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Oxymètre de pouls et méthode d'oxymétrie de pouls

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(56) References cited:
JP-A- 7 327 964
JP-A- 2005 095 606
JP-A- 2007 090 047
US-A1- 2004 267 140
US-A1- 2007 049 812
US-A1- 2008 033 266

- **"Mode (statistics)", Wikipedia, 19 May 2008 (2008-05-19), XP055054947, Retrieved from the Internet: URL:http://en.wikipedia.org/w/index.php?title=Mode_%28statistics%29&oldid=213470577 [retrieved on 2013-03-01]**

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Description

[0001] The present invention relates to a pulse oximetry which measures continuously arterial oxygen saturation (Sa02) in a non-invasive manner by using a blood volume variation of the tissue arterial blood caused by pulsation, and also to a pulse oximeter which performs such a pulse oximetry.

[0002] Today, in a related-art technique called a pulse oximetry, in the case where Sa02 is to be obtained, the following procedure is usually adopted.

(1) Tissue transmitted or reflected light is continuously measured at a plurality of wavelengths.
(2) The peak and bottom of pulsation of the measured tissue transmitted or reflected light are determined, and the transmitted or reflected light beams at the peak and bottom are indicated by $L + \Delta L$ and L, respectively.
(3) $\Delta A = \log [(L + \Delta L)/L] \approx \Delta L/L$ is obtained.
(4) $\Phi ij = \Delta Ai/\Delta Aj$ is obtained.
(5) Since Φij corresponds on a substantially one-to-one base to Sa02, Φij is converted to Sa02.

Sa02 means arterial blood oxygen saturation. But it should be noted that the value of arterial blood oxygen saturation finally obtained by pulse oximetry is named SpO2.

[0003] Many apparatuses which are currently commercially available, and which measure Sa02 employ two wavelengths, and, when above-described Φij is to be converted to Sa02, use a conversion table. In the case of a two-wavelength apparatus, the use of a conversion table is not particularly problematic. In the case where a larger number of wavelengths are used in order to improve the measurement accuracy, however, the conversion must be performed by using a calculation expression which is obtained theoretically and experimentally.

[0004] For example, as a related-art apparatus which measures continuously Sa02 in a non-invasive manner by using a volume variation of arterial blood caused by pulsation, there is a five-wavelength pulse oximeter which irradiates living tissue with five light beams of different wavelengths (see JP-A-2005-95606).

[0005] The pulse oximeter disclosed in JP-A-2005-95606 includes: a light emitting portion which irradiates living tissue with five light beams of different wavelengths; a light receiving portion which receives the light beams that are emitted from the light emitting portion, and that are transmitted through or reflected from the living tissue, and which converts the light beams to electric signals; an optical-density-variation calculating portion which obtains optical density variations for the living tissue on the basis of variations of the transmitted or reflected light beams of different wavelengths and output from the light receiving portion; an optical-density-variation-ratio calculating portion which obtains at least four of mutual ratios of five optical density variations obtained in the optical-density-variation calculating portion; and an oxygen saturation calculating portion which, based on the optical-density-variation ratios obtained in the optical-density-variation-ratio calculating portion, calculates oxygen saturation in blood while using four unknowns of the Sa02, the venous oxygen saturation, a ratio of variations of arterial blood and venous blood, and a tissue term, and obtains oxygen saturation of arterial blood while eliminating artifacts of variations of venous blood and the tissue.

[0006] According to the thus configured pulse oximeter disclosed in JP-A-2005-95606, in the case where venous blood is pulsated by any reason, an artifact of the pulsation can be surely eliminated, and Sa02 can be accurately measured without producing a time delay and smoothing. In the case where the pulse wave is so small that a pulse oximetry is impossible, body motion is intentionally applied, thereby enabling Sa02 contained in this case to be obtained. The pulse oximeter has another advantage that also venous oxygen saturation can be simultaneously measured.

[0007] A longstanding problem of a pulse oximetry is that transmitted or reflected light is disturbed by mechanical disturbances such as body motion. Namely, disturbances of transmitted or reflected light cause adequate detection of peaks and bottoms of a measured pulsative waveform to be hardly performed.

[0008] A related-art technique which has been proposed or adopted as a countermeasure against these problems is a statistical technique in which the correct value of Sa02 is estimated from preceding and subsequent data. However, the technique has the following problems.

(1) Since a long time delay is produced, detection of, for example, a start of reduction of Sa02 is delayed.
(2) Changes of Sa02 are smoothed. When Sa02 is largely reduced, for example, the degree of the reduction cannot be known.

[0009] In the related-art pulse oximetry technique, it will be further expected that a change in SaO2 of a patient is quickly detected, so that the change is early coped with. In order to utilize the original feature of the pulse oximetry technique, the above-discussed problems must be solved.

[0010] Furthermore, it has been found that, in the related-art pulse oximetry technique which is based on determination of peaks and bottoms of the pulsative waveform of measured transmitted or reflected light cannot obtain a satisfactory measurement result when the body of a patient is vigorously moved.

[0011] From this viewpoint, the following related-art technique has been proposed, a time-segmented pulse oximetry and pulse oximeter in which, with respect to the pulsative waveform of measured transmitted or reflected light, the whole of a signal of the measured transmitted or reflected light is used, whereby SaO2 can be adequately measured (see JP-A-2007-90047).

[0012] In the related-art technique disclosed in JP-A-2007-90047, the whole of time series data of the transmitted or reflected light is used, so that determination of peaks and bottoms of the measured waveform is not necessary. Namely, the related-art technique disclosed in JP-A-2007-90047 is characterized in that light emitting elements irradiate living tissue with a plurality of light beams of different wavelengths, light receiving elements receive the light beams transmitted through or reflected from the living tissue, and converts the respective light beams to electric signals, time series data of the electric signals obtained by the light receiving elements are time-segmented, with respect to the segmented time series data, slope values of regression lines between two different wavelengths are calculated, the calculated slope values are converted to Sa02, respectively, and then smoothing is performed, thereby obtaining Sa02 from which an artifact of body motion is eliminated.

