(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 397 960 A1**

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.07.2024 Bulletin 2024/28

(21) Application number: **24150896.9**

(22) Date of filing: **09.01.2024**

(51) International Patent Classification (IPC):
G01N 21/31 *(2006.01)* ***G01N 21/47*** *(2006.01)*
A61B 5/00 *(2006.01)* ***G01J 1/00*** *(2006.01)*
A61B 5/145 *(2006.01)* ***A61B 5/1455*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
G01N 21/474; A61B 5/00; A61B 5/14546; A61B 5/1455; A61B 5/681; G01J 3/00; G01N 21/31; G01N 2021/4759; G01N 2201/0222; G01N 2201/0662; G01N 2201/0668

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **09.01.2023 KR 20230002877**

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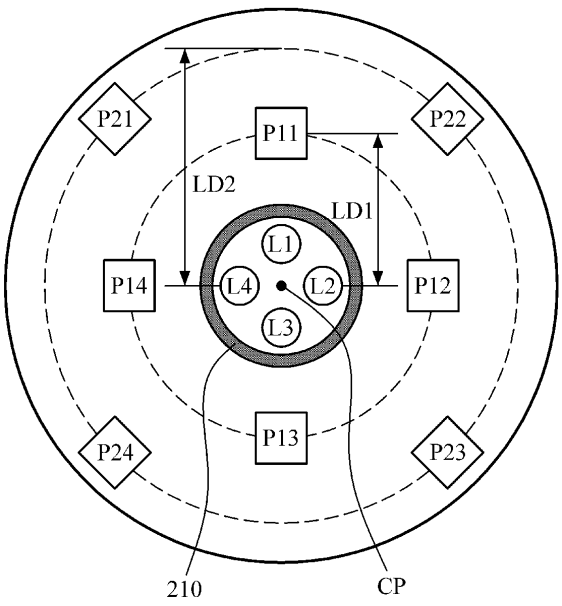
(54) APPARATUS AND METHOD FOR ESTIMATING BIO-INFORMATION

(57) An apparatus (100) for estimating bio-information, includes: a sensor (110) configured to detect at least one first light signal and at least one second light signal, each of the at least one first light signal having a first light path from an object and each of the at least one second light signal having a second light path from the object that is different from the first light path; and a processor (120) configured to: obtain a first absorbance based on the at least one first light signal, obtain a second absorbance based on the at least one second light signal, and estimate bio-information based on a difference between the first absorbance and the second absorbance.

FIG. 2A



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Description

BACKGROUND

1. Field

[0001] The disclosure relates to an apparatus and method for estimating bio-information such as antioxidant levels.

2. Description of Related Art

[0002] Reactive oxygen species (ROS) act as an important biological defense factor against free radicals similar to the protection offered by white blood cells that protect a body against infections. However, it has been known that excessive generation of ROS in the body may lead to various tissue diseases. Common factors that cause generation of ROS include stress, alcohol, peroxides, medicine, and the like. The ROS produced by these factors may cause cranial nerve diseases, circulatory diseases, cancer, digestive tract diseases, liver diseases, arteriosclerosis, renal diseases, diabetes, aging, and the like. Living organisms have a series of antioxidant defense systems to protect against oxygen toxicity. Antioxidants play a role in the normal operation of such antioxidant defense systems. Antioxidants may include, for example, vitamin E, vitamin C, carotenoid, and flavonoid.

SUMMARY

[0003] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0004] Additional aspects will be set forth in part in the description which follows and, in part, will be apparent from the description, or may be learned by practice of the presented embodiments.

[0005] The invention is claimed in the independent claims. Preferred embodiments are specified in the dependent claims.

[0006] According to an aspect of an example embodiment, an apparatus for estimating bio-information, includes: a sensor configured to detect at least one first light signal and at least one second light signal, each of the at least one first light signal having a first light path from an object and each of the at least one second light signal having a second light path from the object that is different from the first light path; and a processor configured to: obtain a first absorbance based on the at least one first light signal, obtain a second absorbance based on the at least one second light signal, and estimate bio-information based on a difference between the first absorbance and the second absorbance.

[0007] The sensor may include: at least one light source configured to emit light to the object; at least one first detector configured to detect the at least one first light signal with the first light path that is scattered or reflected by the object from the light emitted by the at least one light source; and at least one second detector configured to detect the at least one second light signal with the second light path that is scattered or reflected by the object from the light emitted by the at least one light source.

[0008] The at least one light source may be disposed at a center of the sensor, the at least one first detector may include a plurality of first detectors arranged in a first concentric circular shape at a first distance from the center of the sensor, and the at least one second detector may include a plurality of second detectors arranged in a second concentric circular shape at a second distance from the center of the sensor.

[0009] The at least one first detector may be disposed at a center of the sensor, the at least one light source may include a plurality of light sources arranged in a first concentric circular shape at a first distance from the center of the sensor, and the at least one second detector may include a plurality of second detectors arranged in a second concentric circular shape at a second distance from the first concentric circular shape.

[0010] The at least one second detector may be disposed at a center of the sensor, the at least one light source may include a plurality of light sources arranged in a second concentric circular shape that is at a second distance from the center of the sensor, and the at least one first detector arranged in a first concentric circular shape at a first distance from the second concentric circular shape.

[0011] The at least one light source have a wavelength in a range from 400 nm to 600 nm.

[0012] The apparatus may further include at least one partition wall disposed between the at least one light source and the at least one first detector or between the at least one light source and the at least one second detector.

[0013] A difference between the first light path and the second light path may be between 2 mm and 15 mm.

[0014] The processor may be further configured to: based on the at least one first light signal being detected, transform each of the at least one first light signal into a first logarithmic domain and combine the transformed at least one first light signal to obtain the first absorbance, and based on the at least one second light signal being detected, transform

each of the at least one second light signal into a second logarithmic domain and combine the transformed at least one second light signal to obtain the second absorbance.

[0015] The processor may be further configured to combine the transformed at least one first light signal and combine the at least one second light signal using at least one of an arithmetic mean, a harmonic mean, or a geometric mean.

[0016] The bio-information may include an antioxidant level, and the processor may be further configured to: determine an antioxidant peak based on the difference between the first absorbance and the second absorbance for a plurality of wavelengths, and obtain the antioxidant level based on the antioxidant peak.

[0017] According to an aspect of an example embodiment, a method of estimating bio-information, includes: detecting, by a sensor, at least one first light signal, each of the at least one first light signal having a first light path from an object; detecting, by the sensor, at least one second light signal, each of the at least one second light signal having a second light path from the object that is different from the first light path; obtaining, by a processor, a first absorbance based on the at least one first light signal; obtaining, by the processor, a second absorbance based on the at least one second light signal; and estimating, by the processor, bio-information based on a difference between the first absorbance and the second absorbance.

[0018] The sensor may include: at least one light source configured to emit light to the object; at least one first detector configured to detect the at least one first light signal with the first light path that is scattered or reflected by the object from the light emitted by the at least one light source; and at least one second detector configured to detect the at least one second light signal with the second light path that is scattered or reflected by the object from the light emitted by the at least one light source.

[0019] The obtaining the first absorbance may include, based on the at least one first light signal being detected, transforming each of the at least one first light signal into a first logarithmic domain and combining the transformed at least one first light signal to obtain the first absorbance, and the obtaining the second absorbance may include, based on the at least one second light signal being detected, transforming each of the at least one second light signal into a second logarithmic domain and combining the transformed at least one second light signal to obtain the second absorbance.

[0020] The bio-information may include an antioxidant level, and the estimating the bio-information may include determining an antioxidant peak based on the difference between the first absorbance and the second absorbance for a plurality of wavelengths, and obtaining the antioxidant level based on the antioxidant peak.

[0021] According to an aspect of an example embodiment, a device worn on a body part of a user for estimating an antioxidant level of the user, includes: a light source configured to emit light to the body part; a first detector spaced apart from the light source and configured to detect light scattered or reflected by the body part from the light emitted by the light source as a first light signal; a second detector spaced further apart from the light source than the first detector and configured to detect light scattered or reflected by the body part from the light emitted by the light source as a second light signal; and a processor configured to estimate the antioxidant level of the user based on the first light signal and the second light signal.

[0022] The device may be a smart watch configured to be worn on a wrist of the user.

[0023] The processor may be configured to estimate the antioxidant level without prior calibration of the light source.

[0024] The device may further include partition walls disposed between the light source and each of the first detector and the second detector.

[0025] The second detector may be spaced between 2 mm and 15 mm further apart from the light source than the first detector.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The above and other aspects, features, and advantages of certain embodiments of the present disclosure will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram illustrating an apparatus for estimating bio-information according to an example embodiment;

FIGS. 2A, 2B, and 2C are diagrams illustrating various embodiments of the structure of a sensor;

FIGS. 3A and 3B are diagrams for explaining an example of transforming a plurality of light signals detected by a plurality of detector into a logarithmic domain and combining the transformed light signals;

FIG. 4 is a graph showing a deviation between sensors when distance information is averaged and when distance information is not averaged;

FIG. 5 is a block diagram illustrating an apparatus for estimating bio-information according to another example embodiment;

FIG. 6 is a flowchart illustrating a method of estimating bio-information according to an example embodiment; and

FIGS. 7, 8, and 9 are diagrams illustrating structures of an electronic device.

