **24**, the projecting unit **26**, and the image capturing unit **28**, included in the biological component estimating apparatus **10**, to be provided separately from the other functional units.

The input unit **18** is a functional unit allowing a user to make various operation inputs. The input unit **18** is a combination of one or more of a mouse, a button, a remote controller, a keyboard, a voice recognition apparatus such as a microphone, and an image recognition apparatus.

The display unit **20** is a known display device for displaying various types of images. An example of the display unit **20** is a liquid crystal display (LCD).

The input unit **18** and the display unit **20** may be configured integrally. Specifically, the input unit **18** and the display unit **20** may be provided as a user interface (UI) unit **16** having both of an input function and a display function. An example of the UI unit **16** is an LCD with a touch panel.

The driving unit **22** is a driving unit that causes the biological component estimating apparatus **10** to vibrate. The driving unit **22** causes the biological component estimating apparatus **10** to vibrate under the control of the control unit **12**. The sound output unit **24** is a functional unit for outputting sound. An example of the sound output unit **24** is a speaker.

At least one of the display unit **20**, the driving unit **22**, and the sound output unit **24** functions as an output unit **25** that outputs various types of information to the external of the biological component estimating apparatus **10**. The biological component estimating apparatus **10** may also be configured not to include at least one of the driving unit **22** and the sound output unit **24**.

The projecting unit **26** projects light onto the measurement target region E of the biological body. An example of the projecting unit **26** is a projector. The light projected to the measurement target region E includes a wavelength range in a near infrared range. The near infrared range is a range of wavelengths from 0.7 micrometers to 2.5 micrometers, for example.

In the present embodiment, the projecting unit **26** projects structured illumination L to the measurement target region E. The structured illumination L is light having a periodic structure of a given spatial frequency. The light making up the structured illumination L includes a wavelength range in the near infrared range, as mentioned earlier.

The projecting unit **26** projects the structured illumination L to the measurement target region E under the control of the control unit **12**. The spatial frequency of the structured illumination L is adjusted under the control of the control unit **12**.

The light of the structured illumination L projected onto the measurement target region E of the biological body enters the biological body, and is absorbed and scattered. A part of light scattered in the biological body is also scattered the external of the biological body.

The image capturing unit **28** captures a scattered reflection image resultant of such scattered light. Specifically, the image capturing unit **28** photographs the measurement target region E to which the structured illumination L is projected, and acquires a scattered reflection image resultant of the light of the structured illumination L projected to the measurement target region E.

The storage unit **14** stores therein various types of data. In the present embodiment, the storage unit **14** stores therein a reference template, an abnormal amount of change, first information, second information, and third information.

The reference template is a representation of a predetermined shape having a size smaller than a scattering coefficient distribution image (which will be described later in detail). The reference template has a rectangle shape, for example. Specifically, the reference template is a rectangular image that is smaller in size than the scattering coefficient distribution image. The reference template is, however, not limited to an image, and may also be data representing (e.g., coordinate data) such a shape having such a size.

The reference template having a predetermined size and shape is stored in the storage unit **14** in advance. The size and shape of the reference template may be modifiable by a user making operations on the input unit **18**.

The scattering coefficient distribution image is a two-dimensional image having each pixel specified with the corresponding scattering coefficient of the measurement target region E of the biological body. The scattering coefficient is a scattering coefficient of the measurement target region E for the light including wavelengths in the near infrared range. The scattering coefficient distribution image is generated by the control unit **12** (in the manner to be described later in detail).

The abnormal amount of change represents an amount change in the blood glucose level rendered as abnormal from the medical point of view. The abnormal amount of change is stored in the storage unit **14** in advance. The abnormal amount of change may be modifiable by a user making operations on the input unit **18**.

The first information is information in which an acquisition timing, the corresponding amount of change in the blood glucose level, and tracking information are associated with each other. The first information may also include another type of information in which additional information is associated with the information listed above.

The second information is information in which a first time period is associated with an abnormal amount of change. The third information is information in which an amount of change in the blood glucose level is associated with an amount of change in the scattering coefficient.

FIGS. **2**A, **2**B, and **2**C are exemplary schematics of data structures of the first information **30**, the second information **32**, and the third information **34**, respectively.

FIG. **2**A is an exemplary schematic of a data structure of the first information **30**. In the example illustrated in FIG. **2**A, the first information **30** is information in which a user ID, a measurement ID, acquisition timing, an amount of change in the blood glucose level, and tracking information are associated with each other. The data format of the first information **30** is not limited to the format illustrated in FIG. **2**A, and may be a table or a database, for example.

The user ID is identification information for identifying a user using the biological component estimating apparatus **10**. The measurement ID is information for identifying a measurement timing. The measurement timing represents the timing of a measurement covering the duration of one cycle starting from when the biological component estimating apparatus **10** has received a power supply and starts estimating the amount of change in the blood glucose level to when the biological component estimating apparatus **10** ends the estimation of the amount of change in the blood glucose level based on the same measurement target region

E in the biological body, or to when the power supply is shut off (that is, the biological component estimating apparatus **10** is powered off).

The acquisition timing represents the timing at which the control unit **12** acquires a scattering coefficient distribution image which will be described later. More specifically, the acquisition timing is the same as one of the timings at which a plurality of diffuse reflection images (which will be described later in detail) are captured, the diffuse reflection images being used in generating a scattering coefficient distribution image. For example, the acquisition timing matches the earliest one of the timings at which a plurality of respective diffuse reflection images used in generating a scattering coefficient distribution image are captured. The acquisition timing includes a year, a month, a date, hours, minutes, and seconds, for example.

In the example illustrated in FIG. **2**A, the acquisition timing is at a cycle of 10 minutes. However, the acquisition timing is not limited to the cycle of 10 minutes, and may be any cycle between one minute or ten minutes, or any other timing.

An amount of change in the blood glucose level is calculated for each of the scattering coefficient distribution images (in other words, at every acquisition timing) and registered to the first information **30**.

The amount of change in the blood glucose level represents an amount of change with respect to a reference blood glucose level. The reference blood glucose level represents an amount of change in the blood glucose level at one acquisition timing with respect to the blood glucose level at another acquisition timing set as a reference, for example. Specifically, the blood glucose level at the acquisition timing represents the blood glucose level of the measurement target region E of the biological body, at the timing at which the scattered reflection image used in generating the acquired scattering coefficient distribution image is captured.

The blood glucose level set as a reference is, for example, the blood glucose level at the first (initial) acquisition timing, among those belonging to the measurement timings identified with the same measurement ID and with the same user ID, for example. The blood glucose level set as a reference may also be the blood glucose level at the previous acquisition timing, for example.

The amount of change in the blood glucose level registered in the first information **30** is calculated by a process performed by the control unit **12** which will be described later, and registered in the first information **30** in a manner associated with the acquisition timing.

The tracking information is information used in correcting variations in the measurement target region E of the biological body. During the time in which the projecting unit **26** is projecting the structured illumination L to the same measurement target region E of the biological body, and the image capturing unit **28** is capturing the images of the measurement target region E, the area to which the structured illumination L is projected or the area captured by the image capturing unit **28** may be displaced depending on the acquisition timing, due to a movement of the biological body, for example. The tracking information is used in correcting the variation of the measurement target region E resultant of such a displacement.

The tracking information includes a reference template, a first pattern, and a relative position. The reference template is the same as that described above.

The first pattern is an image representing the path and the size of a biological body structure captured in the scattering coefficient distribution image. The first pattern is an image capturing a path of at least one of a blood vessel, a muscle, a tendon, and a ligament included in the biological body (the measurement target region E), for example.

The first pattern is identified in a scattering coefficient distribution image or an absorption coefficient distribution image (which will be described later in detail) by a process performed by the control unit **12** which will also be described later.

The relative position represents a relative position of the reference template with respect to the first pattern within the scattering coefficient distribution image. The relative position represents, for example, the position of the reference template with respect to the first pattern in the scattering coefficient distribution image, as a direction, a distance (number of pixels), or a rotational angle. The relative position may also be a relative position of the reference template with respect to the first pattern in the absorption coefficient distribution image having been acquired at the same timing as the scattering coefficient distribution image.

The relative position is calculated by a process performed by the control unit **12** which will be described later.

FIG. **2**B is an exemplary schematic of a data structure of the second information **32**. The second information **32** is information in which a first time period is associated with an abnormal amount of change corresponding to the first time period. The first time period represents a time period requiring some attention from the medical point of view with regard to the amount of change in the biological component, for example, depending on the type of the biological component that is used as the target of the measurement.

