



(11) **EP 3 342 332 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
04.07.2018 Bulletin 2018/27

(51) Int Cl.:
A61B 5/00 (2006.01) **A61B 5/02** (2006.01)
A61B 5/0205 (2006.01) **A61B 5/021** (2006.01)
A61B 5/026 (2006.01) **A61B 5/029** (2006.01)
A61B 5/0402 (2006.01) **A61B 5/0488** (2006.01)
A61B 5/11 (2006.01)

(21) Application number: **17210907.6**

(22) Date of filing: **28.12.2017**

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD TN

(72) Inventors:
• **PARK, Chang Soon**
Chungcheongbuk-do (KR)
• **KWON, Ui Kun**
Gyeonggi-do (KR)
• **JANG, Dae Geun**
Gyeonggi-do (KR)
• **KIM, Young Soo**
Seoul (KR)

(30) Priority: **28.12.2016 KR 20160181373**
11.12.2017 KR 20170169187

(74) Representative: **Grünecker Patent- und Rechtsanwälte**
PartG mbB
Leopoldstraße 4
80802 München (DE)

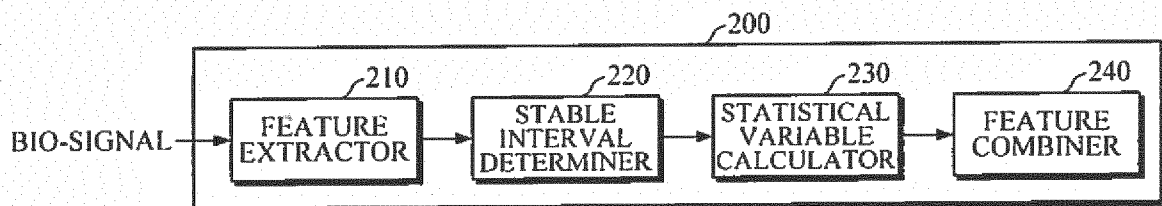
(71) Applicant: **Samsung Electronics Co., Ltd.**
Gyeonggi-do 16677 (KR)

(54) **ADAPTIVE BIO-SIGNAL FEATURE COMBINING APPARATUS AND METHOD**

(57) An adaptive bio-signal feature combining apparatus includes: a feature extractor configured to extract first feature values and second feature values from a bio-signal of an object; a stable interval determiner configured to determine at least one stable interval in the bio-signal; a statistical variable calculator configured to calculate a statistical variable value of a first feature and a statistical variable value of a second feature for each

of the at least one stable interval based on the first and second feature values extracted from the at least one stable interval; and a feature combiner configured to calculate an integrated combining coefficient that is used to combine the first feature and the second feature, based on the statistical variable value of the first feature and the statistical variable value of the second feature,

FIG. 2



EP 3 342 332 A1

Description

BACKGROUND

5 **1. Field**

[0001] Apparatuses and methods consistent with exemplary embodiments relate to an adaptive bio-signal feature combining apparatus and method.

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

[0002] Healthcare technology has attracted much attention due to the rapid entry into an aging society and relevant social problems such as increase in medical expenses. Accordingly, not only medical devices that can be utilized by hospitals and inspection agencies but also small-sized medical devices that can be carried by individuals such as wearable devices are being developed. In addition, such a small-sized medical device is worn by a user in the form of a wearable device capable of directly measuring cardiovascular health status such as blood pressure or the like, so that the user can directly measure and manage cardiovascular health status.

[0003] Therefore, recently, studies on a method of estimating a blood pressure by analyzing a bio-signal for minimization of a device have been conducted.

20

SUMMARY

[0004] The invention is what is claimed in the independent claims. Preferred embodiments are defined in the dependent claims.

25 **[0005]** According to an aspect of an exemplary embodiment, there is provided an adaptive bio-signal feature combining apparatus including: a feature extractor configured to extract first feature values and second feature values from a bio-signal of an object; a stable interval determiner configured to determine at least one stable interval in the bio-signal; a statistical variable calculator configured to calculate a statistical variable value of a first feature and a statistical variable value of a second feature for each of the at least one stable interval based on the first and second feature values extracted from the at least one stable interval; and a feature combiner configured to calculate an integrated combining coefficient that is used to combine the first feature and the second feature, based on the statistical variable value of the first feature and the statistical variable value of the second feature, wherein the feature extractor, the stable interval determiner, the statistical variable calculator, and the feature combiner are included in one or more processors.

30 **[0006]** The bio-signal may include at least one of an electrocardiogram (ECG) signal, a photoplethysmogram (PPG) signal, an electromyogram (EMG) signal, and a ballistocardiogram (BCG) signal.

35 **[0007]** The first feature may be related to a cardiac output and the second feature is related to a total peripheral vascular resistance.

[0008] The first feature may include at least one of P_{\max}/P_{area} , P_{\max}/P_3 , P_{sys}/P_3 , P_1/P_3 , P_2/P_3 , and $1/T_{\text{period}}$, the second feature may include at least one of $1/(T_3 T_{\text{sys}})$, $1/(T_3 - T_{\max})$, $1/(T_3 - T_1)$, $1/(T_3 - T_2)$, P_2/P_1 , and P_3/P_1 , wherein T_{period} denotes a period of the bio-signal, T_1 denotes a time of a peak point of a first component pulse constituting the bio-signal, P_1 denotes an amplitude of the bio-signal at T_1 , T_2 denotes a time of a peak point of a second component pulse constituting the bio-signal, P_2 denotes an amplitude of the bio-signal at T_2 , T_3 denotes a time of a peak point of a third component pulse constituting the bio-signal, P_3 denotes an amplitude of the bio-signal at T_3 , T_{\max} denotes a time of a peak point of the bio-signal in a first interval, P_{\max} denotes an amplitude of the bio-signal at T_{\max} , T_{sys} denotes an intermediate time between T_1 and T_{\max} , an arbitrary internally dividing point between T_1 and T_{\max} , or an arbitrary internally dividing point between T_1 and T_2 , P_{sys} denotes an amplitude of the bio-signal at T_{sys} , and P_{area} denotes a sum of amplitudes of the bio-signal in a second interval.

[0009] The stable interval determiner may determine the at least one stable interval based on an output value of an acceleration or gyro sensor attached to the object.

50 **[0010]** The stable interval determiner may compare the output value of the acceleration or gyro sensor at a time of bio-signal measurement with a predetermined threshold value, and, in response to the output value of the acceleration or gyro sensor being maintained less than or equal to the threshold value for a predetermined time period, the stable interval determiner may be further configured to determine that the predetermined time period is a stable interval.

[0011] The stable interval determiner may determine the at least one stable interval based on an amount of change in the first feature or second feature extracted from the bio-signal.

55 **[0012]** The amount of change in the first feature or second feature may be defined as a fluctuation with respect to a mean value of the corresponding first feature or second feature.

[0013] The fluctuation may include a variance, a standard deviation, and a mean absolute deviation.

[0014] The stable interval determiner may compare the amount of change in the first feature or second feature extracted during a time period with a predetermined threshold value and determine the time period as the stable interval when the amount in change in the first feature or second feature is less than or equal to the predetermined threshold value.

[0015] The statistical variable may include a mean, a variance, a standard deviation, and a mean absolute deviation.

[0016] The feature combiner may calculate a combining coefficient of each stable interval based on the statistical variable values of the first and second features which are calculated for each stable interval.

[0017] The feature combiner may calculate the combining coefficient of each stable interval by dividing the statistical variable value of the first feature of each stable interval by the statistical variable value of the second feature of each stable interval.

[0018] The feature combiner may calculate the integrated combining coefficient by arithmetically averaging the combining coefficients calculated for each stable interval.

[0019] The feature combiner may calculate the feature combining coefficient by applying different weights to the combining coefficients calculated for each stable interval and linearly combining the combining coefficients to which the different weights are applied.

[0020] The feature combiner may apply a higher weight to a combining coefficient of a temporally later stable interval.

[0021] The feature combiner may linearly combine the first feature and the second feature based on the calculated integrated combining coefficient.

[0022] The adaptive bio-signal feature combining apparatus may further include a controller configured to update the integrated combining coefficient.

[0023] The controller may control the feature extractor, the stable interval determiner, the statistical variable calculator, and the feature combiner to update the integrated combining coefficient according to a designated update period.

[0024] The controller may control the feature extractor, the stable interval determiner, the statistical variable calculator, and the feature combiner to constantly update the integrated combining coefficient by overlapping the at least one stable interval in a sliding-window scheme.

[0025] The adaptive bio-signal feature combining apparatus may further include a joint statistical variable calculator configured to calculate a joint statistical variable value between the first feature and the second feature, wherein the feature combiner calculates the integrated combining coefficient based on the statistical variable value of the first feature, the statistical variable value of the second feature, and the joint statistical variable value.

[0026] The joint statistical variable may include a covariance and a correlation coefficient.

[0027] According to an aspect of another exemplary embodiment, there is provided an adaptive bio-signal feature combining method including: extracting first feature values and second feature values from a bio-signal of an object; calculating a statistical variable value of a first feature and a statistical variable value of a second feature based on the first feature values and the second feature values which are extracted from at least one stable interval; and calculating an integrated combining coefficient that is used to combine the first feature and the second feature based on the statistical variable values of the first and second features.