[0013] According to the related-art technique disclosed in JP-A-2007-90047, with respect to the pulsative waveform of measured transmitted or reflected light, therefore, determination of peaks and bottoms of the measured waveform is not performed, and the whole of time series data of the transmitted or reflected light is used, whereby the effect of an artifact of body motion is decreased, contribution to improvement of the measurement accuracy of SaO2 is obtained, and measurement flexibility of a measurement portion can be enhanced. Even with these two related-art techniques, an artifact of the body motion can not be eliminated sufficiently.

[0014] Document US 2007/0049812 A1 discloses providing time-segmented pulse oximetry and a pulse oximeter performing the same, thereby eliminating artifacts exerted by body motions and contributing to improvement of measurement accuracy of an arterial oxygen saturation (Sa02). The pulse oximeter comprises a light receiver for receiving light transmitted through living tissue and performs the step of dividing each of the transmitted light signals into predetermined time segments, calculating gradients of regression lines, each of which pertains to two data sets on different wavelengths, converting the thus calculated gradients into respective values of Sa02, smoothing the thus-converted time series data pertaining to Sa02, thereby calculating an oxygen saturation in blood (Sp02). Fig. 6A shows a waveform indicating SpO_2 values where no smoothing was performed. Fig. 6B shows a state where 10 data sets were averaged and smoothed, and Fig. 6C shows a state where 20 data sets were similarly averaged and smoothed.

[0015] Document US 2008/0033266 A1 discloses a pulse oximeter and describes, in particular, an embodiment of a saturation transform module in the pulse oximeter implemented with a bank of filters. Two banks of filters are provided. The first filter bank receives infrared signal samples and the second filter bank receives red samples in the presented embodiment. The outputs of the saturation equation modules are collected for each of a matched filter pairs. In order to form a saturation transform curve, a histogram or the like is generated. The arterial saturation can be calculated from the histogram by selecting the peak (greatest number of occurrences in the area of interest) corresponding to the highest saturation value.

SUMMARY

[0016] It is therefore an object of the invention to provide a pulse oximetry and pulse oximeter in which, with respect to the pulsative waveform of measured transmitted or reflected light, the whole of time series data of the transmitted or reflected light is used, whereby an artifact of body motion is eliminated, and contribution to further improvement of the measurement accuracy of Sa02 is obtained.

[0017] In order to achieve the object, according to the invention, there is provided a pulse oximeter as defined in claim 1, and a pulse oximetry method as defined in claim 4.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018]

Fig. 1 is a diagram schematically showing the configuration of a pulse oximeter which performs a pulse oximetry of the present invention.

Fig. 2 is a diagram showing the configuration of a system in a calculating portion of the pulse oximeter shown in Fig. 1.

Fig. 3 is a waveform chart showing a change of Sp02 which is obtained in a rest side by a five-wavelength calculation while peaks and bottoms are determined for each beat.

Fig. 4 is a waveform chart showing a change of Sp02 which is obtained in a body-motion side by the five-wavelength calculation while peaks and bottoms are determined for each beat.

Fig. 5 is a waveform chart showing a change of 5wSall which is obtained in the body-motion side for each time segment.

Fig. 6 is a waveform chart showing a display example of a histogram in the pulse oimtery of the invention.
Fig. 7 is a waveform chart showing a change of Sp02 which is obtained in the body-motion side by the pulse oimtery of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0019] Next, an embodiment of a pulse oximetry of the present invention will be described in relation with the configuration of a pulse oximeter which performs the pulse oximetry, in detail with reference to the accompanying drawings.

I. Summary of configuration of pulse oximeter

[0020] Fig. 1 is a diagram schematically showing the configuration of a pulse oximeter which performs a pulse oximetry of the present invention. In Fig. 1, the reference numeral 10 denotes a light emitting portion in which five light emitting elements LED1 to LED5 that irradiate living tissue with five light beams of different wavelengths, respectively, 12 denotes the living tissue which is irradiated with the light beams emitted from the light emitting portion 10, and 14 denotes a light receiving portion configured by: a light receiving element PD which receives light beams transmitted through or reflected from the living tissue 12; a current-voltage converter 16; and an AD converter 18.

[0021] The reference numeral 20 denotes a storage portion configured by transmitted-light-signal temporary storage devices 20A to 20E which temporarily store transmitted or reflected light signals obtained by the light receiving element PD of the light receiving portion 14, in time series for the respective wavelengths. For example, 60 transmitted or reflected light signals are stored per second in each of the storage devices.

[0022] The reference numeral 30 denotes a calculating portion which, on the basis of the transmitted or reflected light signals L1 to L5 that are temporarily stored in time series in the respective transmitted-light-signal temporary storage devices 20A to 20E, performs the following procedures: (1) the transmitted or reflected light signals L1 to L5 are segmented for each predetermined time; (2) with respect to each of the transmitted or reflected light signals L1 to L5 which are segmented for each predetermined time, then, a slope value of a regression line between each two different wavelengths is calculated; (3) Sa02 is calculated based on the calculated slope values; (4) a correlation coefficient is further calculated, a slope value in the case where the correlation coefficient is less than a predetermined value is deleted, and a histogram of Sa02 is constructed for every predetermined number of time segments; and (5) a mode value of the histogram is set as an Sp02 value.

[0023] The reference numeral 22 denotes a timing device which is configured so as to control light emitting timings of the light emitting elements LED1 to LED5 of the light emitting portion 10, and timings of storing the transmitted or reflected light signals in the transmitted-light-signal temporary storage devices 20A to 20E of the storage portion 20.