For example, when the biological component is blood glucose, the amount of change in the blood glucose level during an early morning time period may require some attention from the medical point of view. In such a case, the first time period is a time period representing early morning (e.g., 3 o'clock ante meridiem (AM) to 8 o'clock AM). The abnormal amount of change associated with the first time period represents the amount of change in the blood glucose level considered abnormal from the medical point of view during the first time period that is associated with the amount of change.

The second information **32** is stored in the storage unit **14** in advance. The number of pairs of the first time period and the abnormal amount of change stored in the second information **32** is not limited to one. In other words, the second information **32** may store therein a plurality of pairs of the first time period and the abnormal amount of change. The second information **32** may be modifiable by a user making instructions through operations.

FIG. **2**C is an exemplary schematic of a data structure of the third information **34**. The third information **34** is information in which the amount of change in the blood glucose level is associated with the amount of change in the scattering coefficient.

The scattering coefficient of the biological body for the light is correlated with a blood glucose concentration (in other words, a blood glucose level).

FIG. **3** is a schematic for explaining how the light scatters in the biological body. The light scatters on the biological body due to the difference between the refractive index of extracellular fluid (ECF) B and that of fine floating particles A such as cell components and protein aggregate.

The refractive index nECF of the extracellular fluid B for the light in the near infrared range is from 1.35 to 1.36. The refractive index nS of fine floating particles A serving as scattering bodies is from 1.35 to 1.41. When the glucose concentration in the biological body increases, the refractive

index of the extracellular fluid B also increases. Denoting this increase in the refractive index as δnglcose, the difference Δn between the refractive index of the extracellular fluid B and that of the fine floating particles A can be expressed as the following Equation (A).

$$\Delta n = nS - nECF + \delta nglcose \quad (A)$$

As indicated by Equation (A), the refractive index difference Δn decreases when the glucose concentration increases. The scattering coefficients in the biological body comply with the Mie scattering theoretical model. Therefore, when the refractive index difference Δn decreases, the scattering coefficient of the biological body also decreases.

For example, the scattering coefficient changes at a ratio of 0.6% mM-1 (0.33%/(10 mg/dL)) with respect to an amount of change in the blood glucose concentration.

The biological component estimating apparatus **10** according to the present embodiment measures or calculates an amount of change in the blood glucose level with respect to an amount of change in the scattering coefficient in advance. The biological component estimating apparatus **10** then registers the measured or calculated amount of change in the scattering coefficient in the third information **34**, in a manner associated with the amount of change in the blood glucose level.

Referring back to FIG. **1**, the control unit **12** controls the biological component estimating apparatus **10**. The control unit **12** includes a first acquiring unit **12**A, a first estimating unit **12**B, a projection control unit **12**F, an image capturing control unit **12**G, a third identifying unit **12**H, a second calculating unit **12**I, a storing control unit **12**J, a detecting unit **12**K, a receiving unit **12**L, a display control unit **12**M, and an output control unit **12**N.

Some or all of the first acquiring unit **12**A, the first estimating unit **12**B, the projection control unit **12**F, the image capturing control unit **12**G, the third identifying unit **12**H, the second calculating unit **12**I, the storing control unit **12**J, the detecting unit **12**K, the receiving unit **12**L, the display control unit **12**M, and the output control unit **12**N may be implemented by causing a processor such as a central processing unit (CPU) to execute a computer program, that is, implemented as software, or may be implemented as hardware such as an integrated circuit (IC), or as a combination of software and hardware.

The projection control unit **12**F controls the projecting unit **26**. The image capturing control unit **12**G controls the image capturing unit **28**. The receiving unit **12**L receives user operations on the input unit **18**.

The first acquiring unit **12**A acquires the scattering coefficient distribution image. The scattering coefficient distribution image is an image having each pixel specified with the corresponding scattering coefficient of the measurement target region E of the biological body, as described earlier.

The first acquiring unit **12**A acquires a plurality of scattering coefficient distribution images for a measurement target region E positioned at the same position. In other words, the first acquiring unit **12**A acquires a plurality of scattering coefficient distribution images at one measurement timing.

In the present embodiment, the first acquiring unit **12**A also acquires the absorption coefficient distribution images. The first acquiring unit **12**A acquires an absorption coefficient distribution image and a scattering coefficient distribution image as a pair at each acquisition timing.

The absorption coefficient distribution image is an image having each pixel specified with the corresponding absorption coefficient for light. The light includes a wavelength range in the near infrared range, as described earlier.

The first acquiring unit **12**A may acquire a plurality of scattering coefficient distribution images and a plurality of absorption coefficient distribution images from the storage unit **14** or from an external apparatus.

In the example explained in the present embodiment, the first acquiring unit **12**A generates a scattering coefficient distribution image and an absorption coefficient distribution image from the diffuse reflection images captured by the image capturing unit **28**.

FIGS. **4**A to **4**F are schematics for explaining the generation of a scattering coefficient distribution image and an absorption coefficient distribution image.

To begin with, the first acquiring unit **12**A controls the projecting unit **26** to project the structured illumination L at a plurality of different spatial frequencies f_k (where k is an integer equal to or greater than one, and equal to or smaller than "a", where "a" is an integer equal to or greater than two) to the measurement target region E.

At this time, the first acquiring unit **12**A controls the projecting unit **26** to project the structured illumination L at different phases (2πp/m (where "m" is an integer equal to or greater than three, and "p" is an integer satisfying $|p| \leq m$)) to the measurement target region E for each of the different spatial frequencies f_k. The first acquiring unit **12**A controls the projecting unit **26** to output the structured illumination L at each of the spatial frequencies f_k, while shifting the phase equally in an increment of 2πp/m.

Specifically, the first acquiring unit **12**A transmits a projection instruction including a spatial frequency f_k and a phase 2πp/m to the projecting unit **26**. The projecting unit **26** receiving the projection instruction projects the structured illumination L at the spatial frequency f_k and at the phase 2πp/m included in the projection instruction onto the measurement target region E. For example, the projecting unit **26** generates the structured illumination L by modulating a sine wave with the spatial frequency f_k and the phase 2πp/m included in the projection instruction, and projects the structured illumination L to the measurement target region E.

The image capturing unit **28** then captures an image of the measurement target region E every time the projecting unit **26** projects the structured illumination L to the measurement target region E, and acquires the scattered reflection image. The image capturing unit **28**, as a result, acquires a scattered reflection image corresponding to each of the spatial frequencies f_k and the phases 2πp/m included in the projection instruction.

FIGS. **4**A and **4**B are exemplary schematics of the scattered reflection image **40**. FIG. **4**A is an exemplary schematic of a scattered reflection image **40**A when the structured illumination L at the spatial frequency f**1** is projected. FIG. **4**B is an exemplary schematic of a scattered reflection image **40**B when the structured illumination L at the spatial frequency f**2** is projected.

In the example illustrated in FIGS. **4**A and **4**B, the light at wavelengths of 660 nanometers±5 nanometers is used as the light of the structured illumination L. However, the light of the structured illumination L may be any light including wavelengths in the near infrared range, and is not limited to the light in the wavelength range mentioned above. Because an absorption coefficient and a scattering coefficient of a biological body for light exhibit wavelength-dependent characteristics, it is preferable to keep the wavelength range within ±10 nanometers for the light of the structured illumination L.

The image capturing unit **28** acquires "m" diffuse reflection images **40** at the respective different phases $2\pi p/m$, for each of the different spatial frequencies f_k. In other words, the image capturing unit **28** acquires a plurality of diffuse reflection images **40** at the respective different phases for one spatial frequency f_k.

The first acquiring unit **12**A calculates, at each of the spatial frequencies f_k, a diffuse amplitude ($M_{ac}(r, f_k)$) for each pixel, using the diffuse reflection images **40** captured by the image capturing unit **28** with the projecting light at the respective different phases at the spatial frequency f_k. "r" in $M_{ac}(r, f_k)$ represents the position of the specific pixel. In other words, the first acquiring unit **12**A generates a diffuse amplitude image having each pixel specified with a diffuse amplitude, from the diffuse reflection images **40**.

FIGS. **4**C and **4**D are exemplary schematics of a diffuse amplitude image **42**. FIG. **4**C is an exemplary schematic of a diffuse amplitude image **42**A calculated using a plurality of diffuse reflection images including the scattered reflection image **40**A illustrated in FIG. **4**A captured by projecting the light at a plurality of respective different phases. FIG. **4**D is an exemplary schematic of a diffuse amplitude image **42**B calculated using a plurality of diffuse reflection images including the scattered reflection image **40**B illustrated in FIG. **4**B captured by projecting the light at the respective different phases.