[0028] According to an aspect of still another exemplary embodiment, there is provided a blood pressure measurement apparatus including: a stable interval determiner configured to determine a stable interval of a bio-signal of an object; a statistical variable calculator configured to calculate a statistical variable value of a first feature and a statistical variable value of a second feature, the first feature and the second feature being extracted from the stable interval of the bio-signal; a feature combiner configured to calculate an integrated combining coefficient based on the statistical variable values of the first and second features and combine the first feature and the second feature based on the calculated integrated combining coefficient; and a blood pressure estimator configured to estimate a blood pressure of the object based on the combined feature, wherein the stable interval determiner, the statistical variable calculator, the feature combiner, and blood pressure estimator are included in one or more processors.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The above and/or other aspects will be more apparent by describing certain exemplary embodiments, with reference to the accompanying drawings, in which:

FIG. 1 is a diagram illustrating a bio-signal according to an exemplary embodiment;

FIG. 2 is a block diagram illustrating an adaptive bio-signal feature combining apparatus according to an exemplary embodiment;

FIG. 3 is a graph for describing a first feature and a second feature of a bio-signal;

FIG. 4 illustrates graphs for describing a method of obtaining $P_n(P_1, P_2, P_3)$ and $T_n(T_1, T_2, T_3)$ of FIG. 3;

FIG. 5 illustrates graphs for describing a method of obtaining P_{max} and T_{max} of FIG. 3;

FIG. 6 is a diagram showing an example of change of a blood pressure and changes of the first feature and the second feature extracted from the bio-signal;

FIG. 7A is a diagram for describing the process of obtaining a combining coefficient of each feature;
 FIG. 7B is a diagram for describing the process of obtaining an integrated combining coefficient;
 FIG. 8 is a block diagram illustrating an adaptive bio-signal feature combining apparatus according to another exemplary embodiment;
 FIG. 9 is a diagram illustrating an example of periodically updating an integrated combining coefficient;
 FIG. 10 is a diagram illustrating an example of updating an integrated combining coefficient in a sliding-window scheme;
 FIG. 11 is a block diagram illustrating an adaptive bio-signal feature combining apparatus according to another exemplary embodiment;
 FIG. 12 is a flowchart illustrating an adaptive bio-signal feature combining method according to an exemplary embodiment;
 FIG. 13 is a flowchart illustrating operation in which the feature combining coefficient is calculated according to an exemplary embodiment;
 FIG. 14 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment;
 FIG. 15 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment;
 FIG. 16 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment;
 FIG. 17 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment;
 FIG. 18 is a flowchart illustrating an adaptive bio-signal feature combining method according to still another exemplary embodiment;
 FIG. 19 is a flowchart illustrating an adaptive bio-signal feature combining method according to yet another exemplary embodiment;
 FIG. 20 is a block diagram illustrating a blood pressure measurement apparatus according to an exemplary embodiment; and
 FIG. 21 is a flowchart illustrating a blood pressure measurement method according to an exemplary embodiment;

DETAILED DESCRIPTION

[0030] Exemplary embodiments are described in greater detail below with reference to the accompanying drawings.

[0031] In the following description, like drawing reference numerals are used for like elements, even in different drawings. The matters defined in the description, such as detailed construction and elements, are provided to assist in a comprehensive understanding of the exemplary embodiments. However, it is apparent that the exemplary embodiments can be practiced without those specifically defined matters. Also, well-known functions or constructions are not described in detail since they would obscure the description with unnecessary detail.

[0032] It should be noted that in some alternative implementations, the functions/acts noted in the blocks may occur out of the order noted in the flowcharts. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved.

[0033] Terms described in below are selected by considering functions in the embodiment and meanings may vary depending on, for example, a user or operator's intentions or customs. Therefore, in the following embodiments, when terms are specifically defined, the meanings of terms should be interpreted based on definitions, and otherwise, should be interpreted based on general meanings recognized by those skilled in the art.

[0034] As used herein, the singular forms are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," or "includes" and/or "including" when used in this description, specify the presence of stated features, numbers, steps, operations, elements, components or combinations thereof, but do not preclude the presence or addition of one or more other features, numbers, steps, operations, elements, components or combinations thereof.

[0035] It will also be understood that the elements or components in the following description are discriminated in accordance with their respective main functions. In other words, two or more elements may be made into one element or one element may be divided into two or more elements in accordance with a subdivided function. Additionally, each of the elements in the following description may perform a part or whole of the function of another element as well as its main function, and some of the main functions of each of the elements may be performed exclusively by other elements. Each element may be realized in the form of a hardware component, a software component, and/or a combination thereof.

[0036] Meanwhile, an apparatus for providing a health status of the cardiovascular system described herein may be

implemented as a software module or in the form of a hardware chip and be mounted in an electronic device. In this case, the electronic device may include a mobile phone, a smart phone, a notebook computer, a personal digital assistant (PDA), a portable multimedia player (PMP), a navigation system, an MP3 player, a digital camera, a wearable device, etc., and the wearable device may include various types of wearable devices, such as a wristwatch type, a wristband type, a ring type, a belt-type, a necklace type, an ankle band type, a thigh band type, a forearm band type, and the like. However, the electronic device is not limited to the above mentioned examples, and the wearable device is also not limited to the above-described examples.

[0037] FIG. 1 is a diagram illustrating a bio-signal according to an exemplary embodiment. Specifically, FIG. 1 illustrates a photoplethysmogram (PPG) signal.

[0038] Referring to FIG. 1, a waveform of a PPG signal 100 may be a summation of a propagation wave 110, which is caused by blood flow and propagates from the heart to peripheral parts of a body, and reflection waves 120 to 150, which is caused by the blood flow and returns from the peripheral parts of the body. In the illustrated example, the PPG signal 100 is a summation of five component pulses 110 to 150.

[0039] Change in blood pressure may depend on a cardiac output, which represents the amount of blood ejected by the heart in a unit of time, and a total peripheral vascular resistance. It may be expressed as Equation 1.

$$BP = CO \times TPR \quad \dots(I)$$

[0040] Here, *BP* represents a blood pressure difference between the right and left ventricles, *CO* represents a cardiac output, and *TPR* represents a total peripheral vascular resistance.

[0041] As the cardiac output or the total peripheral vascular resistance increases, so does the blood pressure. Thus, when a feature related to the cardiac output and a feature related to the total peripheral vascular resistance are extracted from the PPG signal 100 and a feature obtained by adequately combining the two extracted features is used in blood pressure estimation, it may be possible to increase the accuracy in blood pressure estimation.

[0042] FIG. 2 is a block diagram illustrating an adaptive bio-signal feature combining apparatus according to an exemplary embodiment.

[0043] Referring to FIG. 2, the adaptive bio-signal feature combining apparatus 200 includes a feature extractor 210, a stable interval determiner 220, a statistical variable calculator 230, and a feature combiner 240. The adaptive bio-signal feature combining apparatus 200 may be included in one or more processors.

[0044] The feature extractor 210 may extract first feature values and second feature values from a bio-signal. Here, the bio-signal may be an electrical signal transmitted between cells in vivo and may include an electrocardiogram (ECG) signal, a PPG signal, an electromyogram (EMG) signal, a ballistocardiogram (BCG) signal, etc.

[0045] According to one exemplary embodiment, a first feature may be a feature related to a cardiac output, and a second feature may be a feature related to the total peripheral vascular resistance.

[0046] According to an exemplary embodiment, a time interval may be divided into two intervals by the time corresponding to the third of numerous local maximum points included in a second-order differential bio-signal (also referred to as reference time), and the time interval preceding the reference time may be determined as the systolic region and the subsequent time interval may be determined as the diastolic region.

[0047] The first and second features will be described later in detail with reference to FIGS. 3 to 5.

[0048] The stable interval determiner 220 may determine at least one stable interval in the bio-signal. Here, the stable interval may be an interval during which a blood pressure of an object is maintained stable and the bio-signal measured from the object remains stable.

[0049] According to an exemplary embodiment, the stable interval determiner 220 may determine at least one stable interval in the bio-signal using an output value of an acceleration or gyro sensor attached to the object. For example, the stable interval determiner 220 may compare the output value of the acceleration or gyro sensor at the time of bio-signal measurement with a predetermined threshold value, and, when the output value of the acceleration or gyro sensor is maintained less than or equal to the threshold value for a specified period of time, the stable interval determiner 220 may determine that the specified time period is a stable interval. When the output value of the acceleration or gyro sensor attached to the object exceeds the predetermined threshold value, the stable interval determiner 220 may determine that the object is in motion, and the blood pressure or the bio-signal of the object cannot be remain stable. By contrast, when the output value of the acceleration or gyro sensor attached to the object is maintained less than or equal to the predetermined threshold value for the specified period of time, the stable interval determiner 220 may determine that the object stays still or is in a stable state without a large movement, and may determine that the blood pressure or the bio-signal of the object is maintained stable. Therefore, the stable interval determiner 220 may be allowed to identify the stable interval of the bio-signal using the output value of the acceleration or gyro sensor attached to the object.

[0050] According to another exemplary embodiment, the stable interval determiner 220 may determine at least one

stable interval in the bio-signal using the amount of change in the feature (e.g., the first feature or the second feature) extracted from the bio-signal. Here, the amount of change in the feature may mean the fluctuation with respect to the mean value of the corresponding feature. For example, the stable interval determiner 220 may calculate a variance, a standard deviation, and/or a mean absolute deviation of the feature values (e.g., first feature values or second feature values) extracted from a predetermined time interval of the bio-signal and calculate the amount of change in the feature by dividing the calculated variance, standard deviation, or mean absolute deviation by the mean of the feature values. The stable interval determiner 220 may compare the calculated amount of change in the feature with a predetermined threshold value and determine a corresponding time interval as a stable interval when the calculated amount of change in the feature is less than or equal to the predetermined threshold value.