DETAILED DESCRIPTION

[0027] Details of example embodiments are included in the following detailed description and drawings. Advantages and features of the disclosure, and a method of achieving the same will be more clearly understood from the following embodiments described in detail with reference to the accompanying drawings. Throughout the drawings and the detailed description, unless otherwise described, the same drawing reference numerals will be understood to refer to the same elements, features, and structures. In the drawings, the relative size and depiction of these elements may be exaggerated for clarity, illustration, and convenience.

[0028] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms may be used to distinguish one element from another. Also, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that when an element is referred to as "comprising" another element, the element is intended not to exclude one or more other elements, but to further include one or more other elements, unless explicitly described to the contrary. In the following description, terms such as "unit" and "module" indicate a unit for processing at least one function or operation and they may be implemented by using hardware, software, or a combination thereof.

[0029] FIG. 1 is a block diagram illustrating an apparatus for estimating bio-information according to an example embodiment.

[0030] Referring to FIG. 1, an apparatus 100 for estimating bio-information includes a sensor 110 and a processor 120.

[0031] The sensor 110 may measure two or more light signals having different light paths from an object of the user. For example, the object may include a palm or sole in which an epidermal layer is thick, an area in which venous blood or capillary blood is located or which is adjacent to the radial artery, and other peripheral parts of the human body, such as fingers, toes, or earlobes, which have a high density of blood vessels, and body parts such as wrists, or inner ears.

[0032] The sensor 110 may include a light source 111 configured to emit light to the object and a detector 112 configured to detect light reflected from the object. The light source 111 may include a light emitting diode (LED), a laser diode, a phosphor, or the like. The wavelength of the light source may range from 400 nm to 600 nm. The light source 111 may be provided in singular or plural numbers (e.g., three or more) and each may emit light of a different wavelength. The number, wavelength band, and the like of the light source 11 may be vary without limitation according to the type of bio-information, the size of form factor of the apparatus 100, and the like. A plurality of light sources 111 may be sequentially driven in a time-division manner, or simultaneously driven. Alternatively, a group of a predetermined number of light sources may be set as a unit group, the unit groups of the light sources are driven sequentially while the light sources in each group are simultaneously driven. The detector 112 may include, for example, a photodiode, a photo transistor, or the like, and one or more detectors 112 may be provided. However, this embodiment is not limited thereto, and the detector 112 may include a complementary metal-oxide semiconductor (CMOS) image sensor, a charge-coupled device (CCD) image sensor, or the like.

[0033] The light source 111 and the detector 112 may be arranged to have two or more light paths. For example, a detector (hereinafter referred to as a "first detector") may be disposed at a first distance from the light source 111 to have a first light path, and a detector (hereinafter referred to as a "second detector") may be disposed at a second distance from the light source 111 to have a second light path. The number and arrangement of the light sources and the detectors are not particularly limited. The second detector may be disposed 2 mm to 15 mm further away from the light source 111 than the first detector. A difference between the light paths may be 2 mm or greater and 15 mm or less. This embodiment is not limited thereto, and the difference between the light paths may vary without limitations according to the size of form factor, the contact area of the object, and the like.

[0034] FIGS. 2A, 2B, and 2C are diagrams illustrating various embodiments of the structure of the sensor 110.

[0035] Referring to FIG. 2A, light sources L1, L2, L3, and L4 may be disposed at the center of the sensor 110, and first detectors P11, P12, P13, and P14 and second detectors P21, P22, P23, and P24 may be disposed in a concentric circular shape at a first distance LD1 and a second distance LD2, respectively, from the center CP of the light sources L1, L2, L3, and L4. The center CP of the light sources L1, L2, L3, and L4 may mean the center of the light sources when there is one light source, and may mean the center of a space formed by a plurality of light sources when there are a plurality of light sources.

[0036] Referring to FIG. 2B, the first detector P11 may be disposed at the center of the sensor 110, and the light sources L1, L2, L3, and L4 may be disposed in a concentric circular shape at the first distance LD1 from the center of the first detector P11. The second detectors P21, P22, P23, and P24 may be disposed in a concentric circular shape at the second distance LD2 from the light sources L1, L2, L3, and L4. That is, the distance between the concentric circle on which the light sources L1, L2, L3, and L4 are disposed and the concentric circle on which the second detectors P21, P22, P23, and P24 may be the second distance LD2.

[0037] Referring to FIG. 2C, the second detector P21 may be disposed at the center of the sensor 110, and the light sources L1, L2, L3, and L4 may be disposed in a concentric circular shape at the second distance LD2 from the center of the second detector P21. Also, the first detectors P11, P12, P13, and P14 may be disposed in a concentric circular

shape at the first distance LD1 from the light sources L1, L2, L3, and L4 in an inward direction.

[0038] Referring to FIGS. 2A, 2B, and 2C, the sensor 110 may further include partition walls 210, 221, 222, 231, 233, and 234 to prevent light emitted from the light sources L1, L2, L3, and L4 from being directly incident onto the first detectors P11, P12, P13, and P14 and the second detectors P21, P22, P23, and P24. The partition walls may be have a ring shape that surrounds the entire light sources L1, L2, L3, and L4 (partition wall 210 in FIG. 2A and partition wall 222 in FIG. 2B), a ring shape that surrounds each of the light sources L1, L2, L3, and L4 (partition walls 231, 232, 233, and 234 in FIG. 2C), a ring shape that surrounds the detector P11 (partition wall 221 in FIG. 2B), or the like. However, the shape of the partition wall is not limited to the ring shape, and may be modified in various shapes, such as a triangular shape, a rectangular shape, or the like, and may be omitted as necessary in consideration of the arrangement of the sensor 110, the form factor, the type of bio-information to be estimated, the purpose of estimation, required accuracy, etc.

[0039] Referring back to FIG. 1, the processor 120 may be electrically connected to the sensor 110 or connected thereto via wireless communications and control the sensor 110. The processor 120 may drive the sensor 110 and the light source 111 upon a user's request for estimating antioxidant activity, and may obtain a first light signal and a second light source by driving, respectively, the first detector 112 on a first light path and the second detector 112 on a second light path while the light source 111 is turned on. In this case, the first detector 112 and the second detector 112 may be simultaneously driven, or may be sequentially driven (first detector->second detector or second detector->first detector). In a case where a plurality of light sources 111 are provided, the light sources of each wavelength are sequentially driven in a time-division manner, and a first light signal and a second signal may be obtained for each wavelength.

[0040] The processor 120 may obtain a first absorbance using the first light signal and a second absorbance using the second light signal for each wavelength, and obtain an antioxidant level based on the first absorbance and the second absorbance. For example, the antioxidant level may be estimated based on a difference between the first absorbance and the second absorbance for each wavelength. As described below, since an antioxidant level is estimated using a difference in absorbance of light signals having different light paths, there is no need to perform calibration of the light sources used for obtaining the amount of light emitted initially before estimating the antioxidant level.

[0041] FIGS. 3A and 3B are diagrams for explaining an example of transforming a plurality of light signals detected by a plurality of detector into a logarithmic domain and combining the transformed light signals.

[0042] Referring to FIG. 3A, generally, when light emitted from a light source L is scattered or reflected by an object and reaches a detector P, the amount of light measured at the detector P may be represented by Equation 1 based on the Lambert-Beer's law as shown below.

$$I = I_0 10^{-\varepsilon c d} \quad \ldots(1)$$

[0043] In Equation 1, I denotes the amount of light detected by the detector. I_0 denotes the amount of light emitted from the light source, which may be the amount of light measured through a standard reflector at the time of calibration. ε denotes an absorption coefficient of an antioxidant component, c denotes the concentration of the antioxidant component, and d denotes a distance between the light source L and the detector P.

[0044] With respect to the light source of each wavelength, the processor 120 may represent each of a first light quantity of the first light signal detected by the first detector and a second light quantity of the second light signal measured by the second detector as a linear relationship equation of Equation 1.

[0045] The processor 120 may transform a linear domain into a logarithmic domain by applying a logarithmic operation to the linear relationship equation for each of the first light quantity and the second light quantity, which may be represented as shown below in Equation 2. In the logarithmic operation, the base of the logarithm may be 10 or a natural constant e, and is not limited thereto. Also, a nonlinear function, a regression equation, an empirical equation may be used instead of the logarithmic operation depending on the characteristics of the sensor to be fabricated, and the embodiment is not limited thereto.

$$\log I = \log I_0 - \varepsilon c d \quad \ldots(2)$$

[0046] The processor 120 may obtain the first absorbance and the second absorbance by combining the first light quantities transformed into a logarithmic domain and the second light quantities transformed into a logarithmic domain, respectively. In the case where, as shown in (1) of FIG. 3B, four detectors P1, P2, P3, and P4 are disposed at distances d1, d2, d3, and d4, respectively, from the light source L, light quantities, each transformed into a logarithmic domain through Equation 2, may be combined to be averaged as a light quantity detected by one detector P_{avg} at an average distance d_{avg} from the light source L as shown in (2) of FIG. 3B. In this way, a deviation of distances d1, d2, d3, and d4

of the plurality of detectors P1, P2, P3, and P4 from the light source L of a specific wavelength may be canceled. Equation 3 below is an example of combining the light quantities transformed into the logarithmic domain of the four detectors P1, P2, P3, and P4.

$$I_{fm} = f(\log I_{m1},\ \log I_{m2},\ \log I_{m3},\ \log I_{m4}) \quad \ldots(3)$$

[0047] $\log/_{m1}$, $\log/_{m2}$, $\log/_{m3}$, and $\log/_{m4}$ denote values obtained by transforming the light quantities obtained by the respective detectors P1, P2, P3, and P4 into a distance domain for a specific wavelength. I_{fm} denotes a value obtained by combining $\log/_{m1}$, $\log/_{m2}$, $\log/_{m3}$, and $\log/_{m4}$.