The first acquiring unit **12**A prepares a calibration sample with a known absorption coefficient and scattering coefficient. The calibration sample is a model phantom of the biological body with a known absorption coefficient and scattering coefficient, for example. The model phantom of the biological body preferably has a uniform absorption coefficient and scattering coefficient. The calibration sample is prepared in advance. The first acquiring unit **12**A then acquires a plurality of diffuse reflection images **40** at the respective different phases, at each of the spatial frequencies f_k (hereinafter, referred to as calibration diffuse reflection images), in the same manner as that explained above.

The first acquiring unit **12**A then calculates, at each of the spatial frequencies f_k, a diffuse amplitude ($M_{ac,\ ref}(r, f_k)$) for each pixel, using the calibration diffuse reflection images. "r" in $M_{ac,\ ref}(r, f_k)$ represents the position of the specific pixel. In other words, the first acquiring unit **12**A generates a calibration diffuse amplitude image having each pixel specified with a diffuse amplitude, from the calibration diffuse reflection images.

A diffuse reflectance of the biological body for the light of the structured illumination L can be expressed as Equation (1) analytically. Equation (1) below is an equation representing the diffuse reflectance obtained by applying a spatial sine-wave modulated light source to a diffusion equation resultant of diffusion-approximation of the radiative transfer equation (RTE).

$$R_d(f_k) = \frac{3Aa'}{(\mu'_{eff}/\mu_{tr}+1)(\mu'_{eff}/\mu_{tr}+3A)} \tag{1}$$

$R_d(f)$ in Equation (1) represents the diffuse reflectance. f_k represents the spatial frequency. "A" represents a proportionality coefficient, which is expressed as Equation (2) below.

$$A = \frac{1-R_{eff}}{2(1+R_{eff})}; \tag{2}$$

-continued

$$R_{eff} \approx 0.0636n + 0.668 + \frac{0.710}{n} - \frac{1.440}{n^2}$$

"n" in Equation (2) represents the refractive index of the "n" biological body at the wavelength used in the measurement.

μ_{tr} in Equation (1) represents a transfer coefficient, which is expressed by Equation (3). μ_{eff} and μ'_{eff} in Equation (1) are expressed as Equation (4) and Equation (5), respectively. "a'" is an reduced albedo, which is expressed as Equation (6).

$$\mu_{tr}=(\mu_a+\mu_s') \tag{3}$$

μ_a in Equation (3) represents an absorption coefficient, and μ'_s represents an reduced scattering coefficient.

$$\mu_{eff} = (3\mu_a\mu_{tr})^{1/2} \tag{4}$$

$$\mu'_{eff} = (\mu_{eff}^2 + (2\pi f_k)^2)^{1/2} \tag{5}$$

$$a' = \frac{\mu'_s}{\mu_{tr}} \tag{6}$$

The first acquiring unit **12**A substitutes the parameters in Equation (1) with the absorption coefficient and the scattering coefficient of the calibration sample. In this manner, the first acquiring unit **12**A acquires the diffuse reflectance $R_d(f_k)$ of the calibration sample for the light of the structured illumination L at each of the spatial frequencies f_k. Hereinafter, the diffuse reflectance $R_d(f_k)$ of the calibration sample for each pixel at each of the spatial frequencies f_k will be denoted as $R_{d,\ ref}(r, f_k)$.

The first acquiring unit **12**A then acquires the diffuse reflectance $R_d(r, f_k)$ for each pixel, in the measurement target region E of the biological body at each of the spatial frequencies f_k, using Equation (7) below.

$$R_d(r, f_k) = \frac{M_{ac}(r, f_k)}{M_{ac,ref}(r, f_k)} \cdot R_{d,ref}(r, f_k) \tag{7}$$

The first acquiring unit **12**A then calculates an absorption coefficient μ_a and an reduced scattering coefficient μ'_s for each pixel from the diffuse reflectance $R_d(r, f_k)$ for each pixel, at each of the spatial frequencies f_k.

In the present embodiment, the first acquiring unit **12**A uses non-linear regression to calculate the absorption coefficient μ_a and the reduced scattering coefficient μ'_s for each pixel.

FIG. **5** is a chart illustrating a relation between a spatial frequency f_k and a diffuse reflectance in a particular pixel. The first acquiring unit **12**A plots the calculated diffuse reflectance $R_d(r, f_k)$ to the corresponding spatial frequency f_k for each pixel.

These measurement points (plot) follow Equation (1), which is the diffusion equation. The first acquiring unit **12**A therefore calculates the absorption coefficient μ_a and the reduced scattering coefficient μ'_s through non-linear regression with the function expressed as Equation (1).

The first acquiring unit **12**A then generates a scattering coefficient distribution image having each pixel specified with the corresponding scattering coefficient of the measurement target region E of the biological body, by plotting the

reduced scattering coefficient μ'_s calculated for each pixel, to the corresponding pixel position.

The first acquiring unit **12**A also generates an absorption coefficient distribution image having each pixel specified with the corresponding absorption coefficient of the measurement target region E of the biological body, by plotting the absorption coefficient μ_a calculated for each pixel, to the corresponding pixel position.

FIG. **4**E is a schematic of an example of an absorption coefficient distribution image **44**. FIG. **4**F is a schematic of an example of a scattering coefficient distribution image **46**.

Hemoglobin in the biological body absorbs a large portion of the light at a wavelength of 660 nanometers. Therefore, the path of a vein near the skin surface in the measurement target region E of the biological body is clearly visualized in the absorption coefficient distribution image **44**, as illustrated in FIG. **4**E.

In the manner described above, the first acquiring unit **12**A acquires a scattering coefficient distribution image **46** and an absorption coefficient distribution image **44** of the measurement target region E. In other words, in the present embodiment, the first acquiring unit **12**A acquires a scattering coefficient distribution image **46** and an absorption coefficient distribution image **44** by generating the scattering coefficient distribution image **46** and the absorption coefficient distribution image **44** from the diffuse reflection images **40**.

The first acquiring unit **12**A acquires at least the scattering coefficient distribution image **46**. However, it is preferable for the first acquiring unit **12**A to acquire both of the scattering coefficient distribution image **46** and the absorption coefficient distribution image **44**.

At each measurement timing, the first acquiring unit **12**A repeats this sequence of projecting the structured illumination L at the changed spatial frequency and phase onto the measurement target region E and acquiring the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** from the diffuse reflection images **40** by capturing images of the measurement target region E. By repeating this sequence, the first acquiring unit **12**A acquires a plurality of absorption coefficient distribution images **44** and a plurality of scattering coefficient distribution images **46**.

Specifically, an "acquisition timing" mentioned above is representation of a unit of the sequences in which the structured illumination L at the changed spatial frequency and phase is projected to the measurement target region E, a plurality of diffuse reflection images **40** are acquired at each of the respective spatial frequencies and phases by capturing images of the measurement target region E, and a pair of the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** is acquired from the diffuse reflection images **40**.

The first acquiring unit **12**A acquires a plurality of pairs of the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** at different acquisition timings, each of which is a representation of this sequence.

Referring back to FIG. **1**, the first estimating unit **12**B estimates the amount of change in the biological component based on the scattering coefficient distribution image **46** acquired by the first acquiring unit **12**A. In the present embodiment, the first estimating unit **12**B estimates the amount of change in the blood glucose level.

The first estimating unit **12**B calculates a scattering coefficient for each of the scattering coefficient distribution images **46** having different acquisition timings but the same measurement ID (measurement timing). The first estimating unit **12**B calculates a scattering coefficient representative of each of the scattering coefficient distribution images **46** by calculating the arithmetic average of the scattering coefficients specified in the pixels for each of the scattering coefficient distribution images **46**.

The first estimating unit **12**B then calculates, for each of the scattering coefficient distribution images **46** acquired at the respective acquisition timings and having the same measurement ID (measurement timing), the amount of change in the scattering coefficient, with respect to the scattering coefficient in another scattering coefficient distribution image **46** serving as a reference. The other scattering coefficient distribution image **46** serving as a reference is the scattering coefficient distribution image **46** acquired at the previous acquisition timing, as described earlier, for example. The first estimating unit **12**B then reads the amount of change in the blood glucose level that is associated with the calculated amount of change in the scattering coefficient, from the third information **34** (see FIG. **2**C). In this manner, the first estimating unit **12**B estimates the amount of change in the blood glucose level at each acquisition timing.

The first estimating unit **12**B may define the scattering coefficient serving as a reference in advance. The first estimating unit **12**B may then calculate, for each of the scattering coefficient distribution images **46** acquired at the respective acquisition timings, the difference in the scattering coefficient with respect to the reference scattering coefficient, as an amount of change in the scattering coefficient at the corresponding acquisition timing. The first estimating unit **12**B may then read the amount of change in the blood glucose level associated with the calculated amount of change in the scattering coefficient from the third information **34** (see FIG. **2**C). In this manner, too, the first estimating unit **12**B can estimate the amount of change in the blood glucose level at each acquisition timing.