[0051] The statistical variable calculator 230 may calculate statistical variable values of the first and second features for each stable interval based on the first feature values and the second feature values extracted from the stable intervals in the bio-signal. In this case, the statistical variable may include a mean, a variance, a standard deviation, a mean absolute deviation, and the like.

[0052] For example, the statistical variable calculator 230 may calculate the statistical variable values of the first and second features for each interval through Equation 2 and Equation 3.

$$x1_n = \frac{1}{M_n} \sum_{m=1}^{M_n} f1_n(m) \quad \dots(2)$$

$$x2_n = \frac{1}{M_n} \sum_{m=1}^{M_n} f2_n(m) \quad \dots(3)$$

[0053] Here, n denotes an index of a stable interval, $x1_n$ denotes a statistical variable value of the first feature of the n -th stable interval, $x2_n$ denotes a statistical variable value of the second feature of the n -th stable interval, M_n denotes the total number of the first feature values or the second feature values that are extracted from the n -th stable interval, m denotes an index of the first feature value or the second feature value, $f1_n(m)$ denotes the m -th first feature value in the n -th stable interval, and $f2_n(m)$ denotes the m -th second feature value in the n -th stable interval.

[0054] In another example, the statistical variable calculator 230 may calculate the statistical variable values of the first and second features for each stable interval through Equation 4 and Equation 5.

$$x1_n = \frac{1}{M_n} \sum_{m=1}^{M_n} (f1_n(m)) = \frac{1}{M_n} \sum_{m=1}^{M_n} (f1_n(m))^2 \quad \dots(4)$$

$$x2_n = \frac{1}{M_n} \sum_{m=1}^{M_n} (f2_n(m)) = \frac{1}{M_n} \sum_{m=1}^{M_n} (f2_n(m))^2 \quad \dots(5)$$

[0055] Here, n denotes an index of a stable interval, $x1_n$ denotes a statistical variable value of the first feature of the n -th stable interval, $x2_n$ denotes a statistical variable value of the second feature of the n -th stable interval, M_n denotes the total number of the first feature values or the second feature values that are extracted from the n -th stable interval, m denotes an index of the first feature value or the second feature value, $f1_n(m)$ denotes the m -th first feature value in the n -th stable interval, and $f2_n(m)$ denotes the m -th second feature value in the n -th stable interval.

[0056] In still another example, the statistical variable calculator 230 may calculate the statistical variable values of the first and second features for each stable interval through Equation 6 and Equation 7.

$$x1_n = \sqrt{\frac{1}{M_n} \sum_{m=1}^{M_n} (f1_n(m) - \frac{1}{M_n} \sum_{m=1}^{M_n} f1_n(m))^2} \quad \dots(6)$$

5

$$x2_n = \sqrt{\frac{1}{M_n} \sum_{m=1}^{M_n} (f2_n(m) - \frac{1}{M_n} \sum_{m=1}^{M_n} f2_n(m))^2} \quad \dots(7)$$

10

[0057] Here, n denotes an index of a stable interval, $x1_n$ denotes a statistical variable value of the first feature of the n -th stable interval, $x2_n$ denotes a statistical variable value of the second feature of the n -th stable interval, M_n denotes the total number of the first feature values or the second feature values that are extracted from the n -th stable interval, m denotes an index of the first feature value or the second feature value, $f1_n(m)$ denotes the m -th first feature value in the n -th stable interval, and $f2_n(m)$ denotes the m -th second feature value in the n -th stable interval.

15

[0058] In still another example, the statistical variable calculator 230 may calculate the statistical variable values of the first and second features for each stable interval through Equation 8 and Equation 9.

20

$$x1_n = \frac{1}{M_n} \sum_{m=1}^{M_n} \left| f1_n(m) - \frac{1}{M_n} \sum_{m=1}^{M_n} f1_n(m) \right| \quad \dots(8)$$

25

$$x2_n = \frac{1}{M_n} \sum_{m=1}^{M_n} \left| f2_n(m) - \frac{1}{M_n} \sum_{m=1}^{M_n} f2_n(m) \right| \quad \dots(9)$$

30

[0059] Here, n denotes an index of a stable interval, $x1_n$ denotes a statistical variable value of the first feature of the n -th stable interval, $x2_n$ denotes a statistical variable value of the second feature of the n -th stable interval, M_n denotes the total number of the first feature values or the second feature values that are extracted from the n -th stable interval, m denotes an index of the first feature value or the second feature value, $f1_n(m)$ denotes the m -th first feature value in the n -th stable interval, and $f2_n(m)$ denotes the m -th second feature value in the n -th stable interval.

35

[0060] The feature combiner 240 may combine the first feature and the second feature using the statistical variable values of the first feature and the second feature which are calculated for each stable interval.

[0061] According to one exemplary embodiment, the feature combiner 240 may calculate a combining coefficient for the first feature by averaging the statistical variable values of the first feature calculated for each stable interval and calculate a combining coefficient for the second feature by averaging the statistical variable values of the second feature calculated for each stable interval. In addition, the feature combiner 240 may combine the first feature and the second feature using the combining coefficient of the first feature and the combining coefficient of the second feature.

40

[0062] For example, the feature combiner 240 may combine the first feature and the second feature using Equation 10.

45

$$f_{comb} = \frac{1}{x1_{comb}} f1 + \frac{1}{x2_{comb}} f2, \text{ where } x1_{comb} = \frac{1}{N} \sum_{n=1}^N x1_n, x2_{comb} = \frac{1}{N} \sum_{n=1}^N x2_n \quad \dots (10)$$

50

[0063] Here, f_{comb} denotes the combined feature, $f1$ denotes the first feature, $f2$ denotes the second feature, $x1_{comb}$ denotes the combining coefficient of the first feature, $x2_{comb}$ denotes the combining coefficient of the second feature, n denotes an index of the stable interval, $x1_n$ denotes a statistical variable value of the first feature in the n -th stable interval, and $x2_n$ denotes a statistical variable value of the second feature in the n -th stable interval.

[0064] In another example, the feature combiner 240 may combine the first feature and the second feature using Equation 11.

55

$$f_{comb} = u1 \left(\frac{1}{x1_{comb}} f1 + \frac{1}{x2_{comb}} f2 \right) + u2, \text{ where } x1_{comb} = \frac{1}{N} \sum_{n=1}^N x1_n, x2_{comb} = \frac{1}{N} \sum_{n=1}^N x2_n \dots (11)$$

5
[0065] Here, f_{comb} denotes the combined feature, $f1$ denotes the first feature, $f2$ denotes the second feature, $x1_{comb}$ denotes the combining coefficient of the first feature, $x2_{comb}$ denotes the combining coefficient of the second feature, n denotes an index of the stable interval, $x1_n$ denotes a statistical variable value of the first feature in the n -th stable interval, and $x2_n$ denotes a statistical variable value of the second feature in the n -th stable interval. In addition, $u1$ denotes a scaling coefficient, and $u2$ denotes a bias. $u1$ and $u2$ may be variously set according to the performance and purpose of the system.

10
[0066] In still another example, the feature combiner 240 may combine the first feature and the second feature using Equation 12.

$$f_{comb} = u1 \left(\frac{1}{x1_{comb}} f1 + a_{comb} \frac{1}{x2_{comb}} f2 \right) + u2, \text{ where } x1_{comb} = \frac{1}{N} \sum_{n=1}^N x1_n, x2_{comb} = \frac{1}{N} \sum_{n=1}^N x2_n \dots (12)$$

15
[0067] Here, f_{comb} denotes the combined feature, $f1$ denotes the first feature, $f2$ denotes the second feature, $x1_{comb}$ denotes the combining coefficient of the first feature, $x2_{comb}$ denotes the combining coefficient of the second feature, n denotes an index of the stable interval, $x1_n$ denotes a statistical variable value of the first feature in the n -th stable interval, and $x2_n$ denotes a statistical variable value of the second feature in the n -th stable interval. In addition, a_{comb} is an

20
 amplification coefficient for $\frac{1}{x2_{comb}}$, which may be a setting factor given in the system in order to compensate for an

imbalance which may occur in the degree of influence of $\frac{1}{x1_{comb}} f1$ versus $\frac{1}{x2_{comb}} f2$ on f_{comb} .

25
[0068] According to another exemplary embodiment, the feature combiner 240 may calculate a combining coefficient of each stable interval based on the statistical variable values of the first and second features which are calculated for each stable interval. For example, the feature combiner 240 may calculate the combining coefficient of each stable interval by dividing the statistical variable value of the first feature of each stable interval by the statistical variable value of the second feature of each stable interval. This is expressed as Equation 13.

$$w_n = \frac{x1_n}{x2_n} \dots (13)$$

30
[0069] Here, w_n denotes a combining coefficient of the n -th stable interval, $x1_n$ denotes a statistical variable value of the first feature in the n -th stable interval, and $x2_n$ denotes a statistical variable value of the second feature in the n -th stable interval.

35
[0070] In addition, the feature combiner 240 may calculate an integrated combining coefficient by combining the combining coefficients calculated for each stable interval.