[0024] Fig. 2 is a diagram showing the configuration of a system for performing the above-described calculating procedures in an oxygen saturation calculator that functions as the calculating portion 30. In Fig. 2, the reference numeral 32 denotes a segment storage portion for the transmitted or reflected light signals. The segment storage portion is configured by segment storing circuits 32A to 32E which segment the transmitted or reflected light signals L1 to L5 supplied from the transmitted-light-signal temporary storage devices 20A to 20E, for each predetermined time (for example, 0.2 second), and which sequentially store the transmitted or reflected light signals in time series for each of the segmented times.

[0025] The reference numeral 34 denotes a slope-value calculating portion. The calculating portion is configured by slope-value calculating circuits 34a, 34b, 34c, 34d calculate, using output of 32, slope values $\Phi 12$, $\Phi 32$, $\Phi 42$, $\Phi 52$ of the regression lines, respectively.

[0026] The reference numeral 36 denotes a first calculating circuit which obtains the Sa02 value as a solution of simultaneous equations with the slope values $\Phi 12$, $\Phi 32$, $\Phi 42$, $\Phi 52$ of the regression lines that are obtained by the slope-value calculating circuits 34a, 34b, 34c, 34d. The value which is the solution of simultaneous equations obtained by the first calculating circuit is called 5wSall.

[0027] The reference numeral 38 denotes a second calculating circuit which, with respect to Sa02 that is obtained as the solution of the simultaneous equations, obtains a histogram for every predetermined number of time segments (for example, every 5 seconds), and which determines the mode value of the histogram. Therefore, the second calculating circuit 38 calculates blood oxygen saturation [Sp02]. This is output of this pulse oximetry.

[0028] In order to obtain a higher accuracy, it is preferred to additionally perform at least one of the following methods. <1> a low-frequency component of log Li is eliminated. <2> $\Phi i2$ is selected based on correlation between two data. <3> Smoothing is performed on the histogram.

II. Calculating processing of pulse oximeter

[0029] Next, the operation of calculating Sa02 by the configuration of the above-described pulse oximeter, i.e., the

pulse oximetry of the invention will be described together with the function of the pulse oximeter.

(1) Processing of time-segmenting transmitted or reflected light signal

[0030] First, the five light emitting elements LED1 to LED5 of the light emitting portion 10 sequentially emit light beams of different wavelengths λ1, λ2, λ3, λ4, and λ5, respectively, on the basis of a signal from the timing device 22. Therefore, the light receiving portion 14 receives light beams transmitted through or reflected from the living tissue 12, and, in accordance with the wavelengths of the light emitting elements LED1 to LED5, the transmitted or reflected light signals L1, L2, L3, L4, L5 are stored at respective predetermined timings into the transmitted-light-signal temporary storage devices 20A to 20E of the storage portion 20 (see Fig. 1).

[0031] The transmitted or reflected light signals L1 to L5 which are stored respectively in the transmitted-light-signal temporary storage devices 20A to 20E in this way are supplied to the segment storing circuits 32A to 32E of the segment storage portion 32 in the calculating portion 30, segmented for each predetermined time (for example, 0.2 second), and then sequentially stored in time series for each of the segmented times (see Fig. 2).

(2) Calculating processing of obtaining slope value of regression line relating to time-segmented transmitted or reflected light beams

[0032] The calculation of blood oxygen saturation SaO2 is performed based on optical density variations (ΔAi) which are obtained for the transmitted or reflected light beams of, for example, five wavelengths. The oxygen saturation is obtained by the following expression using a ratio (Φij, i and j are wavelength number) of the optical density variations.

[0033] The elements constituting the pulsation of a transmitted or reflected light beam are arterial blood (a), venous blood (v), and tissue other than blood, i.e., pure tissue (t).

$$\Phi ij \equiv \Delta Ai/\Delta Aj$$

$$= [\sqrt{\{Eai(Eai + F)\}} + \sqrt{\{Evi(Evi + F)\}} * V + Exi]$$

$$/[\sqrt{\{Eaj(Eaj + F)\}} + \sqrt{\{Evj(Evj + F)\}} * V + Exj]$$

where

$$\Delta Ai \equiv \log[(Li + \Delta Li)/Li] \cong \Delta Li/Li$$

$$Eai \equiv SaEoi + (1 - Sa)Eri$$

$$Evi \equiv SvEoi + (1 - Sv)Eri$$

$$V \equiv \Delta Dv/\Delta Da$$

$$Exi \equiv Zti\Delta Dt/(Hb\Delta Da) \equiv AiEx2 + Bi$$

[0034] In the above expression, Li is a tissue transmitted or reflected light beam, ΔAi is an optical density variation, Eoi is an extinction coefficient of oxygenated hemoglobin, Eri is an extinction coefficient of deoxygenated hemoglobin, Sa is Sa02, Sv is oxygen saturation of peripheral venous blood (SvO2), ΔDa is a variation of the effective thickness of arterial blood, ΔDv is a variation of the effective thickness of venous blood, ΔDt is a variation of the effective thickness of pure tissue, Zti is a constant of attenuation of pure tissue, Ex2 is the value of Exi at a second wavelength, and Ai and Bi are tissue constants (determined by actual measurement).

[0035] Therefore, the above expression has four unknowns of Sa, Sv, V, and Ex2.

[0036] In this case, tissue transmitted or reflected light beams are measured at five adequate wavelengths, simultaneous equations with 4 unknowns are set with respect to the above expression, and then Sa can be obtained as the solution of the simultaneous equations. Preferred examples of the five wavelengths are $\lambda 1$= 805 nm, $\lambda 2$ = 875 nm, $\lambda 3$ = 660 nm, $\lambda 4$ = 700 nm, and $\lambda 5$ = 730 nm.