In the manner described above, the biological component estimating apparatus **10** according to the present embodiment estimates the amount of change in the biological component based on the scattering coefficient distribution images **46**. Therefore, the amount of change in the biological component can be estimated accurately using scattering coefficient distribution images non-invasively, without requiring repeated drawing of blood by needling.

It is also possible to draw blood by needling and to measure the blood glucose level using an enzyme through the known method in at least one of a plurality of acquisition timings. In such a case, the first estimating unit **12**B stores the blood glucose level at the acquisition timing in the storage unit **14**. The first estimating unit **12**B then calculates the amount by which the scattering coefficient represented by another scattering coefficient distribution image **46** has changed with respect to that represented by the scattering coefficient distribution image **46** at the corresponding acquisition timing for which the blood glucose level is determined. The first estimating unit **12**B then calculates the sum of the calculated amount of change and the blood glucose level at the acquisition timing for which the blood glucose level has been determined, as the blood glucose level at the acquisition timing for which the amount of change is calculated. In this manner, the first estimating unit **12**B can estimate the varying blood glucose level less invasively and accurately.

During the time in which the projecting unit **26** is projecting the structured illumination L to the same measurement target region E, and during the time in which the image capturing unit **28** is capturing images of the measurement

target region E, the area to which the structured illumination L is projected or the area captured by the image capturing unit **28** may be displaced, due to a movement of the biological body, for example.

Therefore, it is preferable for the first estimating unit **12**B to estimate the amount of change in the blood glucose level (biological component) based on a first area, which is a partial area of the scattering coefficient distribution image **46**.

In such a case, it is preferable for the first estimating unit **12**B to include a first identifying unit **12**C, a second identifying unit **12**D, and a second estimating unit **12**E.

The first identifying unit **12**C identifies a first pattern included in the scattering coefficient distribution image **46**. The first pattern is an image representing the path and the size of the biological body structure included in the scattering coefficient distribution image **46**, as described earlier.

The first identifying unit **12**C reads the first pattern associated with the current measurement ID from the first information **30** (see FIG. **2**A). The tracking information including the first pattern registered in the first information **30** is generated using the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** acquired at the first one of the acquisition timings corresponding to that measurement ID (the process of which will be described later in detail).

The first identifying unit **12**C identifies the first pattern included in the scattering coefficient distribution image **46**. In other words, the first identifying unit **12**C identifies an area representing the path of the biological body structure matching the read first pattern in the scattering coefficient distribution image **46**. Any known pattern matching may be used to identify the first pattern in the scattering coefficient distribution image **46**.

FIGS. **6**A and **6**B are schematics illustrating examples of the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46**, respectively. FIGS. **6**A and **6**B are schematics illustrating the absorption coefficient distribution image **44**A and the scattering coefficient distribution image **46**A, respectively, acquired at the same acquisition timing.

For example, the first identifying unit **12**C identifies an area representing the path of the biological body structure that matches the first pattern P in the scattering coefficient distribution image **46**A.

The pattern of a blood vessel such as that of a vein can be identified more easily in the absorption coefficient distribution image **44** than in the scattering coefficient distribution image **46**. By contrast, a muscle, a tendon, or a ligament pattern can be identified more easily in the scattering coefficient distribution image **46** than in the absorption coefficient distribution image **44**.

In this manner, the pattern of a biological body structure is sometimes more identifiable in the absorption coefficient distribution image **44**A (see FIG. **6**A) than in the scattering coefficient distribution image **46**A (see FIG. **6**B), depending on the measurement target region E.

In such a case, to begin with, the first identifying unit **12**C identifies an area representing the path of the biological body structure that matches the first pattern P from the absorption coefficient distribution image **44**A. The first identifying unit **12**C then places the identified first pattern P onto the scattering coefficient distribution image **46**A acquired at the same acquisition timing as the absorption coefficient distribution image **44**A.

More specifically, the first identifying unit **12**C reads the pixel positions of the respective pixels constituting the identified first pattern P from the absorption coefficient distribution image **44**A. The first identifying unit **12**C then identifies the pattern represented by the pixels at the read pixel positions in the scattering coefficient distribution image **46**A acquired at the same acquisition timing, as the first pattern P. In this manner, the first identifying unit **12**C identifies the first pattern P included in the scattering coefficient distribution image **46**A.

As described above, the pattern of a blood vessel such as that of a vein can be identified more easily in the absorption coefficient distribution image **44** than in the scattering coefficient distribution image **46**. In the absorption coefficient distribution image **44**, the pattern of a blood vessel is represented as an area brighter than the other area. Therefore, the first identifying unit **12**C may also use the absorption coefficient distribution image **44**A itself (the entire absorption coefficient distribution image **44**A) as the first pattern P. In other words, the first identifying unit **12**C may use the absorption coefficient distribution image **44**A itself (the entire absorption coefficient distribution image **44**A) as a template used for the pattern matching.

The second identifying unit **12**D identifies the area inside of a reference template T that is positioned at the relative position with respect to the identified first pattern P in the scattering coefficient distribution image **46**, as a first area S.

The second identifying unit **12**D reads the relative position included in the tracking information that is associated with the current measurement ID from the first information **30** (see FIG. **2**A). The second identifying unit **12**D then places the reference template T at the read relative position with respect to the identified first pattern P, in the scattering coefficient distribution image **46**.

For example, as illustrated in FIG. **6**B, the second identifying unit **12**D places the reference template T in the scattering coefficient distribution image **46**A. The position where the reference template T is placed in the scattering coefficient distribution image **46**A is the same as the read relative position with respect to the first pattern P in the absorption coefficient distribution image **44**A (see FIG. **6**A) acquired at the same acquisition timing.

The second identifying unit **12**D then identifies the area inside of the reference template T placed in the scattering coefficient distribution image **46**A as the first area S.

The second estimating unit **12**E then estimates the amount of change in the biological component (for example, the blood glucose level) based on the scattering coefficients specified in the respective pixels constituting the identified first area S in the scattering coefficient distribution image **46**A.

More specifically, the second estimating unit **12**E calculates an arithmetic average of the scattering coefficients specified in the respective pixels constituting the identified first area S, as a scattering coefficient corresponding to the scattering coefficient distribution image **46**A.

The second estimating unit **12**E then calculates the amount by which the current scattering coefficient having been just calculated has changed with respect to the scattering coefficient corresponding to the previous acquisition timing that is associated with the same measurement ID (measurement timing).

The second estimating unit **12**E then reads the amount of change in the blood glucose level associated with the calculated amount of change in the scattering coefficient from the third information **34** (see FIG. **2**C). In this manner, the second estimating unit **12**E estimates the amount of change in the blood glucose level.

In the manner described above, the first estimating unit **12**B can correct the variation of the measurement target region E of the biological body, by estimating the amount of change in the blood glucose level (biological components) based on the first area S, which is a partial area of the scattering coefficient distribution image **46**.

FIGS. **7**A and **7**B are schematics illustrating examples of an absorption coefficient distribution image **44**B and a scattering coefficient distribution image **46**B, with the measurement target region E slightly displaced with respect to the position at the acquisition timing at which the scattering coefficient distribution image **46**A and the absorption coefficient distribution image **44**A illustrated in FIGS. **6**A and **6**B, respectively, are acquired.

As illustrated in FIG. **7**A, the first pattern P in the absorption coefficient distribution image **44**B is displaced with respect to that in the absorption coefficient distribution image **44**A (see FIG. **6**A).

As illustrated in FIG. **7**A, even when the position or the angle of the first pattern P in the absorption coefficient distribution image **44**B is displaced, the relative position of the reference template T with respect to the first pattern P remains the same. The first pattern represents the path of a blood vessel, a muscle, a tendon, a ligament, or the like, and such a path does not change very much within several hours to several tens of hours during which the transition in the amount of change in the blood glucose level is being monitored. Furthermore, because the first pattern represents the path of a biological body structure (such as a blood vessel), the path does not change very much even when the thickness of the blood vessel changes due to a change in the posture or the blood pressure of the subject, for example. The path represented by the first pattern delineates a unique pattern depending on the subject or the measurement target region E.

Therefore, the first estimating unit **12**B can estimate the amount of change in the blood glucose level using the first area S inside of the constant reference template T, the relative position of which with respect to the first pattern P always remains the same, in the scattering coefficient distribution image **46**.