[0048] A combination function f may be one of arithmetic mean (see Equation 4 below), harmonic mean (see Equation 5 below), and geometric mean (see Equation 6 below), but is not limited thereto. The processor 120 may use an arithmetic mean filter, a harmonic mean filter, or a geometric mean filter to perform arithmetic mean, harmonic mean, or geometric mean.

$$I_{fm} = \frac{\log I_{m1} + \log I_{m2} + \log I_{m3} + \log I_{m4}}{4} \quad \ldots(4)$$

$$I_{fm} = \frac{4(\log I_{m1} \times \log I_{m2} \times \log I_{m3} \times \log I_{m4})}{\log I_{m1} + \log I_{m2} + \log I_{m3} + \log I_{m4}} \quad \ldots(5)$$

$$I_{fm} = \sqrt[4]{\log I_{m1} \times \log I_{m2} \times \log I_{m3} \times \log I_{m4}} \quad \ldots(6)$$

[0049] The arrangement deviation of a light source and a detector of the sensor may cause a change in the length of a light path between the light source and the detector, which may change the intensity of a measured signal and thus reduce the accuracy of bio-information estimation. In this example embodiment, a plurality of light quantities obtained by a plurality of detectors may be transformed into a logarithmic domain and then combined, thereby canceling a distance deviation. FIG. 4 is a graph showing a deviation between sensors when distance information is averaged and when distance information is not averaged. The X axis shows a general case (general) where distance information is not averaged, a case (log arithmetic) of arithmetic mean of distance information, a case (log geometric) of geometric mean of distance information, and a case (log harmonic) of harmonic mean of distance information, and the Y-axis represents a deviation between sensors in percentage. It can be seen that the deviation in the case of measuring bio-information by averaging distance information transformed into the logarithmic domain is maintained constant and is lower than the deviation in the general case where the distance information is not averaged.

[0050] The processor 120 may obtain the first absorbance and the second absorbance by combining the first light quantities of the first light path and the second light quantities of the second light path for each wavelength, respectively, and obtain an antioxidant level using a difference between the first absorbance and the second absorbance. The difference between the first absorbance and the second absorbance is obtained by Equation 7 as shown below.

$$A_2 - A_1 = -\log_{10}\frac{I_1}{I_0} + \log_{10}\frac{I_2}{I_0} = \varepsilon c\Delta = \log_{10}\frac{I_1}{I_2} \quad \ldots(7)$$

[0051] A_1 and A_2 represent a first absorbance and a second absorbance of a light source of a specific wavelength. I_1 and I_2 denote a combined value of first quantities and a combined value of second quantities, respectively. Δ represents a difference between a first light path and a second light path. I_0 denotes the amount of light emitted from the light source, and is eliminated in a relationship equation. Therefore, it is not necessary to perform a calibration process for measuring the amount of light emitted from the light source using a standard reflected wave, etc., so that user convenience can be improved. Also, accuracy may be improved by automatically correcting the change in light quantity due to temperature change, device deterioration and sensor fabrication characteristics by using light quantities on two or more light paths.

[0052] When the difference between the first absorbance and the second absorbance for each wavelength is obtained, the processor 120 may obtain an antioxidant level using the difference in absorbance. The processor 120 may obtain an antioxidant peak as a feature value. As shown below, Equation 8 is an example of obtaining an antioxidant peak by using three wavelengths and Equation 9 is an example of obtaining an antioxidant peak by using four wavelengths.

$$AO = A_{\lambda_2} - \left(\frac{\lambda_3 - \lambda_2}{\lambda_3 - \lambda_1}\right) \times A_{\lambda_1} - \left(\frac{\lambda_2 - \lambda_1}{\lambda_3 - \lambda_1}\right) \times A_{\lambda_3} \quad \ldots(8)$$

[0053] Here, *AO* represents an antioxidant peak as an example of a feature value. λ_1 λ_2, and λ_3 represent wavelengths, and $A_{\lambda 1}$, $A_{\lambda 2}$, and $A_{\lambda 3}$ represent the difference in absorbance for each wavelength obtained through Equation 7 above. The wavelengths may be longer in the order of $A_{\lambda 1}$, $A_{\lambda 2}$, and $A_{\lambda 3}$.

$$AO = aA_{\lambda_1} + bA_{\lambda_2} + cA_{\lambda_3} + dA_{\lambda_4} + e \quad \ldots(9)$$

[0054] Here, $A_{\lambda 1}$, $A_{\lambda 2}$, $A_{\lambda 3}$, and $A_{\lambda 4}$ represent the difference in absorbance for each wavelength obtained through Equation 7 above. *a*, *b*, *c*, and *d* are predetermined coefficients, and e is a predetermined constant.

[0055] The processor 120 may obtain an antioxidant level based on an antioxidant peak obtained through Equations 8 and 9. In one example, an antioxidant peak value may be obtained as the antioxidant level. In another example, an antioxidant level may be obtained by inputting an antioxidant peak value into an antioxidant estimation model defined as shown in Equation 10. Equation 10 represents a linear equation, but is not limited thereto, and may be defined as a nonlinear equation, such as a logarithmic equation and an exponential equation.

$$Y = a \times AO + b \quad \ldots(10)$$

[0056] Here, Y represents an antioxidant level, and a and b represent preset values.

[0057] FIG. 5 is a block diagram illustrating an apparatus for estimating bio-information according to another example embodiment.

[0058] Referring to FIG. 5, an apparatus 500 for estimating bio-information may include a sensor 510, a processor 520, a storage (or memory) 530, an output interface 540, and a communication interface 550. The sensor 510 and the processor 520 are the same as the sensor 110 and the processor 120 of the example embodiment shown in FIG. 1, and thus detailed descriptions thereof will not be reiterated.

[0059] The storage 530 may store programs (e.g., application software) to be executed by the processor 520. The program may store one or more commands for performing various functions including the aforementioned bio-information estimation and input data and/or output data for the commands. For example, the storage 530 may store driving conditions of the sensor 510, a bio-information estimation model, user information (e.g., age, gender, height, weight, etc.), light signals measured by the sensor, an estimated bio-information value, and the like.

[0060] The storage 530 may include at least one type of storage medium of a flash memory type, a hard disk type, a multimedia card micro type, a card type memory (for example, secure digital (SD) or extreme digital (XD) memory), a random access memory (RAM), a static random access memory (SRAM), a read-only memory (ROM), an electrically erasable programmable read-only memory (EEPROM), a programmable read-only memory (PROM), a magnetic memory, a magnetic disk, and an optical disk, but is not limited thereto.

[0061] The output interface 540 may output processing results of the processor 520 to a user. The output interface 540 may include a display device 541, provide a graphic user interface through the display device 541, and visually display the result of estimating bio-information on the graphic user interface. For example, the output interface 540 may display a graph showing change over time in antioxidant level, and may display a visual object movable on a time line above the graph. When the user moves the visual object to select an intended point in time, the output interface 540 may display bio-information, absorbance information, and the like at the selected point in time in response to the user's selection. In addition, when the bio-information falls outside a normal range, the output interface 540 may display warning information. In addition, the output interface 540 may further include a voice output module, a haptic module, and the like in addition to the display device and provide the bio-information estimation result to the user through non-visual methods such as voice, vibration, tactile sensation, and the like.

[0062] The communication interface 550 may be connected to an external device and transmit/receive various types

data using wired/wireless communication technology under the control of the processor 520. The external device may include an information processing device, such as a smartphone, a tablet personal computer (PC), a desktop PC, a notebook PC, cloud, and the like. For example, the communication interface 540 may receive light signal data measured by a sensor of the external device, transmit the received light signal data to the processor 520, and transmit an estimated bio-information value measured by the processor 520 to the external device.

[0063] The communication interface 550 may communicate with the external device by using various wired/wireless communication technology such as Bluetooth communication, Bluetooth low energy (BLE) communication, near field communication (NFC), wireless local access network (WLAN) communication, ZigBee communication, infrared data association (IrDA) communication, Wi-Fi Direct (WFD) communication, ultra-wideband (UWB) communication, Ant+ communication, Wi-Fi communication, radio frequency identification (RFID) communication, 3G communication, 4G communication, 5G communication, and 6G communication. However, the embodiment is not limited thereto.