[0037] In the time-segmented oximetry of the invention, based on the transmitted or reflected light signals L1 to L5 of the five wavelengths ($\lambda 1$ to $\lambda 5$) which are time-segmented and stored, therefore, the segment storage portion 32 obtains the slope values (Φij, i and j are wavelength number) of the regression lines by using the following expression. Namely, the slope value (Φij) in the above corresponds to $\Phi ij = \Delta Ai/\Delta Aj$ above. In the following expression, n is the number of data in a time segment, t is a segmented time (for example, 0.2 second), and E is a sum of data in a segmented time.

$$\Phi ij \equiv \{n\Sigma[Li(t)*Lj(t)] - \sum Li(t) * \sum Lj(t)\}$$
$$/\{n\Sigma Lj(t)^2 - [\Sigma Lj(t)]^2\}$$

(3) Calculating processing of obtaining solution of simultaneous equations with slope values

[0038] On the basis of the above expression, simultaneous equations with 4 unknowns are set with respect to the slope values (Φ12, Φ32, Φ42, 052) of the regression lines for the tissue transmitted or reflected light beams of the five wavelengths ($\lambda 1$ to $\lambda 5$), and Sa is calculated as a solution of the simultaneous equations (see Fig. 2). These Sa are named 5wSall.

III. Example of calculating processing

[0039] An example where, based on the above-described pulse oximetry, SaO2 is calculated with respect to actual measurement data of a subject will be described together with graphs in which the example is compared with the case of a related-art pulse oximetry, and which show their measurement results.

[0040] The light emitting portion 10 and the light receiving portion 14 are attached to a finger tip of a subject, and breathing is performed in the following manner.

<1> Air breathing is performed.
<2> Sa02 is reduced by holding breath.
<3> Air breathing is again performed.
<4> Sa02 is increased by oxygen breathing.

[0041] In the middle of <1>, a motion of squeezing a sponge by hand is performed. The body motion is continued to the middle of <4>.

[0042] Similarly, a light emitting portion and a light receiving portion are attached to the other hand opposite to the one which performs the body motion. The other hand is kept at rest, and data of the other hand are set as control data.

[0043] Fig. 3 shows a result of Sp02 which is obtained in the rest side by a five-wavelength calculation while peaks and bottoms are determined for each beat. In Fig. 3, a change of SpO2 due to a change of breathing is clearly shown. In the graph, timings when breathing is changed and the body motion is started and ended are indicated by vertical bars.

[0044] Fig. 4 shows a result of SpO2 which is obtained in the body-motion side by a five-wavelength calculation while peaks and bottoms are determined for each beat. In Fig. 4, SpO2 is largely disturbed. This disturbance is caused by the artifact of the body motion.

[0045] Fig. 5 shows the distribution characteristic of 5wSall which is obtained in the body-motion side for each 0.2 second by the method of the disclosure. Namely, Fig. 5 is a view showing results of the following processing.

<1> The transmitted or reflected light signal Li is logarithmically converted to log Li.
<2> A low-frequency component of log Li is eliminated. Specifically, the average value of log Li for each 0.1 second is subtracted from log Li.
<3> For each 0.2 second, a slope Φi2 of a regression line of log Li (i = 1, 3, 4, and 5) and log L2 is obtained.
<4> For each 0.2 second, correlation coefficients R12, R32, R42, R52 are obtained, and they are correlation between log L1 and log L2, log L3 and log L2, log L4 and log L2, and log L5 and log L2, respectively. Then, PR = R12*R32*R42*R52 is obtained.
<5> Φi2 in the case of PR < 0.9 is deleted.

<6> The remaining Φi2 is converted to Sa02 on the basis of simultaneous equations. This is 5wSall.
<7> 5wSall is time-segmented for each 5 seconds, and a histogram of time segments of 5 seconds is obtained.
<8> The histogram is smoothed. Fig. 6 shows a display example of such a histogram.
<9> The mode value is determined on the basis of the histogram of 5wSall.
<10> The result is output as Sp02. Fig. 7 shows a change of Sp02 which is obtained in the body-motion side.

[0046] As described above, according to the pulse oximetry, an artifact of body motion is sufficiently eliminated, and a rapid change of Sa02 is definitely measured. Particularly, it is confirmed that the timing when the reduction of Sa02 is started can be detected without delay.

[0047] In the above, the preferred embodiment of the invention has been described. However, the invention is not restricted to the embodiment. Although the case where five wavelengths are used has been described, the invention can be applied also to the case where the number of wavelengths is larger or smaller than five. Furthermore, the invention can be applied also to all of measurement objects which pulsate, for instance, together with arterial blood, such as CO hemoglobin in blood, the diluted state of a dye injected from the outside of the body, etc. The interval of the time segment may be adequately changed in accordance with the respective objects. Various modifications may be performed without departing from the invention as defined in the claims. According to an aspect of the invention, with respect to the pulsative waveform of measured transmitted or reflected light, determination of peaks and bottoms of the measured waveform is not performed, and the whole of time series data of the transmitted or reflected light is used, whereby an artifact of body motion is eliminated, and contribution to improvement of the measurement accuracy of SaO2 is obtained.

Claims

1. A pulse oximeter adapted to calculate blood oxygen saturation, Sp02, of living tissue, comprising:

a light emitter (10), adapted to irradiate living tissue (12) with light beams of at least five different wavelengths,
a light receiver (14), adapted to receive the light beams transmitted through or reflected from the living tissue (12) and which converts the received light beams to electric signals which correspond to the at least five different wavelengths,
a processor (32), adapted to segment time series data of the electric signals into time segments to provide segmented time series data of the electric signals,
a slope value calculator (34), adapted to calculate, with respect to each of the segmented time series data of the electric signals, four slope values of regression lines between each two of the electric signals,
an Sa02 calculator (36), adapted to calculate an arterial oxygen saturation, Sa02, based on the slope values of each of the segmented time series data of the electric signals;
characterized by
further comprising:

a histogram constructer, adapted to construct a histogram of Sa02 for each predetermined number of time segments, and
a mode value obtainer, adapted to obtain a mode value from the histogram as output of the pulse oximeter, Sp02.

2. The pulse oximeter according to claim 1, further comprising a filter adapted to, when the time series data of the electric signals are passed through the filter, block a low-frequency component before time-segmenting the time series data of the electric signals by the processor (32).