In other words, the first area S inside the reference template T placed in the scattering coefficient distribution image **46**B (see FIG. **7**B) acquired at the same acquisition timing as the absorption coefficient distribution image **44**B represents the same area of the biological body as the first area S inside the reference template T placed in the scattering coefficient distribution image **46**A (see FIG. **6**B) acquired at a different acquisition timing.

Therefore, even when the area to which the structured illumination L is projected is displaced or when the area captured by the image capturing unit **28** is displaced due to a movement of the biological body, for example, it is possible to suppress the reduction in the estimation accuracy of the amount of change in the biological component, due to such a displacement.

In other words, by allowing the first estimating unit **12**B to estimate the amount of change in the blood glucose level based on the first area S, which is a partial area of the scattering coefficient distribution image **46**, the amount of change in the biological component can be estimated more accurately.

The tracking information such as the first pattern corresponding to each of the measurement IDs (measurement timings) is generated by the third identifying unit **12**H, the second calculating unit **12**I, and the storing control unit **12**J, and registered in the first information **30**.

Specifically, the third identifying unit **12**H performs image analysis on the scattering coefficient distribution image **46** or the absorption coefficient distribution image **44** acquired at the first acquisition timing, among a plurality of scattering coefficient distribution images **46** associated with the same measurement ID (measurement timing), and identifies the pattern of the biological body structure included in the scattering coefficient distribution image **46** as the first pattern. The pattern is an image in which the path of the biological body structure is captured.

For example, a plurality of types of reference patterns, each representing a basic path that can be identified as a biological body structure, such as a blood vessel, a muscle, a tendon, or a ligament, are stored in the storage unit **14** in advance.

The third identifying unit **12**H then performs the pattern matching, for example, using known image processing, to identify the part representing the same path at least partially as the basic pattern in the scattering coefficient distribution image **46** acquired at the first acquisition timing, as the first pattern.

When a plurality of scattering coefficient distribution images **46** that are associated with the same measurement ID have already been acquired, the third identifying unit **12**H identifies the pattern of the biological body structure in one of the scattering coefficient distribution images **46** associated with the same measurement ID as the first pattern. In other words, the scattering coefficient distribution image **46** in which the first pattern is identified is not limited to the scattering coefficient distribution image **46** acquired at the first acquisition timing.

As mentioned earlier, the pattern of a blood vessel such as that of a vein can be identified more easily in the absorption coefficient distribution image **44** than in the scattering coefficient distribution image **46**. By contrast, the pattern of a muscle, a tendon, or a ligament can be identified more easily in the scattering coefficient distribution image **46** than in the absorption coefficient distribution image **44**.

Therefore, it is preferable for the third identifying unit **12**H to identify the first pattern, using both of the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** acquired at the first acquisition timing.

This difference will now be explained with reference to FIGS. **6**A and **6**B. It is assumed therein that the absorption coefficient distribution image **44**A and the scattering coefficient distribution image **46**A respectively illustrated in FIGS. **6**A and **6**B are the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** acquired at the first acquisition timing.

In the example illustrated in FIGS. **6**A and **6**B, the absorption coefficient distribution image **44**A (see FIG. **6**A) allows the pattern of the biological body structure to be identified more easily than the scattering coefficient distribution image **46**A (see FIG. **6**B). In such a case, the third identifying unit **12**H identifies the pattern of the biological body structure included in the absorption coefficient distribution image **44**A as the first pattern P (see FIG. **6**A).

There are some other cases in which the scattering coefficient distribution image **46**A allows the pattern of the biological body structure to be identified more easily than the absorption coefficient distribution image **44**A. In such a case, the third identifying unit **12**H identifies the pattern of the biological body structure in the scattering coefficient distribution image **46**A as the first pattern P.

The second calculating unit **12**I places the reference template in the absorption coefficient distribution image **44**A

from which the first pattern P is identified. The second calculating unit **12**I then calculates the relative position of the placed reference template with respect to the identified first pattern P, in the absorption coefficient distribution image **44**A (see FIG. **6**A).

When the third identifying unit **12**H identifies the first pattern P from the scattering coefficient distribution image **46**A, the second calculating unit **12**I places the reference template T in the scattering coefficient distribution image **46**A. The second calculating unit **12**I then calculates the relative position of the placed reference template with respect to the identified first pattern P, in the scattering coefficient distribution image **46**A (see FIG. **6**B).

As mentioned earlier, the reference template T represents a predetermined shape (for example, a rectangular frame) with a size smaller than that of the scattering coefficient distribution image **46**A (the scattering coefficient distribution image **46**). The scattering coefficient distribution image **46** has the same size as the absorption coefficient distribution image **44**. Therefore, the size of the reference template T is also smaller than the absorption coefficient distribution image **44**A (the absorption coefficient distribution image **44**).

The reference template T may be placed at any position in the scattering coefficient distribution image **44**A or the scattering coefficient distribution image **46**A, as long as the entire frame represented by the reference template T fits inside of the scattering coefficient distribution image **46**A or the absorption coefficient distribution image **44**B. Furthermore, it is preferable for the reference template T to be placed in such a manner that at least a part of the reference template T is not continuous to (not brought into contact with) an end of the scattering coefficient distribution image **46**A or the absorption coefficient distribution image **44**A. This is because the ends of the scattering coefficient distribution image **46**A and the absorption coefficient distribution image **44**A may fail to be captured at the next acquisition timing, due to displacement of the measurement target region E.

The storing control unit **12**J then stores the first pattern P identified by the third identifying unit **12**H, the relative position calculated by the second calculating unit **12**I, and the reference template T, in the storage unit **14** in a manner associated with the current measurement ID. More specifically, the storing control unit **12**J creates the tracking information by associating the first pattern P identified by the third identifying unit **12**H, the relative position, and the reference template T, with one another, and registers the tracking information to the first information **30** in a manner associated with the measurement ID associated with the acquisition timing at which absorption coefficient distribution image **44**A or the scattering coefficient distribution image **46**A in which the first pattern P is identified is acquired.

As a result, the tracking information (the reference template, the first pattern, and the relative position) is registered to the first information **30** in a manner associated with the corresponding measurement ID, as illustrated in FIG. **2**A. The same reference template T may be, however, shared among different measurement IDs. The reference template T may be therefore not registered to the first information **30**, and may be stored separately in the storage unit **14**.

Referring back to FIG. **1**, the display control unit **12**M displays various images on the display unit **20**.

For example, the display control unit **12**M displays an image representing the amount of change in the biological component (for example, blood glucose level) estimated by the first estimating unit **12**B on the display unit **20**.

Examples of the image representing the amount of change in the biological component include a graph or a chart presenting temporal transitions of the amount of change, and an image presenting numbers representing the amount of change.

At this time, it is preferable for the display control unit **12**M to display a section representing an abnormal amount of change in the image representing the amount of change in the biological component (for example, blood glucose level) estimated by the first estimating unit **12**B, on the display unit **20** in a display mode that is different from a display mode in which the other section is displayed. A different display mode is a mode presenting at least one of the color, the brightness, a blinking interval, and a size (e.g., thickness) differently.

FIG. **8** is an exemplary schematic of a display screen **52** presenting an image representing the amount of changes in the blood glucose level. The display control unit **12**M displays the display screen **52** on the display unit **20**, for example.

In the example illustrated in FIG. **8**, the display screen **52** includes a chart **54** indicating the amount of change in the blood glucose level against time, as the image representing the amount of change in the blood glucose level. For example, a part of the chart **54** is the normal section **54**A, and the other part is an abnormal section **54**B. The normal section **54**A is a section of the acquisition timing (time) during which the amount of change in the blood glucose level is normal. The abnormal section **54**B is a section of the acquisition timing (time) during which the amount of change in the blood glucose level is abnormal. It is preferable for the display control unit **12**M to display the abnormal section **54**B in a display mode that is different from a display mode in which the normal section **54**A is displayed.

Specifically, the display control unit **12**M reads the abnormal amount of change from the storage unit **14**. The display control unit **12**M then identifies a section indicating the abnormal amount of change, from the amount of change in the blood glucose level at each acquisition timing and estimated by the first estimating unit **12**B. The display control unit **12**M then displays the identified section indicating the abnormal amount of change (abnormal section **54**B) in a display mode that is different from a display mode in which the other section (normal section **54**A) is displayed on the display unit **20**.

Referring back to FIG. **1**, the detecting unit **12**K detects a positional displacement of the image capturing unit **28** with respect to the measurement target region E. The detecting unit **12**K detects the positional displacement when the first identifying unit **12**C is incapable of identifying the first pattern P in the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46**.

In other words, there are some cases in which the path of the corresponding first pattern P cannot be identified in the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** that are acquired at a particular acquisition timing. In such a case, if the amount of change in the blood glucose level is measured using the same area, the estimation accuracy of the amount of change in the blood glucose level may deteriorate.