[0064] FIG. 6 is a flowchart illustrating a method of estimating bio-information according to an example embodiment.

[0065] The method illustrated in FIG. 6 is an example of a method performed by the apparatuses 100 and 500 for estimating bio-information shown in FIGS. 1 and 5, and will be briefly described below to avoid redundancy. Among operations to be described below, operation 612 to operation 617 may be simultaneously performed irrespective of the order of description. Alternatively, operations 612, 614, and 615 regarding a first light path may be first performed, and thereafter operations 613, 615, and 617 regarding a second light path may be performed, or vice versa.

[0066] First, a light source of a previous wavelength may be turned off and a light source of a wavelength to be driven next may be turned on in operation 611. The light source may be provided in plural to emit light of a plurality of different wavelengths and may be sequentially driven in a predetermined order. The wavelength of the light source may range from 400 nm to 600 nm.

[0067] Then, first light signals for the driven wavelength may be measured using first detectors disposed on the first light path in operation 612, a logarithmic operation may be applied to transform first light quantities of the measured first light signals into a logarithmic domain in operation 614, and a first absorbance may be obtained by combining the first light quantities transformed into a logarithmic domain in operation 616. The first detectors may be disposed at a first distance from the light source to have the first light path. The logarithmic operation may include common logarithms, natural logarithms, and the like, and is not limited thereto. The combination may be one of an arithmetic mean, a geometric mean, and a harmonic mean, but is not limited thereto.

[0068] Similarly, second light signals for the driven wavelength may be measured using second detectors disposed on a second light path in operation 613, and a logarithmic operation may be applied to transform second light quantities of the measured second light signals into a logarithmic domain in operation 615, and a second absorbance may be obtained by combining the second light quantities transformed into a logarithmic domain in operation 617. The second detectors may be disposed at a second distance from the light source to have the second light path.

[0069] Thereafter, a difference between the first absorbance and the second absorbance for the wavelength driven in operation 611 may be calculated in operation 618. In the process of obtaining the difference between the first absorbance and the second absorbance, the amount of light emitted from the light source is canceled, and thus there is no need to perform a calibration process for obtaining the amount of light emitted from the light source, thereby improving user convenience.

[0070] Then, if the next wavelength to be driven remains in operation 619, operations 611 to 618 may be performed for the next wavelength, and if the calculation for all wavelengths is completed in operation 619, bio-information may be estimated based on the difference in absorbance of each wavelength obtained in operation 618 in operation 620. For example, an antioxidant peak may be obtained by combining the difference in absorbance of each wavelength and the antioxidant peak may be input to an antioxidant estimation model to obtain an antioxidant level.

[0071] FIGS. 7, 8, and 9 are diagrams illustrating various structures of an electronic device including the apparatus 100 or 500 for estimating bio-information described above.

[0072] An electronic device may include a wearable device, for example, a smart watch type, a smart band type, smart eyeglass type, a smart earphone type, a smart ring type, a smart patch, and a smart necklace type, a mobile device, such as a smartphone or a tablet PC, a home appliance, or various types of Internet of Things (IoT) device (e.g., home IoT device).

[0073] The electronic device may include a sensor device, a processor, an input device, a communication module, a camera module, an output device, a storage device, and a power module. The components of the electronic device may be integrally mounted in a specific device, or mounted in two or more devices in a distributed manner. The sensor device may include the sensors 110 and 510 of the apparatuses 100 and 500 for estimating bio-information, and may include additional sensors, such as a gyro sensor, and a global positioning system (GPS).

[0074] The processor may control the components connected to the processor by executing a program or the like stored in the storage device, and may perform various data processing including bio-information estimation, or operations. The processor may include a main processor, such as a central processing unit and an application processor, and a co-processor that can be operated independently or together with the main processor, for example, a graphics processing

unit, an image signal processor, a sensor hub processor, and a communication processor.

[0075] The input device may receive a command and/or data to be used in each component of the electronic device from the user or the like. The input device may include a microphone, a mouse, a keyboard, and/or a digital pen (e.g., a stylus pen).

[0076] The communication module may support the establishment of a direct (wired) communication channel and/or wireless communication channel between the electronic device and another electronic device or a server in a network environment or the sensor module and the communication therebetween through the established communication channel. The communication module may be operated independently of the processor 920 and may include one or more communication processors that support direct communication and/or wireless communication. The communication module may include a wireless communication module, such as, a cellular communication module, a short-range wireless communication module, a global navigation satellite system (GNSS) communication module, or the like, and/or a wired communication module, such as a local area network (LAN) communication module, a power line communication module, or the like. Such various types of communication modules may be integrated into a single chip, or may be implemented as a plurality of separate chips. The wireless communication module may verify and authenticate the electronic device in a communication network using subscriber information (e.g., international mobile subscriber identity (IMSI)) stored in a subscriber identity module.

[0077] The camera module may capture still images and moving images. The camera module may include a lens assembly including one or more lenses, image sensors, image signal processors, and/or flashes. The lens assembly included in the camera module may collect light emitted from a subject to be imaged.

[0078] The output device may output data generated or processed by the electronic device in a visual/non-visual manner. The output device may include a sound output device, a display device, an audio module, and/or a haptic module.

[0079] The sound output device may output a sound signal to the outside of the electronic device. The sound output device may include a speaker and/or a receiver. The speaker may be used for general purposes, such as multimedia playback or recording playback, and the receiver may be used to receive incoming calls. The receiver may be combined as part of the speaker or may be implemented as an independent separate device.

[0080] The display device may visually provide information to the outside of the electronic device. The display device may include a display, a hologram device, or a projector, and control circuitry to control a corresponding one of the display, hologram device, and projector. The display device may include touch circuitry adapted to detect a touch, or sensor circuitry (e.g., a pressure sensor) adapted to measure the intensity of force incurred by the touch.

[0081] The audio module may transform a sound into an electrical signal and vice versa. The audio module may obtain the sound via the input device, or output the sound via the sound output device or a speaker and/or a headphone of an external electronic device directly (e.g., wiredly) or wirelessly coupled with the electronic device.

[0082] The haptic module may transform an electrical signal into a mechanical stimulus (e.g., a vibration or motion) or electrical stimulus which may be recognized by a user via his or her tactile sensation or kinesthetic sensation. The haptic module may include, for example, a motor, a piezoelectric element, and/or an electric stimulator.

[0083] The storage device may store driving conditions required for driving the sensor module and various data required by other components of the electronic device, for example, software and input data and/or output data for commands related to the software. The storage device may include volatile memory and/or non-volatile memory.

[0084] The power module may manage power supplied to the electronic device. The power module may be configured as part of a power management integrated circuit (PMIC). The power module may include a battery and the battery may include a non-rechargeable primary cell, a rechargeable secondary cell, and/or a fuel cell.

[0085] Referring to FIG. 7, the electronic device may be implemented as a smart watch 700 and may include a body and a wrist strap. A display may be provided on a front surface of the main body, and various application screens containing time information, received message information, and the like may be displayed thereon. A sensor 710 may be disposed on the rear surface of the main body.

[0086] Referring to FIG. 8, the electronic device may be implemented as a mobile device 800 such as a smartphone. The mobile device 800 may include a housing and a display panel. The housing may form the outer appearance of the mobile device 800. The display panel and cover glass may be sequentially arranged on a first surface of the main body, and the display panel may be exposed to the outside through the cover glass. A sensor 810, a camera module, and/or an infrared sensor may be disposed on the rear surface or lateral surface of the housing. A processor and other various components may be disposed inside the housing.

[0087] Referring to FIG. 9, the electronic device may be implemented as an ear-wearable device 900. The ear-wearable device 900 may include a main body and an ear strap. The user may wear the electronic device by wearing the ear strap on the auricle. The ear strap may be omitted depending on the shape of the ear-wearable device 900. The main body may be inserted into the external auditory meatus of the user. A sensor device 910 and a processor are disposed in the main body and the process may estimate bio-information using light signals measured by the sensor device 910. Alternatively, the ear-wearable device 900 may cooperate with an external device and transmit the light signals measured by the sensor device 910 to the external device through a communication module, thereby allowing a processor of the

external device to estimate bio-information. In this case, an estimated bio-information value may be visually output through a display of the external device, and optionally, may be output through a sound output module provided in the main body of the ear-wearable device.

[0088] The disclosed embodiments may be realized as a computer-readable code written on a computer-readable recording/storage medium. The computer-readable recording/storage medium may be any type of recording device in which data is stored in a computer-readable manner.

[0089] Examples of the computer-readable recording/storage medium include a ROM, a RAM, a compact disc (CD)-ROM, a magnetic tape, a floppy disc, an optical data storage, and a carrier wave (e.g., data transmission through the Internet). The computer-readable recording/storage medium may be distributed over a plurality of computer systems connected to a network so that a computer-readable code is written thereto and executed therefrom in a decentralized manner. Functional programs, codes, and code segments for realizing the embodiments can be easily deduced by programmers of ordinary skill in the art, to which the embodiments pertain.

[0090] Although various example embodiments have been described, it will be understood that various modifications may be made. For example, suitable results may be achieved if the described techniques are performed in a different order and/or if components in a described system, architecture, device, or circuit are combined in a different manner and/or replaced or supplemented by other components or their equivalents. The present invention is claimed in the enclosed claims.