3. The pulse oximeter according to claim 1, further comprising a smoothing unit adapted to apply a smoothing process to the histogram of the SaO2 before obtaining the mode value by the mode value obtainer.

4. A pulse oximetry method to calculate blood oxygen saturation, Sp02, of living tissue by using the pulse oximeter according to claim 1, comprising the steps of:

irradiating living tissue with light beams of at least five different wavelengths,
receiving the light beams transmitted through or reflected from the living tissue and converting the received light beams to electric signals which correspond to the at least five different wavelengths,
time-segmenting time series data of the electric signals into time segments to provide segmented time series data of the electric signals,

calculating, with respect to each of the segmented time series data of the electric signals, four slope values of regression lines between each two of the electric signals,
calculating an arterial oxygen saturation, SaO2, based on the slope values of each of the segmented time series data of the electric signals;
characterized by
constructing a histogram of SaO2 for each predetermined number of time segments, and
obtaining a mode value from the histogram as output of the pulse oximetry method, SpO2.

5. The pulse oximetry method according to claim 4, wherein the time series data of the electric signals are passed through a filter to block a low-frequency component before time-segmenting the time series data of the electric signals.

6. The pulse oximetry method according to claim 4, wherein a smoothing process is applied to the histogram of the SaO2 before obtaining the mode value.

Patentansprüche

1. Pulsoximeter, das ausgebildet ist, eine Blutsauerstoffsättigung, SpO2, von lebendem Gewebe zu berechnen mit:

einem Lichtsender 810), der ausgebildet ist, lebendes Gewebe (12) mit Lichtstrahlen mit mindestens fünf unterschiedlichen Wellenlängen zu bestrahlen,
einem Lichtempfänger (14), der ausgebildet ist, die von dem lebenden Gewebe (12) reflektierten oder von diesem durchgelassenen Lichtstrahlen zu empfangen und die empfangenen Lichtstrahlen in elektrische Signale umzuwandeln, die den mindestens fünf unterschiedlichen Wellenlängen entsprechen,
einem Prozessor (32), der ausgebildet ist, Zeitreihendaten der elektrischen Signale in Zeitsegmente aufzuteilen, um segmentierte Zeitreihendaten der elektrischen Signale bereitzustellen,
einer Steigungswertberechnungseinheit (34), die ausgebildet ist, in Bezug auf jeweils die segmentierten Zeitreihendaten der elektrischen Signale vier Steigungswerte von Regressionslinien zwischen jeweils zwei der elektrischen Signale zu berechnen,
einer Sa02-Berechnungseinheit (36), die ausgebildet ist, eine arterielle Sauerstoffsättigung, Sa02, auf der Grundlage der Steigungswerte jeweils der segmentierten Zeitreihendaten der elektrischen Signale zu berechnen;
dadurch gekennzeichnet, dass ferner vorgesehen ist:

eine Histogrammerzeugungseinheit, die ausgebildet ist, ein Histogramm aus der Sa02 für jede vorbestimmte Anzahl an Zeitsegmenten zu bilden, und
eine Modalwertermittlungseinheit, die ausgebildet ist, einen Modalwert aus dem Histogramm als Ausgabe des Pulsoximeters, SpO2, zu ermitteln.

2. Pulsoximeter nach Anspruch 1, das ferner einen Filter aufweist, der ausgebildet ist, um eine Niederfrequenzkomponente vor der Zeitsegmentierung der Zeitreihendaten der elektrischen Signale durch den Prozessor (32) zu blockieren, wenn die Zeitreihendaten der elektrischen Signale den Filter durchlaufen.

3. Pulsoximeter nach Anspruch 1, das ferner eine Glättungseinheit aufweist, die ausgebildet ist, einen Glättungsprozess auf das Histogramm der SaO2 des Modalwertes durch die Modalwertermittlungseinheit anzuwenden.

4. Pulsoximetrieverfahren zur Berechnung der Blutsauerstoffsättigung, SpO2, von lebendem Gewebe durch Verwendung des Pulsoximeters nach Anspruch 1, mit den Schritten:

Bestrahlen von lebendem Gewebe mit Lichtstrahlen mit mindestens fünf unterschiedlichen Wellenlängen,
Empfangen der Lichtstrahlen, die das lebende Gewebe durchlaufen haben oder davon reflektiert wurden und Umwandeln der empfangenen Lichtstrahlen in elektrische Signale, die den mindestens fünf unterschiedlichen Wellenlängen entsprechen,
zeitliches Unterteilen von Zeitreihendaten der elektrischen Signale in Zeitsegmente, um segmentierte Zeitreihendaten der elektrischen Signale bereitzustellen,
Berechnen von vier Steigungswerten von Regressionslinien zwischen jeweils zwei elektrischen Signalen in Bezug auf die jeweils die segmentierten Zeitreihendaten der elektrischen Signale,
Berechnen einer arteriellen Sauerstoffsättigung, SaO2, auf der Grundlage der Steigungswerte jeweils der seg-

mentierten Zeitreihendaten der elektrischen Signale;
gekennzeichnet durch
Bilden eines Histogramms der SaO2 für jede vorbestimmte Anzahl an Zeitsegmenten, und
Ermitteln eines Modalwertes aus dem Histogramm als Ausgabe des Pulsoximetrieverfahrens, SpO2.

5. Pulsoximetrieverfahren nach Anspruch 4, wobei die Zeitreihendaten der elektrischen Signale durch einen Filter geführt werden, um eine Niederfrequenzkomponente vor der Zeitsegmentierung der Zeitreihendaten der elektrischen Signale abzublocken.

6. Pulsoximetrieverfahren nach Anspruch 4, wobei ein Glättungsprozess auf das Histogramm der SaO2 vor der Ermittlung des Modalwertes angewendet wird.