To address this issue, the detecting unit **12**K detects the positional displacement when the corresponding first pattern P cannot be recognized in the absorption coefficient distri-

bution image **44** and the scattering coefficient distribution image **46** that are acquired at the particular acquisition timing.

When the detecting unit **12**K has detected a positional displacement, it is preferable for the display control unit **12**M to display the information indicating the positional displacement on the display unit **20**. The information representing the positional displacement may include a message recommending correction of the position of the measurement target region E of the biological body.

FIG. **9** is an exemplary schematic of a display screen **50** for the information indicating a positional displacement. When the detecting unit **12**K has detected a positional displacement, the display control unit **12**M displays the information representing the positional displacement or a message recommending correction of the position such as "Measurement position is displaced. Correct the position." on the display unit **20**.

Therefore, the biological component estimating apparatus **10** according to the present embodiment can easily provide a user with the information indicating that the measurement target region E is displaced.

Referring back to FIG. **1**, the output control unit **12**N controls the output unit **25**. As mentioned earlier, the display unit **20**, the driving unit **22**, and the sound output unit **24** function as the output unit **25** for outputting various types of information to the external of the biological component estimating apparatus **10**.

The output control unit **12**N controls the output unit **25** to output information indicating abnormality when the amount of change in the biological component (for example, blood glucose level) estimated based on the scattering coefficient distribution image **46** that is generated from the diffuse reflection images **40** captured during a predetermined first time period represents a predetermined abnormal amount of change.

The output control unit **12**N reads the first time period from the second information **32** (see FIG. **2**B) stored in the control unit **12**. The output control unit **12**N then determines whether the timing at which the diffuse reflection images **40**, from which the amount of change estimated by the first estimating unit **12**B is calculated, are captured is within the first time period. If the timing is within the first time period, the output control unit **12**N determines whether the amount of change in the blood glucose level estimated based on the diffuse reflection images **40** captured at such a timing matches the abnormal amount of change corresponding to the first time period specified in the second information **32**. If the output control unit **12**N determines that the amount of change matches the abnormal amount of change, the output control unit **12**N then controls the output unit **25** to output information representing the abnormality.

Specifically, the output control unit **12**N controls at least one of the display unit **20**, the driving unit **22**, and the sound output unit **24** to output information representing the abnormality.

More specifically, the output control unit **12**N controls the output unit **25** to output information indicating the abnormality by controlling the driving unit **22** to cause the biological component estimating apparatus **10** to vibrate. As another example, the output control unit **12**N controls the output unit **25** to output information indicating the abnormality by controlling the sound output unit **24** to output a predetermined sound. As yet another example, the output control unit **12**N controls the output unit **25** to output information indicating the abnormality by displaying a predetermined message representing the abnormality to the display unit **20**.

Through such a process performed by the output control unit **12**N, when an amount of change in the blood glucose level considered to be abnormal from the medical point of view is estimated during the first time period requiring some attention from the medical point of view, the subject can be presented with information indicating that the estimation result of the amount of change in the blood glucose level represents abnormality.

A biological component estimating process performed by the biological component estimating apparatus **10** according to the present embodiment will now be explained.

FIG. **10** is a flowchart illustrating the biological component estimating process performed by the biological component estimating apparatus **10** according to the present embodiment. The control unit **12** in the biological component estimating apparatus **10** performs the process illustrated in FIG. **10** at each measurement timing (measurement ID) associated with one user identified by the corresponding user ID. Every time the process is completed for each measurement ID (measurement timing), the biological component estimating apparatus **10** increments the measurement ID.

To begin with, the first acquiring unit **12**A acquires the scattering coefficient distribution image **46** and the absorption coefficient distribution image **44** (Step S**100**).

The first estimating unit **12**B then estimates the amount of change in the biological component based on the scattering coefficient distribution image **46** and the absorption coefficient distribution image **44** acquired at Step S**100** (Step S**102**).

The first estimating unit **12**B then stores the estimated amount of change in the biological component in the control unit **12** in a manner associated with the current measurement ID and acquisition timing (Step S**104**).

The receiving unit **12**L then determines whether an instruction for displaying the amount of change in the biological component has been received (Step S**106**). If the input unit **18** has received an input of the instruction for displaying the amount of change in the biological component from a user, for example, the input unit **18** outputs the instruction to the control unit **12**. The receiving unit **12**L in the control unit **12** makes this determination at Step S**106** by determining whether an input of the instruction for displaying the amount of change in the biological component is received from the input unit **18**.

If the receiving unit **12**L determines to be Yes at Step S**106** (Yes at Step S**106**), the process is shifted to Step S**108**. At Step S**108**, the display control unit **12**M displays the image representing the amount of change in the biological component on the display unit **20** (Step S**108**). The process is then shifted to Step S**110**.

If the receiving unit **12**L determines to be No at Step S**106** (No at Step S**106**), the process is shifted to Step S**110**.

At Step S**110**, the receiving unit **12**L determines whether an ending instruction has been received from the input unit **18** (Step S**110**). Users can give an instruction for ending the measurement by making an operation on the input unit **18**. When an instruction for ending the measurement is provided by a user through the operation on the input unit **18**, the input unit **18** outputs the instruction for ending the measurement to the control unit **12**. The receiving unit **12**L in the control unit **12** determines whether the instruction for ending the measurement has been received from the input unit **18**.

If the receiving unit **12**L determines to be No at Step S**110** (No at Step S**110**), the process is returned to Step S**100**.

If the receiving unit **12**L determines to be Yes at Step S**110** (Yes at Step S**110**), this routine is ended.

The process at Step S**100** will now be explained in detail. FIG. **11** is a flowchart illustrating the process at Step S**100** in FIG. **10**.

To begin with, the first acquiring unit **12**A sets "k" representing the spatial frequency f_k to one (Step S**200**). The first acquiring unit **12**A then sets "p" representing the phase ($2\pi p/m$) to one (Step S**202**).

The first acquiring unit **12**A then transmits a projection instruction containing the set spatial frequency f_k and phase $2\pi p/m$ to the projecting unit **26** (Step S**204**). The projecting unit **26** that has received the projection instruction projects the structured illumination L at the spatial frequency f_k and the phase $2\pi p/m$ included in the projection instruction to the measurement target region E.

The image capturing control unit **12**G transmits an instruction for capturing an image of the measurement target region E to the image capturing unit **28** (Step S**206**). The image capturing unit **28** then acquires a scattered reflection image **40** by capturing an image of the measurement target region E, and outputs the scattered reflection image **40** to the control unit **12**. The first acquiring unit **12**A acquires the scattered reflection image **40** from the image capturing unit **28** (Step S**208**). The first acquiring unit **12**A then stores the acquired scattered reflection image **40** in the storage unit **14** (Step S**210**).

The first acquiring unit **12**A then determines whether "p" in the phase ($2\pi p/m$) matches "m" that is the maximum value of "p" (Step S**212**). If the first acquiring unit **12**A determines to be No at Step S**212** (No at Step S**212**), the first acquiring unit **12**A adds one to "p" (Step S**214**), and the process is returned to Step S**204**.

If the first acquiring unit **12**A determines to be Yes at Step S**212** (Yes at Step S**212**), the process is shifted to Step S**216**.

At Step S**216**, the first acquiring unit **12**A determines whether "k" of the spatial frequency f_k matches "a" that is the maximum value of "k" (Step S**216**). If the first acquiring unit **12**A determines to be No at Step S**216** (No at Step S**216**), the process is shifted to Step S**218**. At Step S**218**, the first acquiring unit **12**A adds one to "k" (Step S**218**), and the process is returned to Step S**202**.

If the first acquiring unit **12**A determines to be Yes at Step S**216** (Yes at Step S**216**), the process is shifted to Step S**220**. At Step S**220**, the first acquiring unit **12**A calculates the diffuse amplitude ($M_{ac}(r, f_k)$) for each pixel, at each of the spatial frequencies f_k, using a plurality of diffuse reflection images **40** captured at different phases at each of the spatial frequencies f_k and acquired through the process at Steps S**200** to S**216** (Step S**220**).

The first acquiring unit **12**A also performs the process from Steps S**200** to S**220** on the calibration sample as mentioned earlier, and calculates the diffuse amplitude ($M_{ac,\ ref}(r, f_k)$ for each pixel.

The first acquiring unit **12**A then calculates the diffuse reflectance $R_d(r, f_k)$ for each pixel, in the measurement target region E of the biological body, at each of the spatial frequencies f_k, using Equation (7) (Step S**222**).