The following is a list of further preferred embodiments of the invention:

[0091]

Embodiment 1. An apparatus for estimating bio-information, the apparatus comprising:

a sensor configured to detect at least one first light signal and at least one second light signal, each of the at least one first light signal having a first light path from an object and each of the at least one second light signal having a second light path from the object that is different from the first light path; and
a processor configured to:

obtain a first absorbance based on the at least one first light signal,
obtain a second absorbance based on the at least one second light signal, and
estimate bio-information based on a difference between the first absorbance and the second absorbance.

Embodiment 2. The apparatus of embodiment 1, wherein the sensor comprises:

at least one light source configured to emit light to the object;
at least one first detector configured to detect the at least one first light signal with the first light path that is scattered or reflected by the object from the light emitted by the at least one light source; and
at least one second detector configured to detect the at least one second light signal with the second light path that is scattered or reflected by the object from the light emitted by the at least one light source.

Embodiment 3. The apparatus of embodiment 2, wherein the at least one light source is disposed at a center of the sensor,

wherein the at least one first detector comprises a plurality of first detectors arranged in a first concentric circular shape at a first distance from the center of the sensor, and
wherein the at least one second detector comprises a plurality of second detectors arranged in a second concentric circular shape at a second distance from the center of the sensor.

Embodiment 4. The apparatus of embodiment 2, wherein the at least one first detector is disposed at a center of the sensor,

wherein the at least one light source comprises a plurality of light sources arranged in a first concentric circular shape at a first distance from the center of the sensor, and
wherein the at least one second detector comprises a plurality of second detectors arranged in a second concentric circular shape at a second distance from the first concentric circular shape.

Embodiment 5. The apparatus of embodiment 2, wherein the at least one second detector is disposed at a center

of the sensor,

wherein the at least one light source comprises a plurality of light sources arranged in a second concentric circular shape that is at a second distance from the center of the sensor, and
wherein the at least one first detector arranged in a first concentric circular shape at a first distance from the second concentric circular shape.

Embodiment 6. The apparatus of embodiment 2, wherein the at least one light source have a wavelength in a range from 400 nm to 600 nm.

Embodiment 7. The apparatus of embodiment 2, further comprising at least one partition wall disposed between the at least one light source and the at least one first detector or between the at least one light source and the at least one second detector.

Embodiment 8. The apparatus of embodiment 1, wherein a difference between the first light path and the second light path is between 2 mm and 15 mm.

Embodiment 9. The apparatus of embodiment 1, wherein the processor is further configured to:

based on the at least one first light signal being detected, transform each of the at least one first light signal into a first logarithmic domain and combine the transformed at least one first light signal to obtain the first absorbance, and
based on the at least one second light signal being detected, transform each of the at least one second light signal into a second logarithmic domain and combine the transformed at least one second light signal to obtain the second absorbance.

Embodiment 10. The apparatus of embodiment 9, wherein the processor is further configured to combine the transformed at least one first light signal and combine the at least one second light signal using at least one of an arithmetic mean, a harmonic mean, or a geometric mean.

Embodiment 11. The apparatus of embodiment 1, wherein the bio-information comprises an antioxidant level, and wherein the processor is further configured to:

determine an antioxidant peak based on the difference between the first absorbance and the second absorbance for a plurality of wavelengths, and
obtain the antioxidant level based on the antioxidant peak.

Embodiment 12. A method of estimating bio-information, the method comprising:

detecting, by a sensor, at least one first light signal, each of the at least one first light signal having a first light path from an object;
detecting, by the sensor, at least one second light signal, each of the at least one second light signal having a second light path from the object that is different from the first light path;
obtaining, by a processor, a first absorbance based on the at least one first light signal;
obtaining, by the processor, a second absorbance based on the at least one second light signal; and
estimating, by the processor, bio-information based on a difference between the first absorbance and the second absorbance.

Embodiment 13. The method of embodiment 12, wherein the sensor comprises:

at least one light source configured to emit light to the object;
at least one first detector configured to detect the at least one first light signal with the first light path that is scattered or reflected by the object from the light emitted by the at least one light source; and
at least one second detector configured to detect the at least one second light signal with the second light path that is scattered or reflected by the object from the light emitted by the at least one light source.

Embodiment 14. The method of embodiment 12, wherein the obtaining the first absorbance comprises, based on the at least one first light signal being detected, transforming each of the at least one first light signal into a first

logarithmic domain and combining the transformed at least one first light signal to obtain the first absorbance, and wherein the obtaining the second absorbance comprises, based on the at least one second light signal being detected, transforming each of the at least one second light signal into a second logarithmic domain and combining the transformed at least one second light signal to obtain the second absorbance.

Embodiment 15. The method of embodiment 12, wherein the bio-information comprises an antioxidant level, and wherein the estimating the bio-information comprises:

determining an antioxidant peak based on the difference between the first absorbance and the second absorbance for a plurality of wavelengths, and
obtaining the antioxidant level based on the antioxidant peak.

Embodiment 16. A device worn on a body part of a user for estimating an antioxidant level of the user, the device comprising:

a light source configured to emit light to the body part;
a first detector spaced apart from the light source and configured to detect light scattered or reflected by the body part from the light emitted by the light source as a first light signal;
a second detector spaced further apart from the light source than the first detector and configured to detect light scattered or reflected by the body part from the light emitted by the light source as a second light signal; and
a processor configured to estimate the antioxidant level of the user based on the first light signal and the second light signal.

Embodiment 17. The device of embodiment 16, wherein the device is a smart watch configured to be worn on a wrist of the user.

Embodiment 18. The device of embodiment 16, wherein the processor is configured to estimate the antioxidant level without prior calibration of the light source.

Embodiment 19. The device of embodiment 16, further comprising partition walls disposed between the light source and each of the first detector and the second detector.

Embodiment 20. The device of embodiment 16, wherein the second detector is spaced between 2 mm and 15 mm further apart from the light source than the first detector.

Claims

1. An apparatus for estimating bio-information, the apparatus comprising:

a sensor configured to detect at least one first light signal and at least one second light signal, each of the at least one first light signal having a first light path from an object and each of the at least one second light signal having a second light path from the object that is different from the first light path; and
a processor configured to:

obtain a first absorbance based on the at least one first light signal,
obtain a second absorbance based on the at least one second light signal, and
estimate bio-information based on a difference between the first absorbance and the second absorbance.

2. The apparatus of claim 1, wherein the sensor comprises:

at least one light source configured to emit light to the object;
at least one first detector configured to detect the at least one first light signal with the first light path that is scattered or reflected by the object from the light emitted by the at least one light source; and
at least one second detector configured to detect the at least one second light signal with the second light path that is scattered or reflected by the object from the light emitted by the at least one light source.

3. The apparatus of claim 2, wherein the at least one light source is disposed at a center of the sensor,

wherein the at least one first detector comprises a plurality of first detectors arranged in a first concentric circular shape at a first distance from the center of the sensor, and
wherein the at least one second detector comprises a plurality of second detectors arranged in a second concentric circular shape at a second distance from the center of the sensor.

4. The apparatus of claim 2, wherein the at least one first detector is disposed at a center of the sensor,

wherein the at least one light source comprises a plurality of light sources arranged in a first concentric circular shape at a first distance from the center of the sensor, and
wherein the at least one second detector comprises a plurality of second detectors arranged in a second concentric circular shape at a second distance from the first concentric circular shape.

5. The apparatus of claim 2, wherein the at least one second detector is disposed at a center of the sensor,

wherein the at least one light source comprises a plurality of light sources arranged in a second concentric circular shape that is at a second distance from the center of the sensor, and
wherein the at least one first detector arranged in a first concentric circular shape at a first distance from the second concentric circular shape.

6. The apparatus of claim 2, wherein the at least one light source have a wavelength in a range from 400 nm to 600 nm, or further comprising at least one partition wall disposed between the at least one light source and the at least one first detector or between the at least one light source and the at least one second detector.

7. The apparatus of one of claims 1 to 6, wherein a difference between the first light path and the second light path is between 2 mm and 15 mm.

8. The apparatus of one of claims 1 to 7, wherein the processor is further configured to:

based on the at least one first light signal being detected, transform each of the at least one first light signal into a first logarithmic domain and combine the transformed at least one first light signal to obtain the first absorbance, and
based on the at least one second light signal being detected, transform each of the at least one second light signal into a second logarithmic domain and combine the transformed at least one second light signal to obtain the second absorbance.

9. The apparatus of claim 8, wherein the processor is further configured to combine the transformed at least one first light signal and combine the at least one second light signal using at least one of an arithmetic mean, a harmonic mean, or a geometric mean.

10. The apparatus of one of claims 1 to 9, wherein the bio-information comprises an antioxidant level, and
wherein the processor is further configured to:

determine an antioxidant peak based on the difference between the first absorbance and the second absorbance for a plurality of wavelengths, and
obtain the antioxidant level based on the antioxidant peak.