[0071] For example, the feature combiner 240 may calculate the integrated combining coefficient by arithmetically averaging the combining coefficients of the stable intervals. This is expressed as Equation 14.

$$w_{comb} = \frac{1}{N} \sum_{n=1}^N w_n \dots (14)$$

40
[0072] Here, w_{comb} denotes an integrated combining coefficient, n denotes an index of a stable interval, and w_n denotes a combining coefficient of the n -th stable interval.

45
[0073] In another example, the feature combiner 240 may calculate the integrated combining coefficient by applying different weights to the combining coefficients of the stable intervals and linearly combining the resulting combining

coefficients. This is expressed as Equation 15.

$$w_{comb} = \sum_{n=1}^N \alpha_n w_n, \quad \text{where } \sum_{n=1}^N \alpha_n = 1 \quad \dots(15)$$

[0074] Here, w_{comb} denotes an integrated combining coefficient, n denotes an index of a stable interval, w_n denotes a combining coefficient of the n -th stable interval, and α_n denotes a weight of the n -th stable interval. In this case, α_n may be set such that a higher weight is applied to a combining coefficient of a temporally later stable interval, which is, however, merely illustrative, and it is not limited thereto.

[0075] The feature combiner 240 may combine the first feature and the second feature based on the integrated combining coefficient. According to one exemplary embodiment, the feature combiner 240 may linearly combine the first and second features using the feature combining coefficient.

[0076] For example, the feature combiner 240 may combine the first and second features using Equation 16.

$$f_{comb} = f1 + w_{comb}f2 \quad \dots(16)$$

[0077] Here, f_{comb} denotes the combined feature, $f1$ denotes the first feature, $f2$ denotes the second feature, and w_{comb} denotes the integrated combining coefficient.

[0078] In another example, the feature combiner 240 may combine the first and second features using Equation 17.

$$f_{comb} = u1(f1 + w_{comb}f2) + u2 \quad \dots(17)$$

[0079] Here, f_{comb} denotes the combined feature, $f1$ denotes the first feature, $f2$ denotes the second feature, w_{comb} denotes the integrated combining coefficient, $u1$ denotes a scaling coefficient, and $u2$ denotes a bias. Here, $u1$ and $u2$ may be set variously according to the performance and purpose of the system.

[0080] In still another example, the feature combiner 240 may combine the first and second features using Equation 18.

$$f_{comb} = u1(f1 + a_{comb}w_{comb}f2) + u2 \quad \dots(18)$$

[0081] Here, f_{comb} denotes the combined feature, $f1$ denotes the first feature, $f2$ denotes the second feature, w_{comb} denotes the integrated combining coefficient, $u1$ denotes a scaling coefficient, and $u2$ denotes a bias. a_{comb} is an amplification coefficient for the w_{comb} , which is a setting factor given in the system in order to compensate for an imbalance which may occur in the degree of influence of $w_{comb} * f2$ versus $f1$ on f_{comb} .

[0082] FIG. 3 is a graph for describing a first feature and a second feature of a bio-signal, FIG. 4 illustrates graphs for describing a method of obtaining $P_n(P_1, P_2, P_3)$ and $T_n(T_1, T_2, T_3)$ of FIG. 3, and FIG. 5 illustrates graphs for describing a method of obtaining P_{max} and T_{max} of FIG. 3.

[0083] Referring to FIG. 3, the bio-signal 300 may be a superposition of three component pulses 310, 320, and 330. In this case, reference numeral 300 denotes the bio-signal of one period T_{period} , 310 denotes a first component pulse, 320 denotes a second component pulse, and 330 denotes a third component pulse. In addition, T_1 denotes the time of the peak point of the first component pulse 310, P_1 denotes the amplitude of the bio-signal 300 at T_1 , T_2 denotes the time of the peak point of the second component pulse 320, P_2 denotes the amplitude of the bio-signal 300 at T_2 , T_3 denotes the time of the peak point of the third component pulse 330, P_3 denotes the amplitude of the bio-signal 300 at T_3 , T_{max} denotes the time of the peak point of the bio-signal 300 in a predetermined interval (e.g., a first interval), P_{max} denotes the amplitude of the bio-signal 300 at T_{max} , T_{sys} denotes the intermediate time between T_1 and T_{max} , P_{sys} denotes the amplitude of the bio-signal 300 at T_{sys} , τ_{dur} denotes a setting factor ($0 \leq \tau_{dur} \leq 1$) (e.g., 0.7) of the system, and P_{area} denotes the sum of amplitudes of the bio-signal 300 between time 0 and $\tau_{dur} * T_{period}$ (in a second interval).

[0084] The first feature is a feature related to the cardiac output, and it may include, for example, P_{max}/P_{area} , P_{max}/P_3 , P_{sys}/P_3 , P_1/P_3 , P_2/P_3 , $1/T_{period}$, or the like.

[0085] The second feature is a feature related to the total peripheral vascular resistance, and it may include $1/(T_3 - T_{sys})$,

$1/(T_3-T_{\max})$, $1/(T_3-T_1)$, $1/(T_3-T_2)$, P_3/P_1 , P_2/P_1 , or the like.

[0086] Meanwhile, T_{sys} is described as the intermediate time between T_1 and T_{\max} in FIG. 3, but is not limited thereto. For example, T_{sys} may be an arbitrary internally dividing point between T_1 and T_{\max} or an arbitrary internally dividing point between T_1 and T_2 .

[0087] Referring to FIG. 4, $P_n(P_1, P_2, P_3)$ and $T_n(T_1, T_2, T_3)$ of FIG. 3 may be obtained based on a second-order differential signal 400 of the bio-signal 300. When the second-order differential signal 400 is obtained from the bio-signal 300, the second-order differential signal 400 may include a plurality of local minimum points min1, min2, and min3. When the local minimum points min1 to min3 included in the second-order differential signal 400 are arranged in a time-order sequence, the first local minimum point min1 corresponds to T_1 , the second local minimum point min2 corresponds to T_2 , and the third local minimum point min3 corresponds to T_3 . In addition, the amplitude of the bio-signal 300 at T_1 corresponds to P_1 , the amplitude of the bio-signal 300 at T_2 corresponds to P_2 , and the amplitude of the bio-signal 300 at T_3 corresponds to P_3 .

[0088] Referring to FIG. 5, P_{\max} and T_{\max} of FIG. 3 may be obtained based on the second-order differential signal 400 of the bio-signal 300. When the second-order differential signal 400 is obtained from the bio-signal 300, the second-order differential signal 400 may include a plurality of local maximum points max1, max2, and max3. When the local maximum points max1 to max3 included in the second-order differential signal 400 are arranged in a time-order sequence and the time corresponding to the third maximum point is T_{range} , a range for searching P_{\max} may be determined to be the range of $0 \leq \text{time} \leq T_{\text{range}}$. In this case, the time of the peak point of the bio-signal 300 in the range of $0 \leq \text{time} \leq T_{\text{range}}$ corresponds to T_{\max} and the amplitude of the bio-signal 300 at T_{\max} corresponds to P_{\max} .

[0089] FIG. 6 is a diagram showing an example of change of a blood pressure and changes of the first feature and the second feature extracted from the bio-signal.

[0090] Referring to FIG. 6, when a blood pressure value changes, the average change value of the first feature (denoted as FEATURE 1) and the average change value of the second feature (denoted as FEATURE 2) may also change. Specifically, when the cardiac output increases due to exercise or the like and the blood pressure, in turn, rises, the first feature (FEATURE 1) related to the cardiac output, may increase greatly, whereas the second feature (FEATURE 2) related to the total peripheral vascular resistance, may be substantially constant or decreases. In addition, when the blood vessel resistance increases due to the tension of tissue and in turn the blood pressure increases, the second feature (FEATURE 2) related to the total peripheral vascular resistance may increase greatly, whereas the first feature (FEATURE 1) related to the cardiac output may be substantially constant or decreases. In other words, when the blood pressure is out of the stable state, i.e., a stable interval, the balance between changes of the two features is generally disturbed and the change of one feature is relatively larger than the other feature, which may result in change in blood pressure.

[0091] FIG. 7A is a diagram for describing the process of obtaining a combining coefficient of each feature. Specifically, FIG. 7A is a diagram for describing the process of obtaining the combining coefficients of the first feature and the second feature based on the first feature values and the second feature values which are extracted from two stable intervals.

[0092] Referring to FIGS. 2 and 7A, the feature extractor 210 may extract the first feature values and the second feature values from the bio-signal, and the stable interval determiner 220 may determine the two stable intervals 410 and 420 from the bio-signal.

[0093] The statistical variable calculator 230 may calculate a statistical variable value $x1_1$ of the first feature based on the first feature values in a first stable interval 410 and calculate a statistical variable value $x2_1$ of the second feature based on the second feature values in the first stable interval 410. In addition, the statistical variable calculator 230 may calculate a statistical variable value $x1_2$ of the first feature based on the first feature values in a second stable interval 420 and calculate a statistical variable value $x2_2$ of the second feature based on the second feature values in the second stable interval 420. In this case, the statistical variable calculator 230 may calculate the statistical variable values $x1_1$ and $x1_2$ of the first feature and the statistical variable values $x2_1$ and $x2_2$ of the second feature using Equation 2 to Equation 9.

[0094] The feature combiner 240 may calculate a combining coefficient $x1_{\text{comb}}$ of the first feature by arithmetically averaging the statistical variable values $x1_1$ and $x1_2$ of the first feature and calculate a combining coefficient $x2_{\text{comb}}$ of the second feature by arithmetically averaging the statistical variable values $x2_1$ and $x2_2$ of the second feature.