The first acquiring unit **12**A then calculates the absorption coefficient μ_a and the reduced scattering coefficient μ'_s for each pixel from the diffuse reflectance $R_d(r, f_k)$ for each pixel, acquired at each of the spatial frequencies f_k (Step S**224**).

The first acquiring unit **12**A then generates the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** (Step S**226**). At Step S**226**, the first acquiring unit **12**A generates the scattering coefficient distribution image **46** having each pixel specified with the corresponding scattering coefficient of the measurement target region E of the biological body, by placing the reduced scattering coefficient μ'_s calculated and estimated for each pixel at Step S**224** to the corresponding pixel position.

The first acquiring unit **12**A also generates the absorption coefficient distribution image **44** having each pixel specified with the corresponding absorption coefficient of the measurement target region E of the biological body, by placing the absorption coefficient μ_a calculated for each pixel at Step S**224** to the corresponding pixel position.

Through the process at Step S**224**, the first acquiring unit **12**A acquires the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46**.

The first acquiring unit **12**A then stores the current measurement ID, and the generated absorption coefficient distribution image **44** and scattering coefficient distribution image **46** in the storage unit **14** in a manner associated with the acquisition timing at which the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** are acquired (Step S**228**). This routine is then ended.

The process at Step S**102** in FIG. **10** will now be explained in detail. FIG. **12** is a flowchart illustrating the process at Step S**102** in FIG. **10**.

To begin with, the first estimating unit **12**B determines whether the tracking information has been stored in the storage unit **14** (Step S**300**). Specifically, the first estimating unit **12**B makes the determination at Step S**300** by determining whether the tracking information corresponding to the current measurement ID is stored in the first information **30** (see FIG. **2**A). If the first estimating unit **12**B determines to be Yes at Step S**300** (Yes at Step S**300**), the process is shifted to Step S**310** which will be described later.

If the first estimating unit **12**B determines to be No at Step S**300** (Step S**300**), the process is shifted to Step S**302**. At Step S**302**, the third identifying unit **12**H identifies the pattern of the biological body structure included in the scattering coefficient distribution image **46** acquired at first acquisition timing, among those associated with the current measurement ID (measurement timing), as the first pattern (Step S**302**). The third identifying unit **12**H may also identify the first pattern from the absorption coefficient distribution image **44**, as mentioned earlier.

The second calculating unit **12**I then places the reference template T in the scattering coefficient distribution image **46** from which the first pattern is identified at Step S**302** (Step S**304**). The second calculating unit **12**I then calculates the relative position of the placed reference template T with respect to the identified first pattern P in the scattering coefficient distribution image **46** in which the first pattern is identified at Step S**302** (Step S**306**).

The storing control unit **12**J then creates the tracking information by associating the first pattern P identified by the third identifying unit **12**H at Step S**302** with the relative position calculated by the second calculating unit **12**I at Step S**306** and the reference template T, and stores the tracking information in the storage unit **14** (Step S**308**). In other words, the storing control unit **12**J registers the tracking information in the first information **30** (see FIG. **2**A) in a manner associated with the current measurement ID. The process is then shifted to Step S**310**.

At Step S**310**, the first identifying unit **12**C reads the tracking information corresponding to the current measurement ID from the first information **30** (Step S**310**).

The first identifying unit **12**C then reads the absorption coefficient distribution image **44** and the scattering coeffi-

cient distribution image **46** acquired through the process at Step S**100** (Steps S**200** to S**228** in FIGS. **10** and **11**). The absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** are the images acquired by the first acquiring unit **12**A at the same acquisition timing. The first identifying unit **12**C then identifies the first pattern included in the tracking information read at Step S**310**, in the absorption coefficient distribution image **44** or the scattering coefficient distribution image **46** (Step S**312**).

In other words, the first identifying unit **12**C identifies an area representing the path of the biological body structure matching the first pattern in the scattering coefficient distribution image **46** or the absorption coefficient distribution image **44**.

The detecting unit **12**K then determines whether the first identifying unit **12**C has been capable of identifying the first pattern P from the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46** (Step S**314**). If the first identifying unit **12**C has not been capable of identifying the first pattern P (No at Step S**314**), the detecting unit **12**K detects a positional displacement (Step S**316**).

The display control unit **12**M then displays the information representing the positional displacement on the display unit **20** (Step S**318**). The process is then returned to Step S**100** (see FIG. **10**). If the detecting unit **12**K determines to be Yes at Step S**314** (Yes at Step S**314**), the process is shifted to Step S**320**.

At Step S**320**, the second identifying unit **12**D identifies the area inside of the reference template T placed at the relative position with respect to the first pattern P identified at Step S**312** in the absorption coefficient distribution image **44** and the scattering coefficient distribution image **46**, as the first area S (Step S**320**). The relative position used at Step S**320** is the relative position included in the tracking information read at Step S**310**.

The second estimating unit **12**E then estimates the amount of change in the blood glucose level based on the scattering coefficients specified in the respective pixels constituting the first area S identified at Step S**320** in the scattering coefficient distribution image **46** (Step S**322**). The second estimating unit **12**E then registers the estimated amount of change in the blood glucose level to the first information **30**, in a manner associated with the current measurement ID and to the acquisition timing of the scattering coefficient distribution image **46** used in the estimation, and this routine is ended.

The biological component estimating apparatus **10** then performs an interrupting process. FIG. **13** is a flowchart illustrating the interrupting process performed by the biological component estimating apparatus **10**.

The control unit **12** repeats the interrupting process illustrated in FIG. **13**. To begin with, the output control unit **12**N determines whether there is any image capturing timing falling within the first time period stored in the storage unit **14** (Step S**400**). For example, the output control unit **12**N makes the determination at Step S**400** by determining whether there is any image capturing timing falling within the first time period, among a plurality of image capturing timings associated with the current measurement ID and stored in the storage unit **14**.

Every time the image capturing unit **28** acquires a scattered reflection image **40** by capturing an image of the measurement target region E, the image capturing control unit **12**G stores the timing at which the scattered reflection image **40** is captured and the scattered reflection image **40** in the storage unit **14** in a manner associated with each other.

If the output control unit **12**N determines to be No at Step S**400** (No at Step S**400**), this routine is ended. If the output control unit **12**N determines to be Yes at Step S**400** (Yes at Step S**400**), the process is shifted to Step S**402**.

At Step S**402**, the output control unit **12**N determines whether the amount of change in the blood glucose level estimated based on the scattering coefficient distribution image **46** that is generated from the diffuse reflection images **40** captured at the image capturing timing within the first time period matches the abnormal amount of change associated with the first time period in the second information **32** (see FIG. **2**B) (Step S**402**). If the output control unit **12**N determines to be No at Step S**402** (No at Step S**402**), this routine is ended.

If the output control unit **12**N determines to be Yes at Step S**402** (Yes at Step S**402**), the process is shifted to Step S**404**. The output control unit **12**N then controls the output unit **25** to output information representing abnormality at Step S**404** (Step S**404**), and this routine is ended.

As explained above, the biological component estimating apparatus **10** according to the present embodiment includes the first acquiring unit **12**A and the first estimating unit **12**B. The first acquiring unit **12**A acquires the scattering coefficient distribution image **46** having each pixel specified with the corresponding scattering coefficient of the measurement target region E of the biological body for the light including a wavelength range in the near infrared range. The first estimating unit **12**B estimates the amount of change in the biological component based on the scattering coefficient distribution images **46**.

In the manner described above, the biological component estimating apparatus **10** according to the present embodiment estimates the amount of change in a biological component based on a plurality of scattering coefficient distribution images. Therefore, with the biological component estimating apparatus **10** according to the present embodiment, it is no longer necessary to draw blood repeatedly from the subject by needling. Furthermore, because the scattering coefficient distribution image is used, the biological component estimating apparatus **10** can estimate an amount of change in the biological component highly accurately.

The biological component estimating apparatus **10** according to the present embodiment can therefore estimate an amount of change in the biological component non-invasively and accurately.

The biological component estimating apparatus **10** according to the present embodiment also includes the first acquiring unit **12**A, the first estimating unit **12**B, and the display control unit **12**M. The first acquiring unit **12**A acquires a scattering coefficient distribution image **46** having each pixel specified with the corresponding scattering coefficient of the measurement target region E of the biological body for the light including a wavelength range in the near infrared range. The first estimating unit **12**B estimates the amount of change in the biological component based on the scattering coefficient distribution images **46**. The display control unit **12**M displays the image representing the estimated amount of change in the biological component on the display unit **20**.

Therefore, the biological component estimating apparatus **10** according to the present embodiment can provide a user with the amount of change in the biological component easily, in addition to the advantageous effects described above.