Revendications

1. Oxymètre d'impulsion adapté pour calculer la saturation en oxygène sanguin, SpO2, du tissu vivant, comprenant :

un émetteur de lumière (10), adapté pour irradier le tissu vivant (12) avec des faisceaux de lumière d'au moins cinq longueurs d'onde différentes,
un récepteur de lumière (14), adapté pour recevoir les faisceaux de lumière transmis à travers ou reflétés depuis le tissu vivant (12) et qui convertit les faisceaux de lumière reçus en signaux électriques qui correspondent à les au moins cinq longueurs d'onde différentes,
un processeur (32), adapté pour segmenter des données de série de temps des signaux électriques en segments de temps afin de fournir des données de série de temps segmentées des signaux électriques,
un calculateur de valeur de pente (34), adapté pour calculer, par rapport à chacune des données de série de temps segmentés des signaux électriques, quatre valeurs de pente des lignes de régression entre chacun des deux signaux électriques,
un calculateur SaO2 (36), adapté pour calculer une saturation en oxygène artériel, SaO2, sur la base des valeurs de pente de chacune des données de série de temps segmentés des signaux électriques ;
caractérisé en ce qu'il
comprend en outre :

un constructeur d'histogramme, adapté pour construire un histogramme de SaO2 pour chaque nombre de segments de temps prédéterminés, et
un dispositif d'obtention de valeur de mode, adapté pour obtenir une valeur de mode à partir de l'histogramme comme résultat de l'oxymètre d'impulsion, Sp02.

2. Oxymètre d'impulsion selon la revendication 1, comprenant en outre un filtre adapté, lorsque les données de série de temps des signaux électriques passent à travers le filtre, pour bloquer un composant de basse fréquence avant la segmentation de temps des données de série de temps des signaux électriques par le processeur (32).

3. Oxymètre d'impulsion selon la revendication 1, comprenant en outre une unité de lissage adaptée pour appliquer un procédé de lissage à l'histogramme du SaO2 avant l'obtention de la valeur de mode par le dispositif d'obtention de valeur de mode.

4. Procédé d'oxymétrie d'impulsion destiné à calculer la saturation en oxygène sanguin, Sp02, d'un tissu vivant en utilisant l'oxymètre d'impulsion selon la revendication 1, comprenant les étapes de :

irradiation du tissu vivant avec des faisceaux de lumière d'au moins cinq longueurs d'onde différentes,
réception des faisceaux de lumière transmis à travers ou reflétés par le tissu vivant et conversion des faisceaux de lumière reçus en signaux électriques qui correspondent à les au moins cinq longueurs d'onde différentes,
segmentation de temps des données de série de temps des signaux électriques en segments de temps afin de fournir des données de série de temps segmentées des signaux électriques,
calcul, par rapport à chacune des données de série de temps segmentées des signaux électriques, quatre valeurs de pente des lignes de régression entre chacun de deux signaux électriques,
calcul d'une saturation en oxygène artériel, SaO2, sur la base des valeurs de pente de chacune des données de série de temps segmentées des signaux électriques ;
caractérisé par la

construction d'un histogramme de SaO2 pour chaque nombre de segments de temps prédéterminés, et l'obtention d'une valeur de mode à partir de l'histogramme comme résultat du procédé d'oxymétrie d'impulsion, SpO2.

5. Procédé d'oxymétrie d'impulsion selon la revendication 4, dans lequel les données de série de temps des signaux électriques passent à travers un filtre pour bloquer un composant de basse fréquence avant la segmentation de temps des données de série de temps des signaux électriques.

6. Procédé d'oxymétrie d'impulsion selon la revendication 4, dans lequel un procédé de lissage est appliqué à l'histogramme du SaO2 avant l'obtention de la valeur de mode.