[0095] Meanwhile, the feature combiner 240 may combine the first feature and the second feature using Equation 10 to Equation 12, based on the combining coefficient $x1_{\text{comb}}$ of the first feature and the combining coefficient $x2_{\text{comb}}$ of the second feature.

[0096] FIG. 7B is a diagram for describing the process of obtaining an integrated combining coefficient. Specifically, FIG. 7B is a diagram for describing the process of obtaining the integrated combining coefficient based on the first feature values and the second feature values which are extracted from two stable intervals.

[0097] Referring to FIGS. 2 and 7B, the feature extractor 210 may extract the first feature values and the second feature values from the bio-signal, and the stable interval determiner 220 determines the two stable intervals 410 and 420 from the bio-signal.

[0098] The statistical variable calculator 230 may calculate a statistical variable x_{1_1} of the first feature based on the first feature values in a first stable interval 410 and calculates a statistical variable x_{2_1} of the second feature based on the second feature values in the first stable interval 410. In addition, the statistical variable calculator 230 may calculate a statistical variable value x_{1_2} of the first feature based on the first feature values in a second stable interval 420 and calculates a statistical variable value x_{2_2} of the second feature based on the second feature values in the second stable interval 420. In this case, the statistical variable calculator 230 may calculate the statistical variable value x_{1_1} and x_{1_2} of the first feature and the statistical variable value x_{2_1} and x_{2_2} of the second feature using Equation 2 to Equation 9.

[0099] The feature combiner 240 may calculate a combining coefficient w_1 of the first stable interval 410 based on the statistical variable values x_{1_1} and x_{2_1} of the first and second features. In addition, the feature combiner 240 calculates a combining coefficient w_2 of the second stable interval 420 based on the statistical variable values x_{1_2} and x_{2_2} of the first and second features. In this case, the feature combiner 240 may calculate the combining coefficient w_1 of the first stable interval 410 and the combining coefficient w_2 of the second stable interval 420 using Equation 13.

[0100] The feature combiner 240 may calculate an integrated combining coefficient w_{comb} by arithmetically averaging the combining coefficients w_1 and w_2 of the stable intervals.

[0101] Meanwhile, the feature combiner 240 may combine the first feature and the second feature using Equation 16 to Equation 18 based on the integrated combining coefficient w_{comb} .

[0102] FIG. 8 is a block diagram illustrating an adaptive bio-signal feature combining apparatus according to another exemplary embodiment, FIG. 9 is a diagram illustrating an example of periodically updating an integrated combining coefficient, and FIG. 10 is a diagram illustrating an example of updating an integrated combining coefficient in a sliding-window scheme.

[0103] Referring to FIGS. 8 to 10, the adaptive bio-signal feature combining apparatus 800 includes a feature extractor 810, a stable interval determiner 820, a statistical variable calculator 830, a feature combiner 840, and a controller 850. The feature extractor 810, the stable interval determiner 820, the statistical variable calculator 830, the feature combiner 840, and the controller 850 may be included in one or more processors. In this case, the feature extractor 810, the stable interval determiner 820, the statistical variable calculator 830, and the feature combiner 840 may operate in substantially the same manner as the feature extractor 210, the stable interval determiner 220, the statistical variable calculator 230, and the feature combiner 240 of FIG. 2, respectively, and thus detailed descriptions thereof will not be reiterated.

[0104] The controller 850 may constantly update a combining coefficient of a first feature and a combining coefficient of a second feature, or may constantly update an integrated combining coefficient.

[0105] The features of the bio-signal may change according to changes in physiological characteristics of the human body and changes in the surrounding environment (e.g., temperature, etc.). Accordingly, the controller 850 may control the feature extractor 810, the stable interval determiner 820, the statistical variable calculator 830, and the feature combiner 840 so that the combining coefficients of the first feature and the second feature can be constantly updated or the integrated combining coefficient can be constantly updated by taking into account the features of the bio-signal.

[0106] According to one exemplary embodiment, the controller 850 may control the feature extractor 810, the stable interval determiner 820, the statistical variable calculator 830, and the feature combiner 840 to periodically update the integrated combining coefficient according to a designated update period, as shown in FIG. 9. In this case, the update period may be set variously according to the performance or purpose of the system.

[0107] According to another exemplary embodiment, the controller 850 may control the feature extractor 810, the stable interval determiner 820, the statistical variable calculator 830, and the feature combiner 840 so that the integrated combining coefficient can be constantly updated by overlapping at least one stable interval in a sliding-window scheme, as shown in FIG. 10.

[0108] Meanwhile, although FIGS. 9 and 10 illustrate that the integrated combining coefficient is constantly updated for convenience of description, it is possible to constantly update the combining coefficients of the first and second features according to an exemplary embodiment.

[0109] FIG. 11 is a block diagram illustrating an adaptive bio-signal feature combining apparatus according to another exemplary embodiment.

[0110] Referring to FIG. 11, the adaptive bio-signal feature combining apparatus 1100 may include a feature extractor 1110, a stable interval determiner 1120, a statistical variable calculator 1130, a joint statistical variable calculator 1140, and a feature combiner 1150. Here, the feature extractor 1110, the stable interval determiner 1120, and the statistical variable calculator 1130 may operate in substantially the same manner as the feature extractor 210, the stable interval determiner 220, and the statistical variable calculator 230 of FIG. 2, respectively, and thus detailed descriptions thereof will not be reiterated.

[0111] The joint statistical variable calculator 1140 may calculate a joint statistical variable value between a first feature and a second feature. In this case, the joint statistical variable may include a covariance or a correlation coefficient, which is, however, merely illustrative, and it is not limited thereto.

[0112] As described above, since the change in blood pressure is minimized in an interval in which a user remains stable by having a rest or the like, that is, a stable interval, a result of combination of the first and second features

extracted from the bio-signal in the stable interval may be expected to have a small fluctuation. Therefore, the combining coefficient may be adjusted such that a variance that indicates statistical fluctuation of a sum of f_1 and wf_2 , which is the combination result of the two features, is minimized. This may be expressed as Equation 19.

5

$$\begin{aligned} V[f_1 + wf_2] &= E[(f_1 + wf_2)^2] - (E[f_1 + wf_2])^2 \\ &= E[f_1^2 + 2wf_1f_2 + w^2f_2^2] - E[f_1]^2 - 2wE[f_1]E[f_2] - w^2(E[f_2])^2 \\ &= w^2V[f_2] + 2w(E[f_1f_2] - E[f_1]E[f_2]) + V[f_1] \end{aligned} \quad \dots(19)$$

10

[0113] Here, $V[X]$ and $E[X]$ denote a variance and a mean of variable X , respectively, f_1 denotes a first feature, f_2 denotes a second feature, and w denotes a combining coefficient.

[0114] Referring to Equation 19, it is shown that w that minimizes $V[f_1 + wf_2]$ is obtained as Equation 20.

15

$$w = -\frac{E[f_1f_2] - E[f_1]E[f_2]}{V[f_2]} = -\frac{COV(f_1, f_2)}{V[f_2]} \quad \dots(20)$$

20

[0115] Here, $COV(f_1, f_2)$ is a covariance between f_1 and f_2 .

[0116] Referring to Equation 15, it is shown that the combining coefficient w can be obtained using the statistical variable (variance) $v[f_2]$ of the second feature and the covariance $COV(f_1, f_2)$ between the first feature and the second feature.

25

[0117] Equation 20 is expanded as shown in Equation 21.

$$w = -\frac{x_1x_2}{V[f_2]} \times \frac{COV(f_1, f_2)}{x_1x_2} = -\frac{x_1}{x_2} \times \rho_{f_1, f_2} \quad \dots(21)$$

30

[0118] Here, x_1 and x_2 denote a statistical variable of the first feature and a statistical variable of the second feature, respectively, ρ_{f_1, f_2} denotes the correlation coefficient between the first feature and the second feature.

[0119] Referring to FIG. 21, it is shown that the combining coefficient w is obtained using the statistical variable x_1 of the first feature, the statistical variable x_2 of the second feature, and the correlation coefficient ρ_{f_1, f_2} between the first feature and the second feature.

35

[0120] The feature combiner 1150 may calculate the combining coefficient of each stable interval based on the statistical variable of the first feature, the statistical variable of the second feature, and the joint statistical variable (e.g., a covariance, a correlation coefficient, or the like) between the first feature and the second feature. For example, the feature combiner 1150 may calculate the combining coefficient of each stable interval using Equation 20 or Equation 21.

40

[0121] The feature combiner 1150 may calculate the integrated combining coefficient by combining the combining coefficients calculated for each stable interval. For example, the feature combiner 1150 may calculate the integrated combining coefficient using Equation 14 or Equation 15.

45

[0122] The feature combiner 1150 may generate a combined feature by combining the first feature and the second feature based on the integrated combining coefficient. For example, the feature combiner 1150 may combine the first and second features using Equation 16 to Equation 18.

[0123] FIG. 12 is a flowchart illustrating an adaptive bio-signal feature combining method according to an exemplary embodiment. The adaptive bio-signal feature combining method of FIG. 12 may be performed by the adaptive bio-signal feature combining apparatus 200 of FIG. 2.

50

[0124] Referring to FIGS. 2 and 12, the adaptive bio-signal feature combining apparatus 200 extracts first feature values and second feature values are extracted from a bio-signal of an object, in operation 1210. Here, the first feature and the second feature have been described specifically with reference to FIGS. 2 to 5, and hence detailed descriptions thereof will be omitted.