Explained above for the biological component estimating apparatus **10** according to the present embodiment is an

example in which the first estimating unit **12**B estimates the amount of change in the blood glucose level (biological component) by performing pattern matching with the first pattern P included in the scattering coefficient distribution image **46**, using the tracking information.

However, the biological component estimating apparatus **10** may be provided with a known detecting mechanism for detecting at least one of a movement of the biological body, an area to which the structured illumination L is projected, and an area captured by the image capturing unit **28**. In such a case, the first estimating unit **12**B corrects the displacement of the first area S in the scattering coefficient distribution image **46** by using the detection result of the detecting mechanism, and then estimates the amount of change in the blood glucose level (biological component).

A hardware configuration of the biological component estimating apparatus **10** according to the present embodiment will now be explained. FIG. **14** is a block diagram illustrating an exemplary hardware configuration of the biological component estimating apparatus **10** according to the present embodiment.

The biological component estimating apparatus **10** according to the present embodiment includes a display unit **60**, an interface (I/F) unit **61**, an image capturing unit **62**, an input unit **63**, a sound output unit **64**, a central processing unit (CPU) **65**, a read-only memory (ROM) **66**, a random access memory (RAM) **67**, a hard disk drive (HDD) **68**, a projecting unit **69**, and a driving unit **70** that are connected to each other over a bus **71**, and has a hardware configuration using a general computer.

The CPU **65** is a processor controlling the process of the entire biological component estimating apparatus **10**. The RAM **67** stores therein data required for various processes performed by the CPU **65**. The ROM **66** stores therein computer programs and the like for implementing the various processes performed by the CPU **65**. The HDD **68** corresponds to the storage unit **14** described above. The I/F unit **61** is an interface for connecting to an external apparatus or to an external terminal over a communication circuit, and exchanging data with the external apparatus or the external terminal with which the connection is established. The display unit **60**, the image capturing unit **62**, the input unit **63**, the sound output unit **64**, the projecting unit **69**, and the driving unit **70** correspond to the display unit **20**, the image capturing unit **28**, the input unit **18**, the sound output unit **24**, the projecting unit **26**, and the driving unit **22**, respectively.

The computer programs for executing the various processes executed in the biological component estimating apparatus **10** according to the present embodiment are incorporated and provided in the ROM **66** or the like in advance.

The computer programs executed in the biological component estimating apparatus **10** according to the present embodiment may also be recorded and provided in a computer-readable recording medium such as a compact disc read-only memory (CD-ROM), a flexible disk (FD), a compact disc recordable (CD-R), and a digital versatile disc (DVD), as a file in an installable or executable format in the apparatus.

Furthermore, the computer programs executed in the biological component estimating apparatus **10** according to the present embodiment may be stored in a computer connected to a network such as the Internet, and made available for download over the network. The computer programs for executing the processes in the biological component estimating apparatus **10** according to the present embodiment may also be provided or distributed over a network such as the Internet.

The computer programs for executing the various processes executed in the biological component estimating apparatus **10** according to the present embodiment can generate the units described above on the main memory.

The various types of information stored in the HDD **68**, that is, the various types of information stored in the storage unit **14** may also be stored in an external apparatus (such as a server). In such a case, the external apparatus is connected to the CPU **65** over a network or the like.

While a certain embodiment has been described, the embodiment has been presented by way of example only, and is not intended to limit the scope of the inventions. Indeed, the novel embodiment described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiment described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A biological component estimating apparatus comprising:

a processor configured to

acquire a scattering coefficient distribution image having each pixel specified with a scattering coefficient of a measurement target region of a biological body for light including a wavelength range in a near infrared range,

estimate an amount of change in a biological component based on the scattering coefficient distribution image, and

store in a storage unit a reference template having a size smaller than a size of the scattering coefficient distribution image and also having a predetermined shape, a first pattern of a biological body structure included in the scattering coefficient distribution image, and a relative position of the reference template with respect to the first pattern in the scattering coefficient distribution image, wherein

the processor is further configured to

estimate the amount of change in the biological component based on a first area that is a part of the scattering coefficient distribution image,

identify the first pattern included in the scattering coefficient distribution image,

identify, as a first area, an area inside of the reference template placed at the relative position with respect to the identified first pattern in the scattering coefficient distribution image, and

estimate the amount of change in the biological component based on scattering coefficients specified in respective pixels constituting the identified first area in the scattering coefficient distribution image.

2. The apparatus according to claim **1**, wherein the processor is further configured to

project structured illumination having a periodic structure of a given spatial frequency onto the measurement target region,

photograph the measurement target region to which the structured illumination is projected, so as to acquire a scattered reflection image for light of the structured illumination projected to the measurement target region, and

generate the scattering coefficient distribution image from the scattered reflection image, so as to acquire the scattering coefficient distribution image.

3. The apparatus according to claim **1**, wherein the processor is further configured to

identify, as the first pattern, a pattern of the biological body stricture included in one of a plurality of such scattering coefficient distribution images,

calculate the reference template in the scattering coefficient distribution image, and calculate a relative position of the placed reference template with respect to the identified first pattern, and

store the identified first pattern and the calculated relative position in the storage unit in a manner associated with the reference template.

4. The apparatus according to claim **1**, wherein

the processor is further configured to

acquire an absorption coefficient distribution image having each pixel specified with an absorption coefficient for the light,

identify, as the first pattern, a pattern of the biological body structure included in one of a plurality of such absorption coefficient distribution images,

place the reference template in the absorption coefficient distribution image, and calculate a relative position of the placed reference template with respect to the identified first pattern, and

store the identified first pattern and the calculated relative position in the storage unit in a manner associated with the reference template.

5. The apparatus according to claim **1**, wherein the first pattern represents a path of at least one of a blood vessel, a muscle, a tendon, and a ligament included in the biological body.

6. The apparatus according to claim **1**, wherein the amount of change in the biological component is an amount of change in a blood glucose level.

7. The apparatus according to claim **1**, wherein the processor is further configured to display an image representing the estimated amount of change in the biological component on a display unit.

8. The apparatus according to claim **7**, wherein the processor is further configured to display an area representing an abnormal amount of change in the image representing the estimated amount of change in the biological component on the display unit in a display mode that is different from a display mode in which the other area is displayed.

9. The apparatus according to claim **2**, wherein the processor is further configured to control outputting of information representing abnormality when an amount of change in the biological component estimated based on the scattering coefficient distribution image generated from a scattered reflection image captured in a predetermined first time period indicates a predetermined abnormal amount of change.

10. The apparatus according to claim **2**, wherein the processor is further configured to

detect a positional displacement of the biological component estimating apparatus with respect to the measurement target region; and

display, when the processor has detected a positional displacement, information representing the positional displacement on the display unit.

11. A biological component estimating method comprising:

acquiring a scattering coefficient distribution image having each pixel specified with a scattering coefficient of a measurement target region of a biological body for light including a wavelength range in a near infrared range;

estimating an amount of change in a biological component based on the scattering coefficient distribution image; and

storing a reference template having a size smaller than a size of the scattering coefficient distribution image and also having a predetermined shape, a first pattern of a biological body structure included in the scattering coefficient distribution image, and a relative position of the reference template with respect to the first pattern in the scattering coefficient distribution image, wherein

the estimating of the amount of change in the biological component includes

estimating the amount of change in the biological component based on a first area that is a part of the scattering coefficient distribution image,

identifying the first pattern included in the scattering coefficient distribution image,

identifying, as a first area, an area inside of the reference template placed at the relative position with respect to the identified first pattern in the scattering coefficient distribution image, and

estimating the amount of change in the biological component based on scattering coefficients specified in respective pixels constituting the identified first area in the scattering coefficient distribution image.

12. A computer program product comprising a non-transitory computer-readable medium having programmed instructions stored thereon, the instructions causing a computer to execute:

acquiring a scattering coefficient distribution image having each pixel specified with a scattering coefficient of a measurement target region of a biological body for light including a wavelength range in a near infrared range;

estimating an amount of change in a biological component based on the scattering coefficient distribution image; and

storing a reference template having a size smaller than a size of the scattering coefficient distribution image and also having a predetermined shape, a first pattern of a biological body structure included in the scattering coefficient distribution image, and a relative position of the reference template with respect to the first pattern in the scattering coefficient distribution image, wherein

the estimating of the amount of change in the biological component includes

estimating the amount of change in the biological component based on a first area that is a part of the scattering coefficient distribution image,

identifying the first pattern included in the scattering coefficient distribution image,

identifying, as a first area, an area inside of the reference template placed at the relative position with respect to the identified first pattern in the scattering coefficient distribution image, and

estimating the amount of change in the biological component based on scattering coefficients specified in respective pixels constituting the identified first area in the scattering coefficient distribution image.

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