FIG. 1

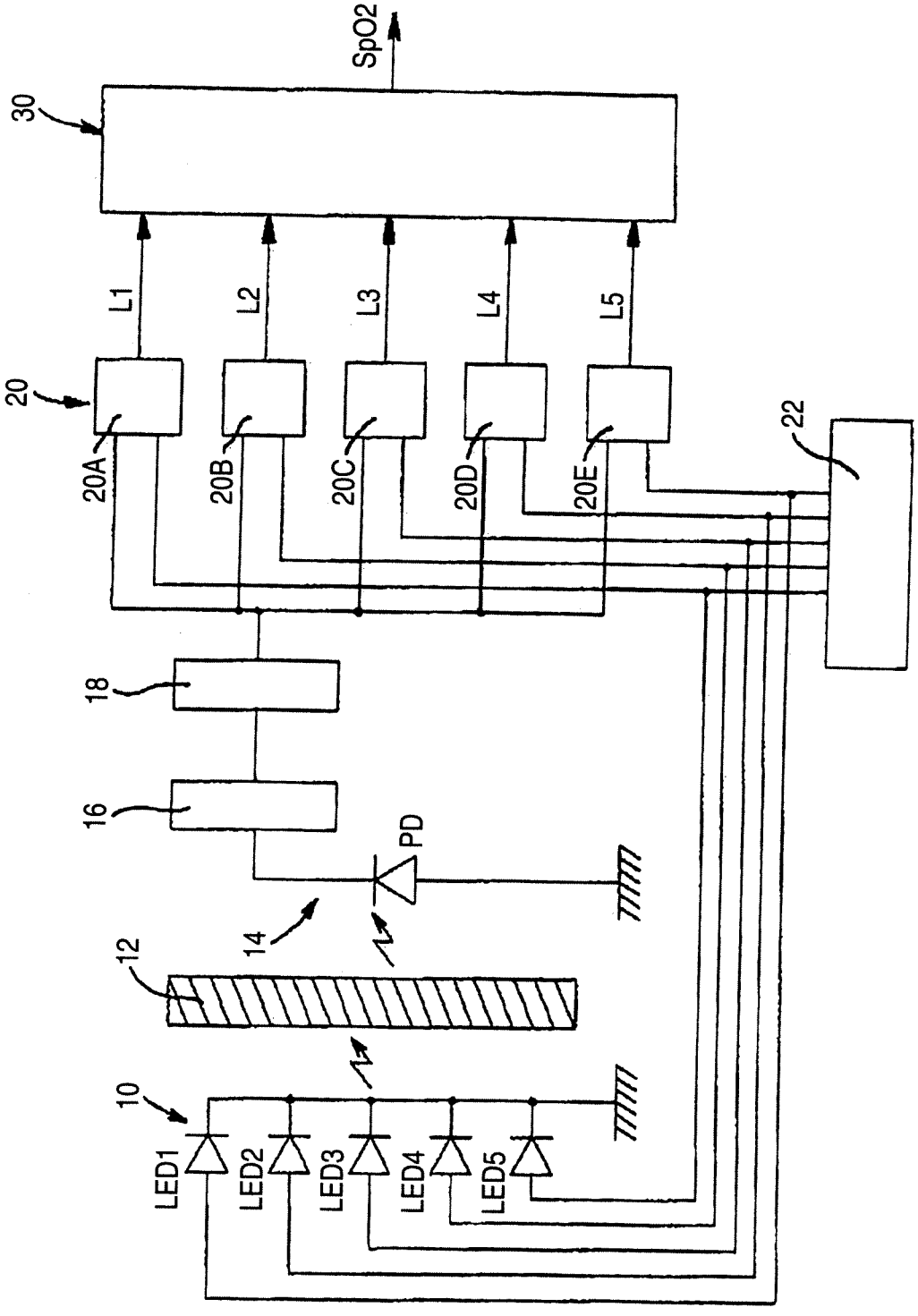

SpO2
30
L1
L2
L3
L4
L5
20
20A
20B
20C
20D
20E
22
18
16
PD
14
12
10
LED1
LED2
LED3
LED4
LED5

FIG. 2

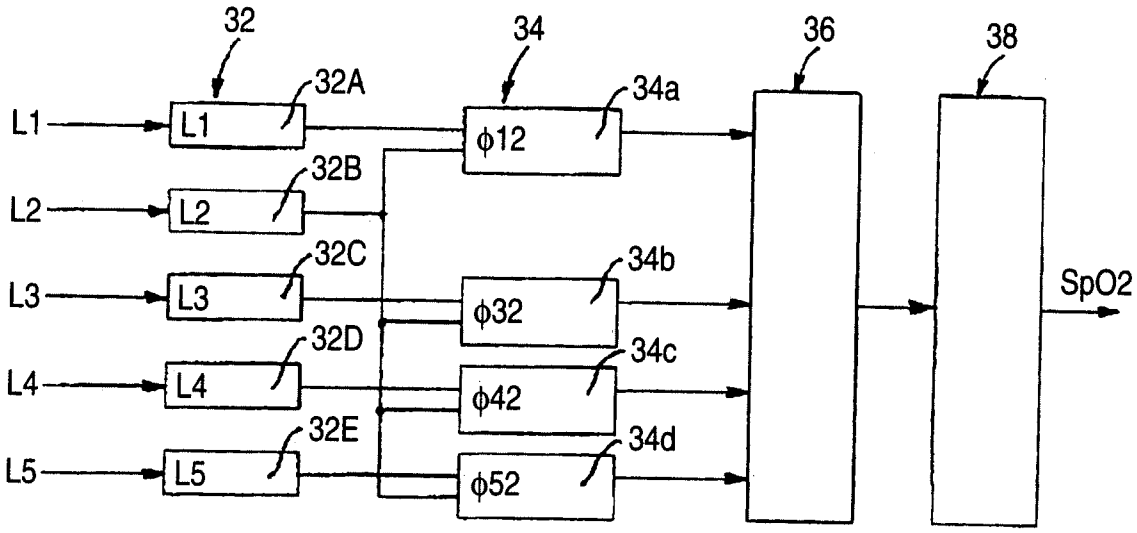


FIG. 3

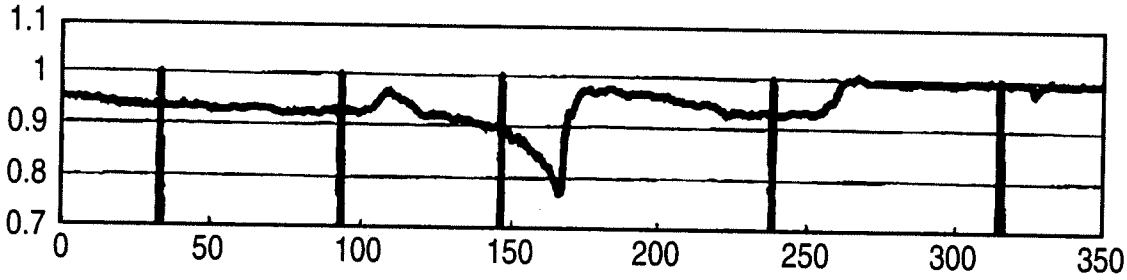


FIG. 4

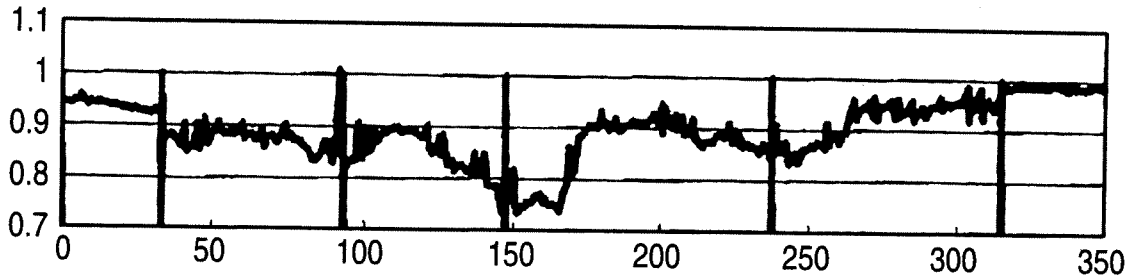


FIG. 5

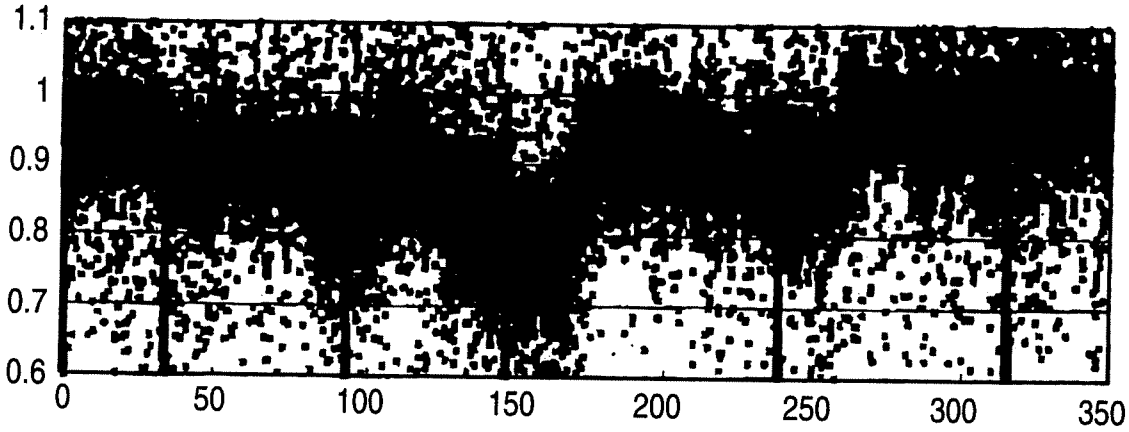


FIG. 6

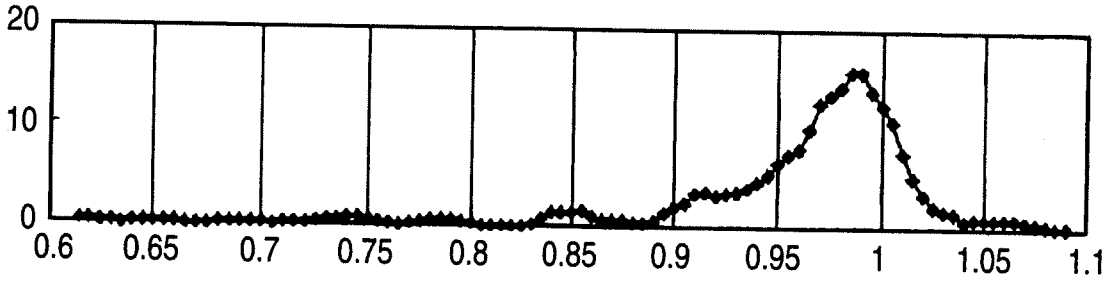
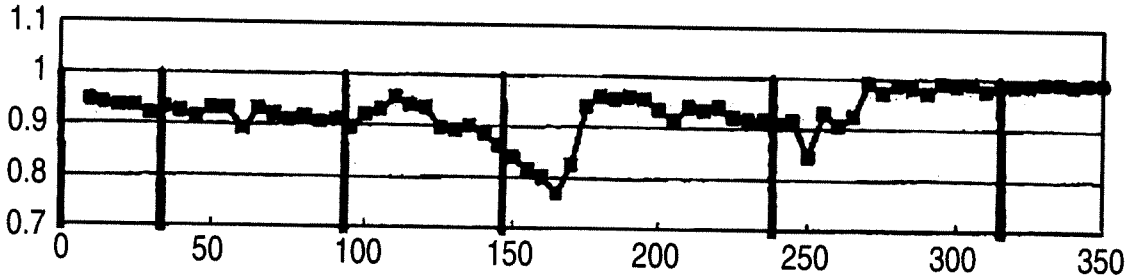


FIG. 7



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2005095606 A **[0004] [0005] [0006]**
- JP 2007090047 A **[0011] [0012] [0013]**
- US 20070049812 A1 **[0014]**
- US 20080033266 A1 **[0015]**

专利名称(译)	脉搏血氧仪和脉搏血氧仪法		
公开(公告)号	EP2135550B1	公开(公告)日	2017-10-18
申请号	EP2009162886	申请日	2009-06-17
[标]申请(专利权)人(译)	日本光电工业株式会社		
申请(专利权)人(译)	日本光电公司		