11. A computer-readable storage medium storing instructions that, when executed by a processor of an apparatus for estimating bio-information having a sensor configured to detect at least one first light signal, each of the at least one first light signal having a first light path from an object, and to detect at least one second light signal, each of the at least one second light signal having a second light path from the object that is different from the first light path, cause the processor to:

obtain a first absorbance based on the at least one first light signal;
obtain a second absorbance based on the at least one second light signal; and
estimate bio-information based on a difference between the first absorbance and the second absorbance.

12. The computer-readable storage medium of claim 11, wherein for obtaining the first absorbance, the processor is further instructed, based on the at least one first light signal being detected, to transform each of the at least one

first light signal into a first logarithmic domain and combine the transformed at least one first light signal to obtain the first absorbance, and
wherein for obtaining the second absorbance, the processor is further instructed, based on the at least one second light signal being detected, to transform each of the at least one second light signal into a second logarithmic domain and combine the transformed at least one second light signal to obtain the second absorbance.

13. The computer-readable storage medium of claim 11 or 12, wherein the bio-information comprises an antioxidant level, and the processor is further instructed to:

determine an antioxidant peak based on the difference between the first absorbance and the second absorbance for a plurality of wavelengths, and
obtain the antioxidant level based on the antioxidant peak.

14. A method of operating a device worn on a body part of a user for estimating an antioxidant level of the user, the method comprising:

emitting, by a light source, light to the body part;
detecting, by a first detector spaced apart from the light source, light scattered or reflected by the body part from the light emitted by the light source as a first light signal;
detecting, by a second detector spaced further apart from the light source than the first detector, light scattered or reflected by the body part from the light emitted by the light source as a second light signal; and
estimating, by a processor, the antioxidant level of the user based on the first light signal and the second light signal.

15. The method of claim 14, further comprising:
operating the device comprises operating a smart watch configured to be worn on a wrist of the user, and/or estimating, by the processor, the antioxidant level without prior calibration of the light source.