55

[0125] The adaptive bio-signal feature combining apparatus 200 determines at least one stable interval in the bio-signal, as depicted in operation 1220.

[0126] According to one exemplary embodiment, the adaptive bio-signal feature combining apparatus 200 may determine at least one stable interval in the bio-signal using an acceleration sensor or a gyro sensor which is attached to

an object. In a case where the adaptive bio-signal feature combining apparatus 200 and the acceleration or gyro sensor are included in a smartwatch or a smartphone, the acceleration or gyro sensor may detect the motion of a user who is wearing the smartwatch or holding the smartphone, and the adaptive bio-signal feature combining apparatus 200 may determine the stable interval based on the detected motion. For example, the adaptive bio-signal feature combining apparatus 200 may compare an output value of the acceleration sensor or the gyro sensor with a predetermined threshold value, and, when the output value of the acceleration or gyro sensor is maintained less than or equal to the threshold value for a specified period of time, the adaptive bio-signal feature combining apparatus 200 may determine that the specified time period is a stable interval.

[0127] According to another exemplary embodiment, the adaptive bio-signal feature combining apparatus 200 may determine at least one stable interval in the bio-signal using the amount of change in the feature (e.g., the first feature or the second feature) extracted from the bio-signal. Here, the amount of change in the feature may mean the fluctuation with respect to the mean value of the corresponding feature. For example, the adaptive bio-signal feature combining apparatus 200 may calculate a variance, a standard deviation, a mean absolute deviation, etc. of the feature values (e.g., first feature values or second feature values) extracted from a predetermined time interval of the bio-signal and calculate the amount of change in the feature by dividing the calculated variance, standard deviation, or mean absolute deviation by the mean of the feature values. The adaptive bio-signal feature combining apparatus 200 may compare the calculated amount of change in the feature with a predetermined threshold value and determine the corresponding time interval as a stable interval when the calculated amount of change in the feature is less than or equal to the predetermined threshold value.

[0128] The adaptive bio-signal feature combining apparatus 200 calculates a statistical variable value of the first feature and a statistical variable value of the second feature for each stable interval based on the first feature values and the second feature values, in operation 1230. In this case, the statistical variable may include a mean, a variance, a standard deviation, a mean absolute deviation, and the like. For example, the adaptive bio-signal feature combining apparatus 200 may calculate the statistical variable values of the first and second features using Equation 2 to Equation 9.

[0129] The adaptive bio-signal feature combining apparatus 200 calculates an integrated combining coefficient based on the statistical variable values of the first and second features which are calculated for each stable interval, in operation 1240.

[0130] Hereinafter, operation 1240 in which the integrated combining coefficient is calculated will be described in detail with reference to FIG. 13.

[0131] FIG. 13 is a flowchart illustrating operation in which the integrated combining coefficient is calculated, according to an exemplary embodiment.

[0132] Referring to FIGS. 2 and 13, the adaptive bio-signal feature combining apparatus 200 calculates the combining coefficient of each stable interval based on the statistical variable values of the first and second features which are calculated for each stable interval, in operation 1310. For example, the adaptive bio-signal feature combining apparatus 200 may calculate the combining coefficient of each stable interval using Equation 13.

[0133] The adaptive bio-signal feature combining apparatus 200 calculates the integrated combining coefficient by combining the combining coefficients calculated for each stable interval, in operation 1320. For example, the adaptive bio-signal feature combining apparatus 200 may calculate the integrated combining coefficient using Equation 14 or Equation 15.

[0134] FIG. 14 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment. The adaptive bio-signal feature combining method of FIG. 14 may be performed by the adaptive bio-signal feature combining apparatus 200 of FIG. 2. Here, operations 1410 to 1440 may be substantially the same as operations 1210 to 1240 of FIG. 12, and thus detailed descriptions thereof will be omitted.

[0135] In operation 1450, the adaptive bio-signal feature combining apparatus 200 combines the first feature and the second feature based on the integrated combining coefficient. For example, the adaptive bio-signal feature combining apparatus 200 may combine the first feature and the second feature using Equation 16 to Equation 18.

[0136] FIG. 15 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment. The adaptive bio-signal feature combining method of FIG. 15 may be performed by the adaptive bio-signal feature combining apparatus 800 of FIG. 8. Here, operations 1510 to 1540 may be substantially the same as operations 1210 to 1240 of FIG. 12, and thus detailed descriptions thereof will be omitted.

[0137] In 1550, the adaptive bio-signal feature combining apparatus 800 constantly updates the integrated combining coefficient.

[0138] According to one embodiment, the adaptive bio-signal feature combining apparatus 800 may repeatedly perform operations 1510 to 1540 so as to periodically update the integrated combining coefficient according to a designated update period, as shown in FIG. 9.

[0139] According to another exemplary embodiment, the adaptive bio-signal feature combining apparatus 800 may repeatedly perform operations 1510 to 1540 to constantly update the integrated combining coefficient by overlapping at least one stable interval in a sliding-window scheme, as shown in FIG. 10.

[0140] FIG. 16 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment. The adaptive bio-signal feature combining method of FIG. 16 may be performed by the adaptive bio-signal feature combining apparatus 1100 of FIG. 11. Here, operations 1610 to 1630 may be substantially the same as operations 1210 to 1230 of FIG. 12, and thus detailed descriptions thereof will be omitted.

[0141] In operation 1640, the adaptive bio-signal feature combining apparatus 1100 calculates a joint statistical variable value between the first feature and the second feature. In particular, the joint statistical variable may include a covariance or a correlation coefficient, which is, however, merely illustrative, and it is not limited thereto.

[0142] In operation 1650, the adaptive bio-signal feature combining apparatus 1100 calculates the combining coefficient of each stable interval based on the statistical variable of the first feature, the statistical variable of the second feature, and the joint statistical variable between the first feature and the second feature, and calculates the feature combining coefficient by combining the combining coefficients calculated for each stable interval. For example, the adaptive bio-signal feature combining apparatus 1100 may calculate the combining coefficient of each stable interval using Equation 20 or Equation 21, and calculates the integrated combining coefficient using Equation 14 or Equation 15.

[0143] FIG. 17 is a flowchart illustrating an adaptive bio-signal feature combining method according to another exemplary embodiment. The adaptive bio-signal feature combining method of FIG. 17 may be performed by the adaptive bio-signal feature combining apparatus 200 of FIG. 2. Here, operations 1710 to 1730 may be substantially the same as operations 1210 to 1230 of FIG. 12, and thus detailed descriptions thereof will be omitted.

[0144] In operation 1740, the adaptive bio-signal feature combining apparatus 200 calculates a combining coefficient of the first feature by averaging statistical variable values of the first feature calculated for each stable interval, and calculates a combining coefficient of the second feature by averaging statistical variable values of the second feature calculated for each stable interval.

[0145] FIG. 18 is a flowchart illustrating an adaptive bio-signal feature combining method according to still another exemplary embodiment. The adaptive bio-signal feature combining method of FIG. 18 may be performed by the adaptive bio-signal feature combining apparatus 200 of FIG. 2. Here, operations 1810 to 1840 may be substantially the same as operations 1710 to 1740 of FIG. 17, and thus detailed descriptions thereof will be omitted.

[0146] In operation 1850, the adaptive bio-signal feature combining apparatus 200 combines a first feature and a second feature based on combining coefficients of the respective features. For example, the adaptive bio-signal feature combining apparatus 200 may combine the first feature and the second feature using Equation 10 to Equation 12.

[0147] FIG. 19 is a flowchart illustrating an adaptive bio-signal feature combining method according to yet another exemplary embodiment. The adaptive bio-signal feature combining method of FIG. 19 may be performed by the adaptive bio-signal feature combining apparatus 800 of FIG. 8. Here, operations 1910 to 1940 may be substantially the same as operations 1710 to 1740 of FIG. 17, and thus detailed descriptions thereof will be omitted.

[0148] In operation 1950, the adaptive bio-signal feature combining apparatus 800 constantly updates combining coefficients of each of features.

[0149] According to one exemplary embodiment, the adaptive bio-signal feature combining apparatus 800 may repeatedly perform operations 1910 to 1940 to periodically update a combining coefficient of a first feature and a combining coefficient of a second feature according to a designated update period as shown in FIG. 9.

[0150] According to another exemplary embodiment, the adaptive bio-signal feature combining apparatus 800 may repeatedly perform operations 1910 to 1940 to constantly update the combining coefficient of the first feature and the combining coefficient of the second feature by overlapping at least one stable interval in a sliding-window scheme, as shown in FIG. 10.

[0151] FIG. 20 is a block diagram illustrating one embodiment of a blood pressure measurement apparatus.

[0152] Referring to FIG. 20, the blood pressure measurement apparatus 2000 includes a stable interval determiner 2010, a statistical variable calculator 2020, a feature combiner 2030, and a blood pressure estimator 2040. Here, the stable interval determiner 2010, the statistical variable calculator 2020, and the feature combiner 2030 may operate in substantially the same manner as the stable interval determiner 220, the statistical variable calculator 230, and the feature combiner 240, respectively, and thus detailed descriptions thereof will be omitted.

[0153] The blood pressure estimator 2040 may estimate a blood pressure of an object based on the combined feature. In particular, the blood pressure estimator 2040 may use Equation 22.

$$\text{Blood Pressure} = af_{comb} + b \quad \dots(22)$$

[0154] Here, a denotes a scale factor and b denotes an offset. a and b may be calculated in advance using a statistical scheme or through a calibration process. f_{comb} may be calculated using Equation 10 to Equation 12 or Equation 16 to

Equation 18.