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[标]发明人	AOYAGI TAKUO KANEMOTO MICHIO FUSE MASAYOSHI UKAWA TEIJI		
发明人	AOYAGI, TAKUO KANEMOTO, MICHIO FUSE, MASAYOSHI UKAWA, TEIJI		
IPC分类号	A61B5/1455 A61B5/00		
CPC分类号	A61B5/1455 A61B5/7207		
优先权	2008160013 2008-06-19 JP		
其他公开文献	EP2135550A1		
外部链接	Espacenet		

摘要(译)

脉搏血氧测定法包括：用多个不同波长的光束照射活组织;接收通过活组织透射或从活组织反射的光束，并将接收到的光束转换成对应于不同波长的电信号;时间分段电信号的时间序列数据;计算关于每个电信号的分段时间序列数据的每两个电信号之间的回归线的斜率值;根据电信号的每个分段时间序列数据的斜率值计算SaO2;为每个预定数量的时间段构建SaO2直方图;从直方图中获得模式值作为SpO2，输出脉搏血氧饱和度。

$$\Phi ij \equiv \Delta Ai/\Delta Aj$$

$$= \left[\sqrt{\left\{Eai\left(Eai + F\right)\right\}} + \sqrt{\left\{Evi\left(Evi + F\right)\right\}}*V + Exi\right]$$

$$/\left[\sqrt{\left\{Eaj\left(Eaj + F\right)\right\}} + \sqrt{\left\{Evj\left(Evj + F\right)\right\}}*V + Exj\right]$$