FIG. 1

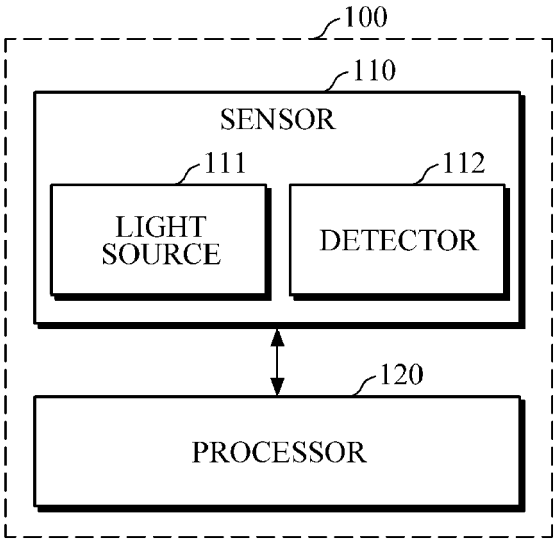


FIG. 2A

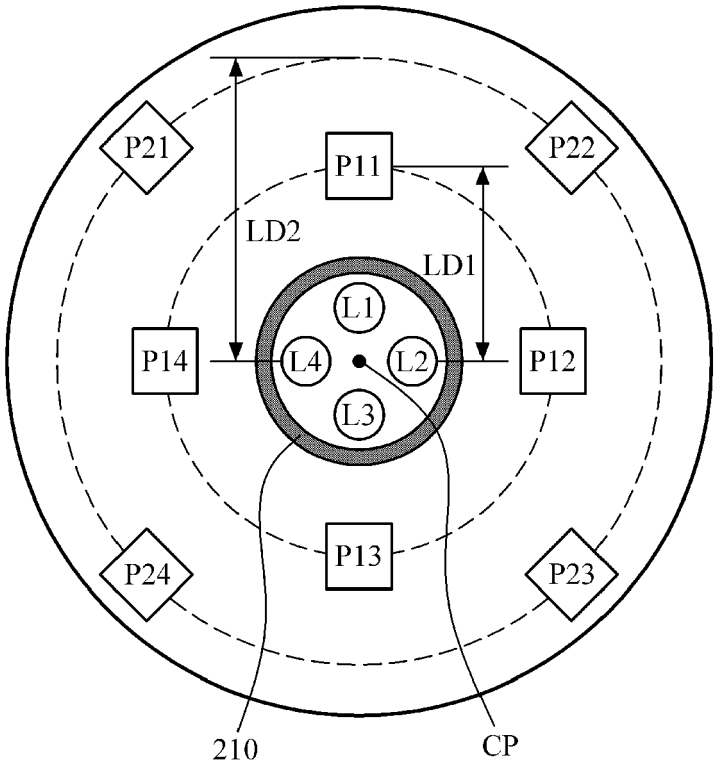


FIG. 2B

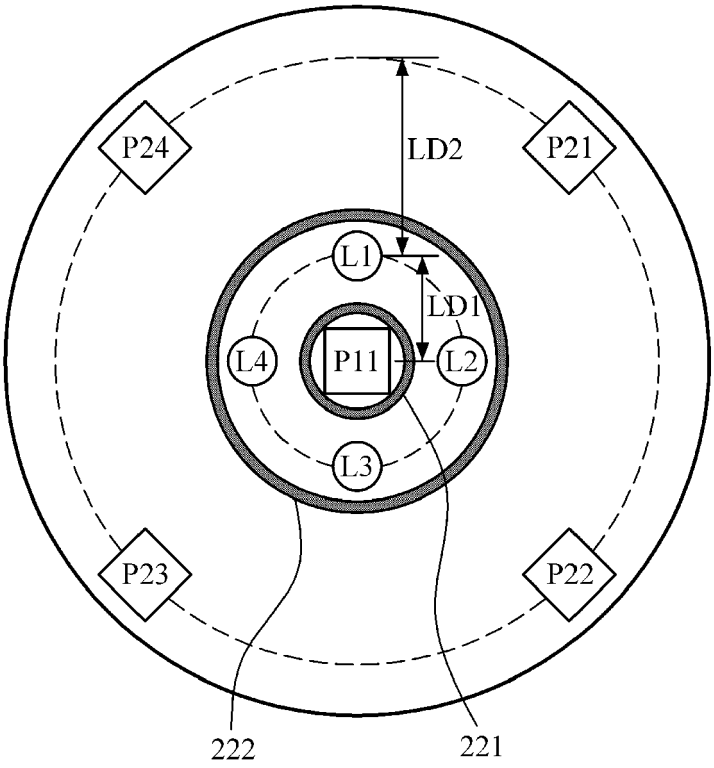


FIG. 2C

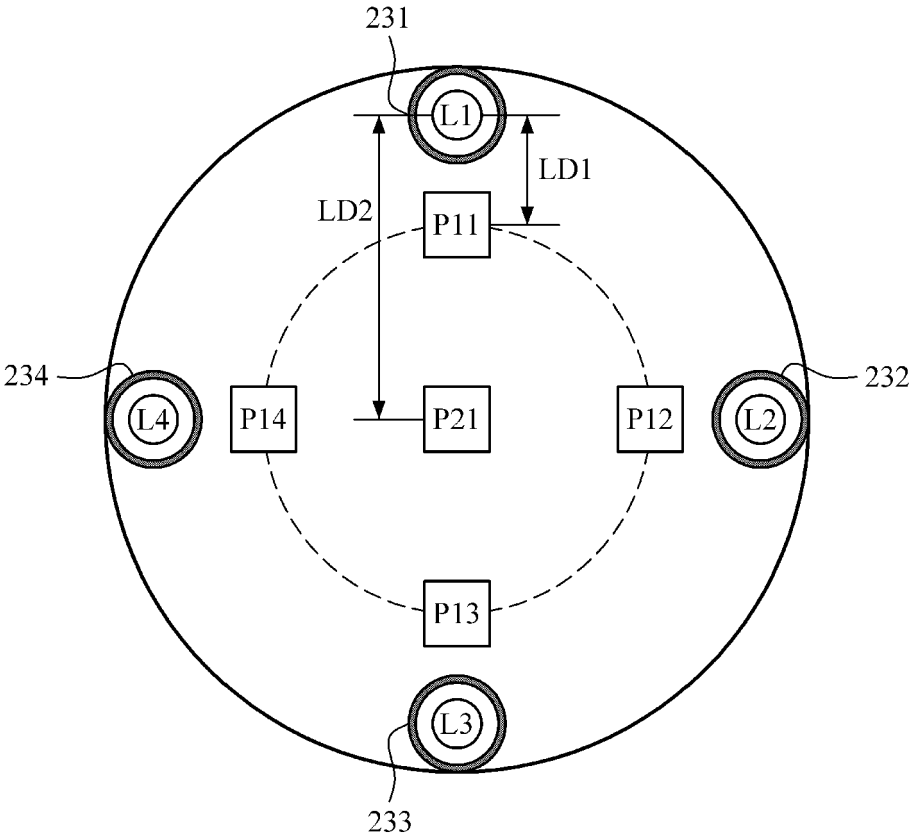


FIG. 3A

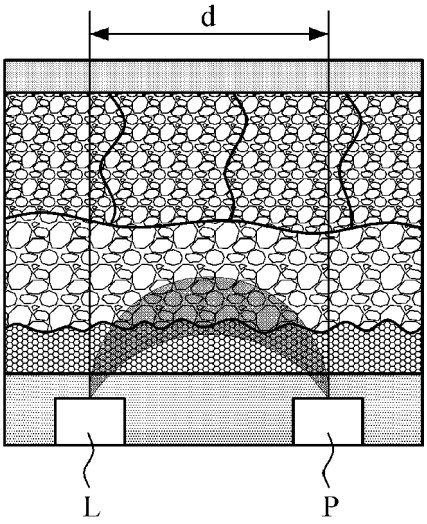


FIG. 3B

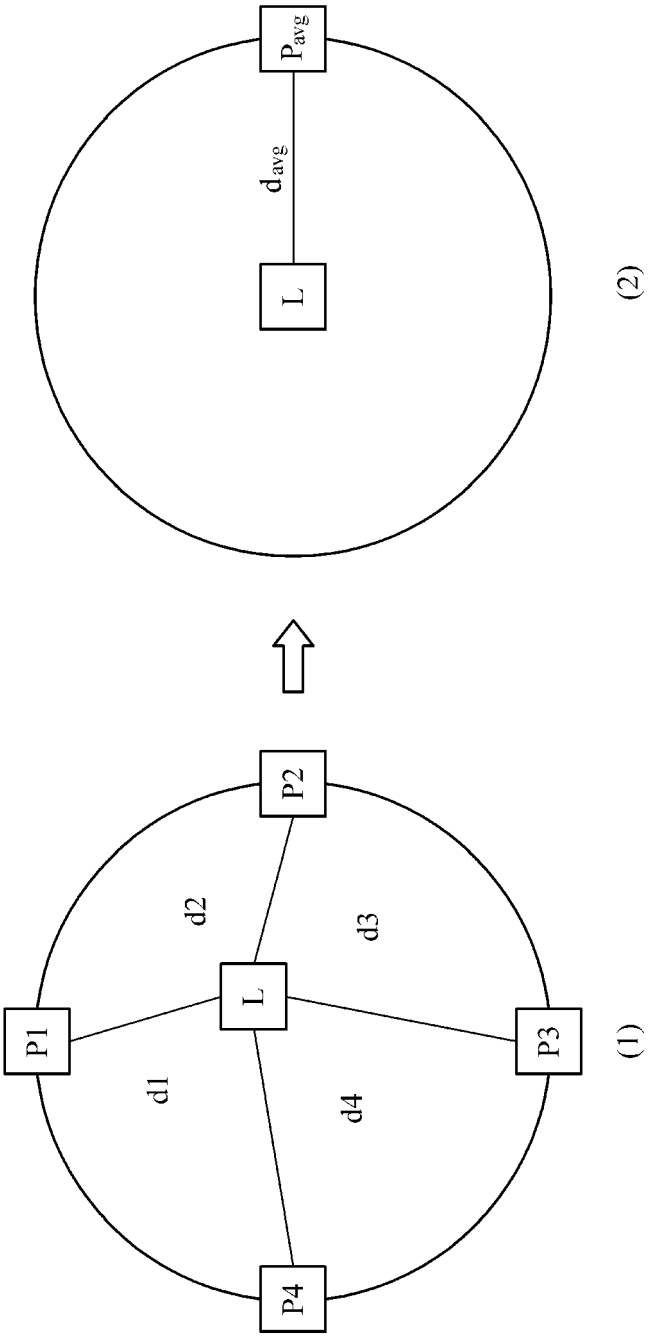


FIG. 3B

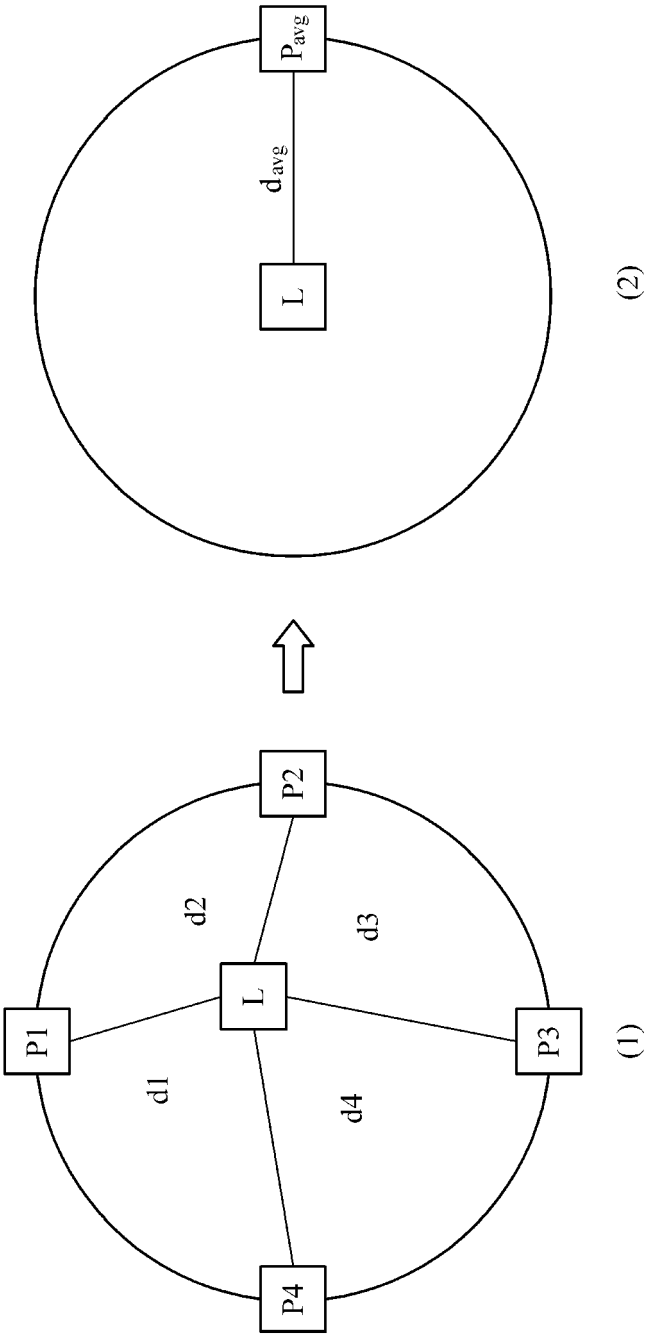


FIG. 4

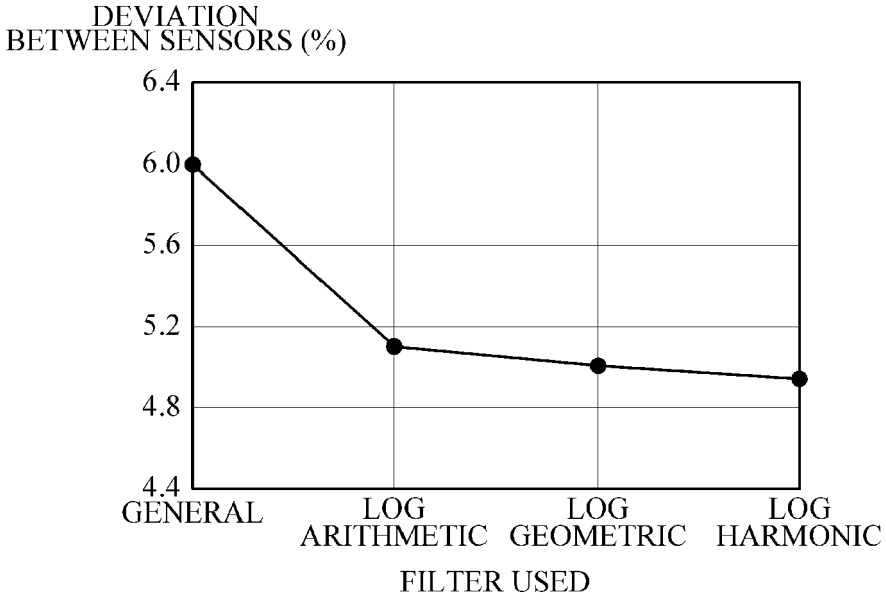

DEVIATION
BETWEEN SENSORS (%)
6.4
6.0
5.6
5.2
4.8
4.4
GENERAL
LOG
ARITHMETIC
LOG
GEOMETRIC
LOG
HARMONIC
FILTER USED

FIG. 5

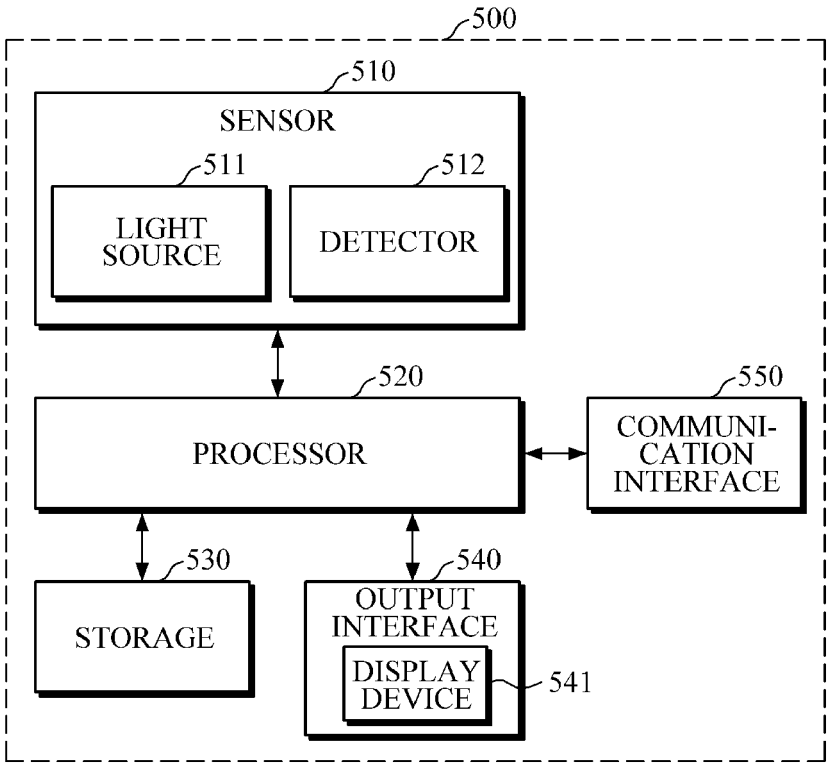

500
510
SENSOR
511
LIGHT SOURCE
512
DETECTOR
520
PROCESSOR
550
COMMUNI-CATION INTERFACE
530
STORAGE
540
OUTPUT INTERFACE
DISPLAY DEVICE
541

FIG. 6

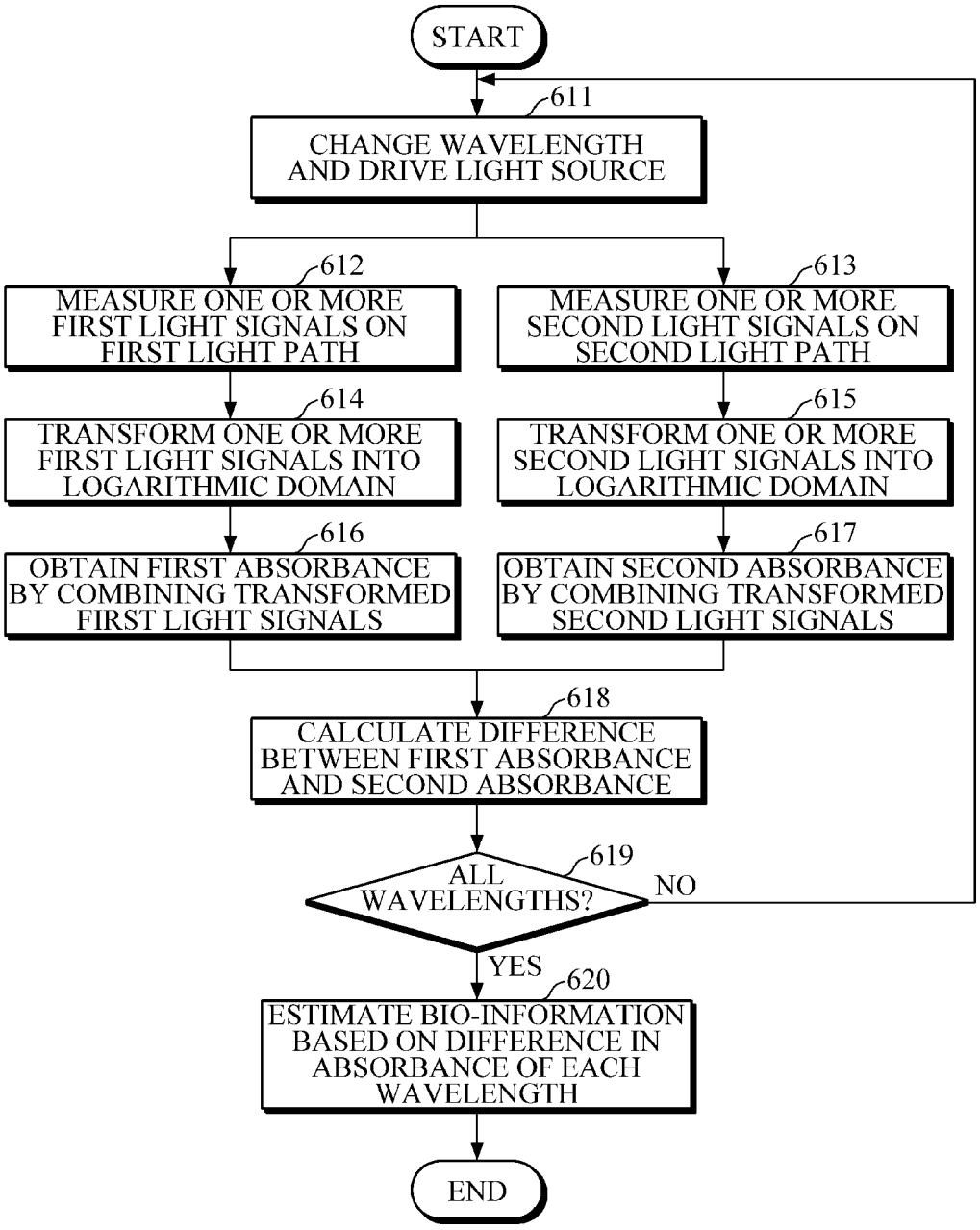

START
611
CHANGE WAVELENGTH AND DRIVE LIGHT SOURCE
612
MEASURE ONE OR MORE FIRST LIGHT SIGNALS ON FIRST LIGHT PATH
613
MEASURE ONE OR MORE SECOND LIGHT SIGNALS ON SECOND LIGHT PATH
614