[0155] According to the exemplary embodiments, a blood pressure measurement apparatus may estimate a blood pressure level from a PPG bio-signal (e.g., a sum of a propagation wave 110 and reflection waves 120 to 150), even without using reference blood pressure levels. In order to estimate the blood pressure level, the blood pressure measurement apparatus may calculate a statistical variable of each of a plurality of features obtained from stable intervals of the PPG bio-signal, derive a feature combining coefficient based on the statistical variable, and linearly combine the features based on the feature combining coefficient. According to the blood pressure measurement apparatus, the blood pressure level is estimated adaptively in accordance with time and user changes, unlike in a related-art method of a blood pressure estimation that uses linear regression which requires a reference blood pressure level. According to the related-art method, the reference blood pressure level needs to be updated or re-obtained when users are changed so that the reference blood pressure level reflects unique biological characteristics of a new user.

[0156] FIG. 21 is a flowchart illustrating a blood pressure measurement method according to an exemplary embodiment.

[0157] The blood pressure measurement method of FIG. 21 may be performed by the blood pressure measurement apparatus 2000 of FIG. 20. Here, operations 2110 to 2140 may be substantially the same as operations 1420 to 1450 of FIG. 14, and thus detailed descriptions thereof will be omitted.

[0158] In operation 2150, the blood pressure measurement apparatus 2000 may estimate a blood pressure of an object based on a combined feature. At this time, the blood pressure measurement apparatus 2000 may use Equation 22.

[0159] While not restricted thereto, an exemplary embodiment can be embodied as computer-readable code on a computer-readable recording medium. The computer-readable recording medium is any data storage device that can store data that can be thereafter read by a computer system. Examples of the computer-readable recording medium include read-only memory (ROM), random-access memory (RAM), CD-ROMs, magnetic tapes, floppy disks, and optical data storage devices. The computer-readable recording medium can also be distributed over network-coupled computer systems so that the computer-readable code is stored and executed in a distributed fashion. Also, an exemplary embodiment may be written as a computer program transmitted over a computer-readable transmission medium, such as a carrier wave, and received and implemented in general-use or special-purpose digital computers that execute the programs. Moreover, it is understood that in exemplary embodiments, one or more units of the above-described apparatuses and devices can include circuitry, a processor, a microprocessor, etc., and may execute a computer program stored in a computer-readable medium.

[0160] The foregoing exemplary embodiments are merely exemplary and are not to be construed as limiting. The present teaching can be readily applied to other types of apparatuses. Also, the description of the exemplary embodiments is intended to be illustrative, and not to limit the scope of the claims, and many alternatives, modifications, and variations will be apparent to those skilled in the art.

Claims

1. An adaptive bio-signal feature combining apparatus comprising:

a feature extractor configured to extract first feature values and second feature values from a bio-signal of an object;

a stable interval determiner configured to determine at least one stable interval in the bio-signal;

a statistical variable calculator configured to calculate a statistical variable value of a first feature and a statistical variable value of a second feature for each of the at least one stable interval based on the first and second feature values extracted from the at least one stable interval; and

a feature combiner configured to calculate an integrated combining coefficient that is used to combine the first feature and the second feature, based on the statistical variable value of the first feature and the statistical variable value of the second feature,

wherein the feature extractor, the stable interval determiner, the statistical variable calculator, and the feature combiner are included in one or more processors.

2. The adaptive bio-signal feature combining apparatus of claim 1, wherein the bio-signal comprises at least one of an electrocardiogram, ECG, signal, a photoplethysmogram, PPG, signal, an electromyogram, EMG, signal, and a ballistocardiogram, BCG, signal, and/or the first feature indicates a cardiac output and the second feature indicates a total peripheral vascular resistance.

3. The adaptive bio-signal feature combining apparatus of claim or 2, wherein the first feature comprises at least one of P_{\max}/P_{area} , P_{\max}/P_3 , P_{sys}/P_3 , P_1/P_3 , P_2/P_3 , and $1/T_{\text{period}}$, the second feature comprises at least one of $1/(T_3-T_{\text{sys}})$, $1/(T_3-T_{\max})$, $1/(T_3-T_1)$, $1/(T_3-T_2)$, P_2/P_1 , and P_3/P_1 , wherein T_{period} denotes a period of the bio-signal,

T_1 denotes a time of a peak point of a first component pulse constituting the bio-signal, P_1 denotes an amplitude of the bio-signal at T_1 , T_2 denotes a time of a peak point of a second component pulse constituting the bio-signal, P_2 denotes an amplitude of the bio-signal at T_2 , T_3 denotes a time of a peak point of a third component pulse constituting the bio-signal, P_3 denotes an amplitude of the bio-signal at T_3 , T_{\max} denotes a time of a peak point of the bio-signal in a first interval, P_{\max} denotes an amplitude of the bio-signal at T_{\max} , T_{sys} denotes an intermediate time between T_1 and T_{\max} , an arbitrary internally dividing point between T_1 and T_{\max} , or an arbitrary internally dividing point between T_1 and T_2 , P_{sys} denotes an amplitude of the bio-signal at T_{sys} , and P_{area} denotes a sum of amplitudes of the bio-signal in a second interval.

4. The adaptive bio-signal feature combining apparatus of one of claims to 3, wherein the stable interval determiner is further configured to determine the at least one stable interval based on one or more of an output value of a sensor that detects a motion of the object, and an amount of change in the first feature or second feature extracted from the bio-signal.

5. The adaptive bio-signal feature combining apparatus of claim 4, wherein the stable interval determiner is further configured to compare the output value of the sensor at a time of bio-signal measurement with a predetermined threshold value, and in response to the output value of the sensor being maintained less than or equal to the predetermined threshold value for a predetermined time period, the stable interval determiner is further configured to determine that the predetermined time period is a stable interval.

6. The adaptive bio-signal feature combining apparatus of claim 4, wherein the amount of change in the first feature or second feature is defined as a fluctuation with respect to a mean value of the corresponding first feature or second feature,

wherein the amount of change in the first feature or second feature is defined as a fluctuation that comprises a variance, a standard deviation, and a mean absolute deviation, and/or wherein the stable interval determiner is further configured to compare the amount of change in the first feature or second feature extracted during a time period with a predetermined threshold value and determine the time period as the stable interval when the amount in change in the first feature or second feature is less than or equal to the predetermined threshold value.

7. The adaptive bio-signal feature combining apparatus of one of claims to 6, wherein the statistical variable comprises a mean, a variance, a standard deviation, and a mean absolute deviation.

8. The adaptive bio-signal feature combining apparatus of one of claims 1 to 7, wherein the feature combiner is further configured to calculate a combining coefficient of each stable interval based on the statistical variable values of the first and second features which are calculated for each stable interval, and/or to linearly combine the first feature and the second feature based on the calculated integrated combining coefficient.

9. The adaptive bio-signal feature combining apparatus of claim 8, wherein the feature combiner is further configured to perform one or more of:

calculate the combining coefficient of each stable interval by dividing the statistical variable value of the first feature of each stable interval by the statistical variable value of the second feature of each stable interval; calculate the integrated combining coefficient by arithmetically averaging the combining coefficients calculated for each stable interval; calculate the integrated combining coefficient by applying different weights to the combining coefficients calculated for each stable interval and linearly combining the combining coefficients to which the different weights are applied; and apply a higher weight to a combining coefficient of a temporally later stable interval.

10. The adaptive bio-signal feature combining apparatus of one of claims to 9, further comprising a controller configured to update the integrated combining coefficient.

11. The adaptive bio-signal feature combining apparatus of claim 10, wherein the controller is further configured to control the feature extractor, the stable interval determiner, the statistical variable calculator, and the feature combiner to update the integrated combining coefficient according to a designated update period, or to constantly update the integrated combining coefficient by overlapping the at least one stable interval in a sliding-window scheme.

12. The adaptive bio-signal feature combining apparatus of one of claims 1 to 11, further comprising:

a joint statistical variable calculator configured to calculate a joint statistical variable value between the first feature and the second feature,

wherein the feature combiner is further configured to calculate the integrated combining coefficient based on the statistical variable value of the first feature, the statistical variable value of the second feature, and the joint statistical variable value,

wherein the joint statistical variable preferably comprises a covariance and a correlation coefficient.

13. The adaptive bio-signal feature combining apparatus one of claims to 12, further comprising:

a blood pressure estimator configured to estimate a blood pressure of the object based on the combined feature, wherein the blood pressure estimator is included in the one or more processors.

14. An adaptive bio-signal feature combining method comprising:

extracting first feature values and second feature values from a bio-signal of an object;

calculating a statistical variable value of a first feature and a statistical variable value of a second feature based on the first feature values and the second feature values which are extracted from at least one stable interval; and

calculating an integrated combining coefficient that is used to combine the first feature and the second feature based on the statistical variable values of the first and second features.

15. A computer-readable storage medium storing instructions that, when executed by one or more processors, perform an adaptive bio-signal feature combining method comprising:

extracting first feature values and second feature values from a bio-signal of an object;

determining at least one stable interval in the bio-signal;

calculating a statistical variable value of a first feature and a statistical variable value of a second feature for each of the at least one stable interval based on the first and second feature values extracted from the at least one stable interval; and

calculating a combining coefficient of the first feature based on the statistical variable value of the first feature, calculating a combining coefficient of the second feature based on the statistical variable value of the second feature, and combining the first feature and the second feature based on the combining coefficients of the first feature and the second feature.