TRANSFORM ONE OR MORE FIRST LIGHT SIGNALS INTO LOGARITHMIC DOMAIN
615
TRANSFORM ONE OR MORE SECOND LIGHT SIGNALS INTO LOGARITHMIC DOMAIN
616
OBTAIN FIRST ABSORBANCE BY COMBINING TRANSFORMED FIRST LIGHT SIGNALS
617
OBTAIN SECOND ABSORBANCE BY COMBINING TRANSFORMED SECOND LIGHT SIGNALS
618
CALCULATE DIFFERENCE BETWEEN FIRST ABSORBANCE AND SECOND ABSORBANCE
619
ALL WAVELENGTHS?
NO
YES
620
ESTIMATE BIO-INFORMATION BASED ON DIFFERENCE IN ABSORBANCE OF EACH WAVELENGTH
END

FIG. 7

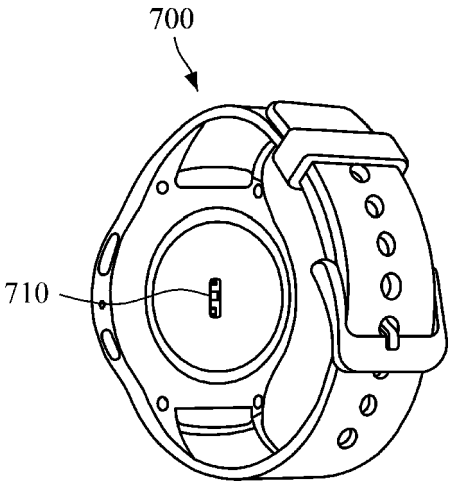


FIG. 8

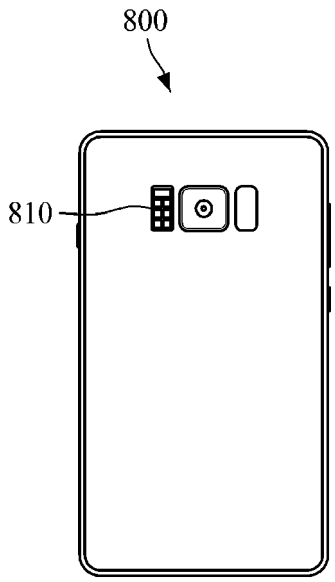
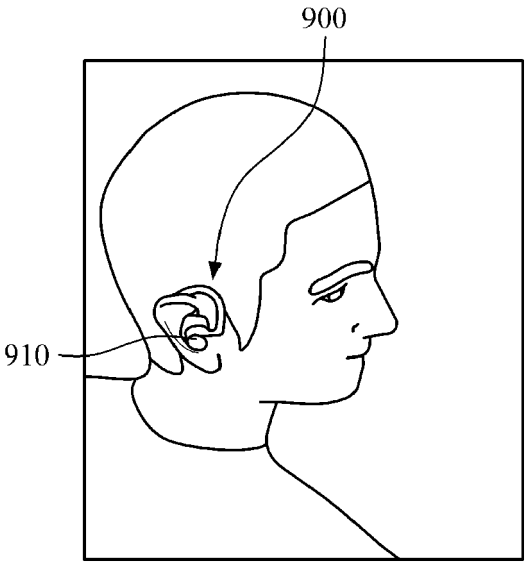


FIG. 9



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European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 24 15 0896

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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Place of search	Date of completion of the search	Examiner
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