FIG. 1

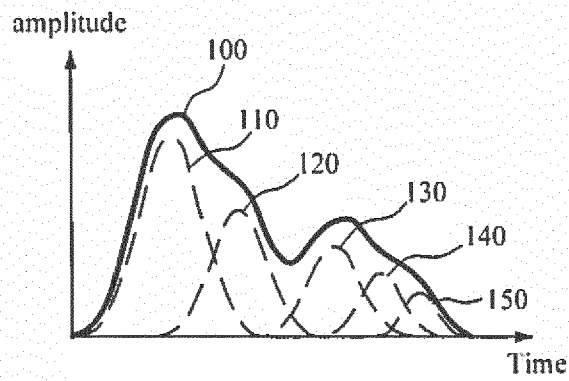


FIG. 2

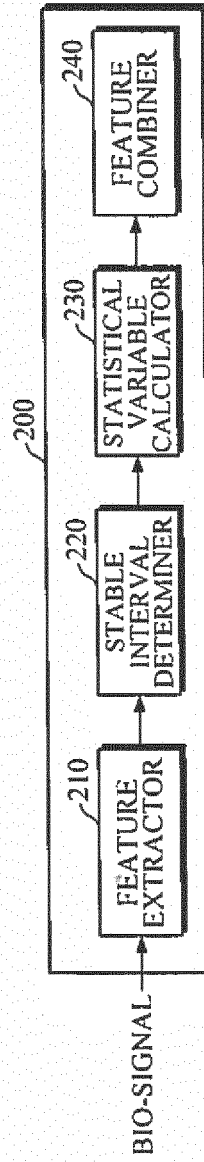


FIG. 3

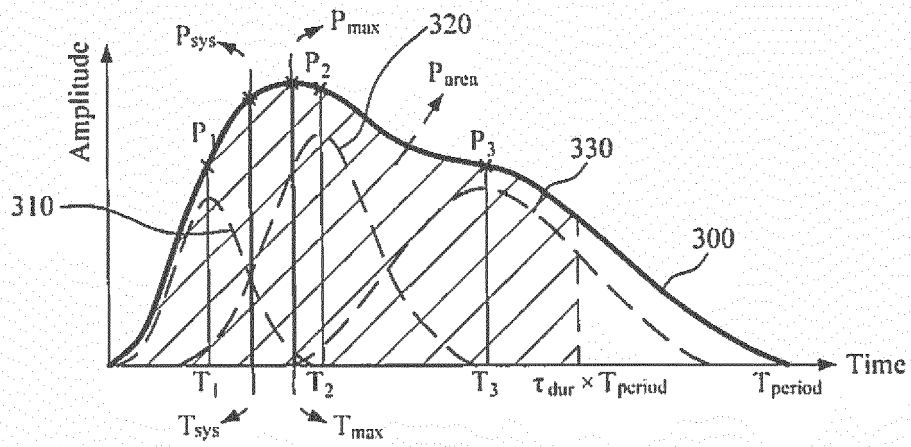


FIG. 4

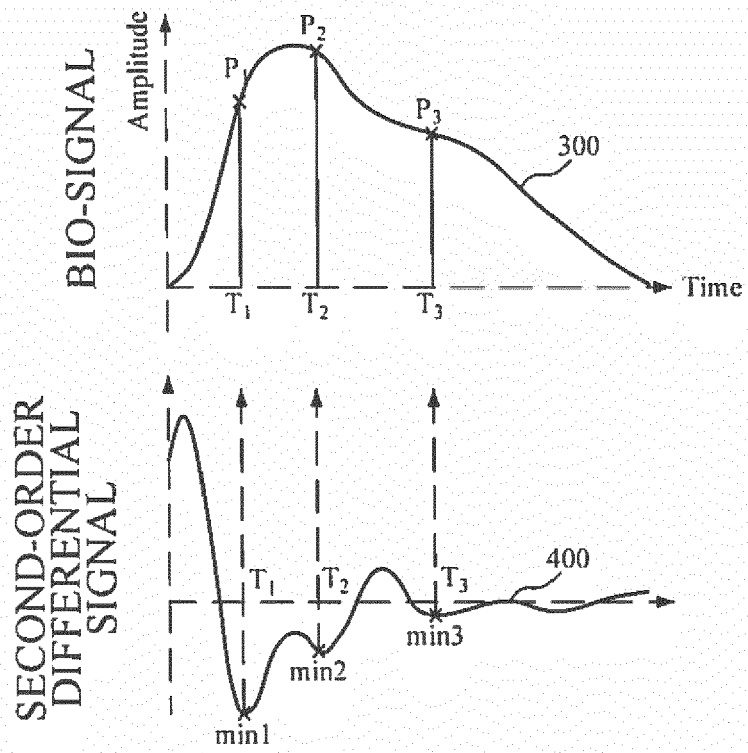


FIG. 5

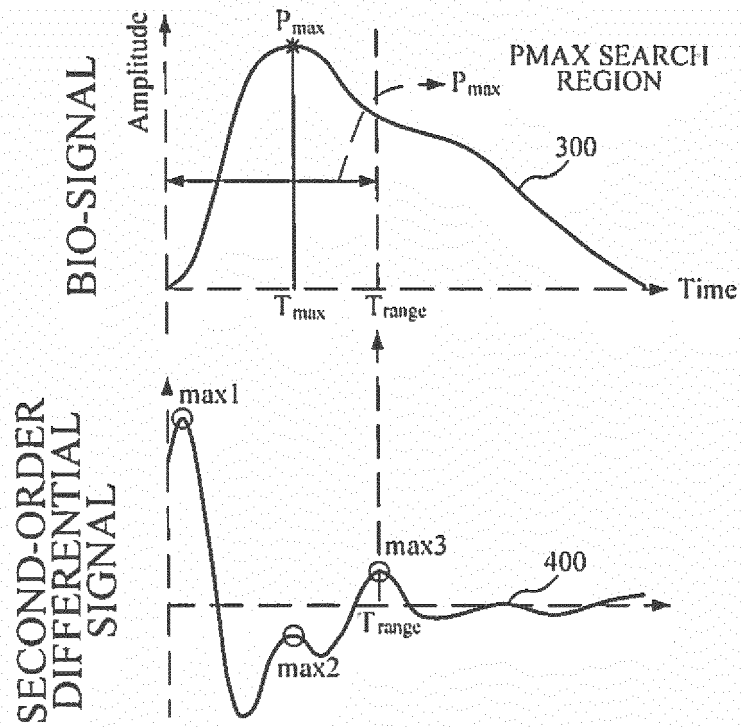


FIG. 6

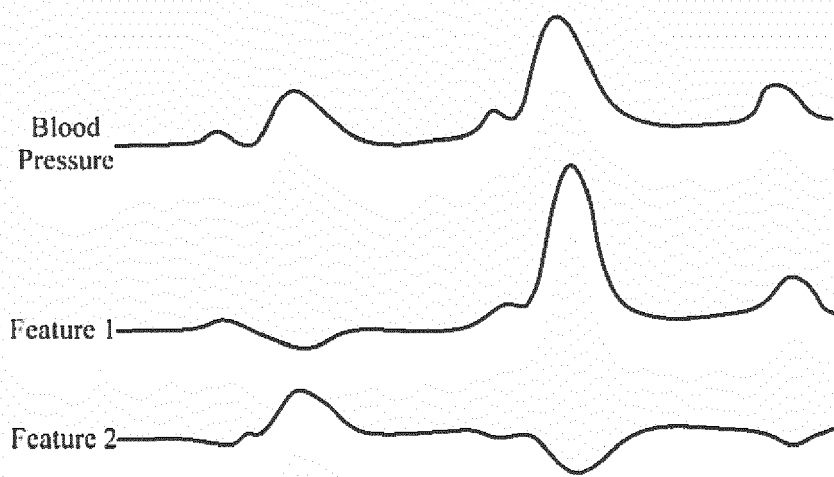


FIG. 7A

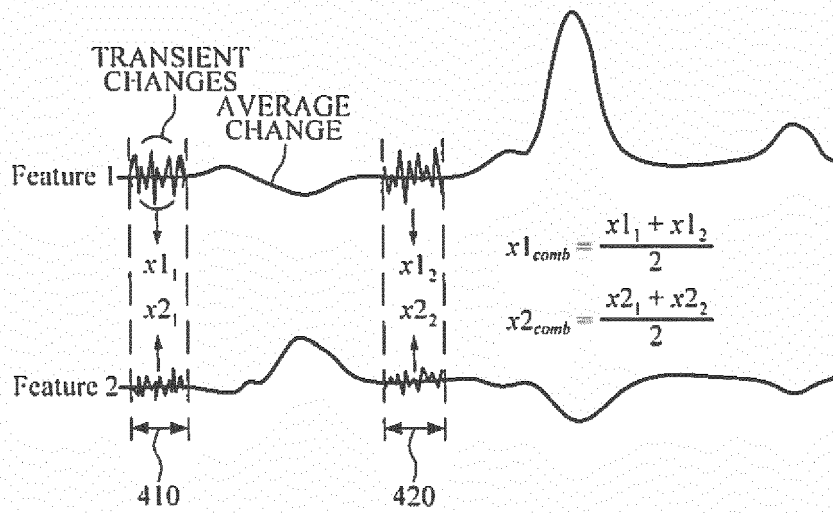


FIG. 7B

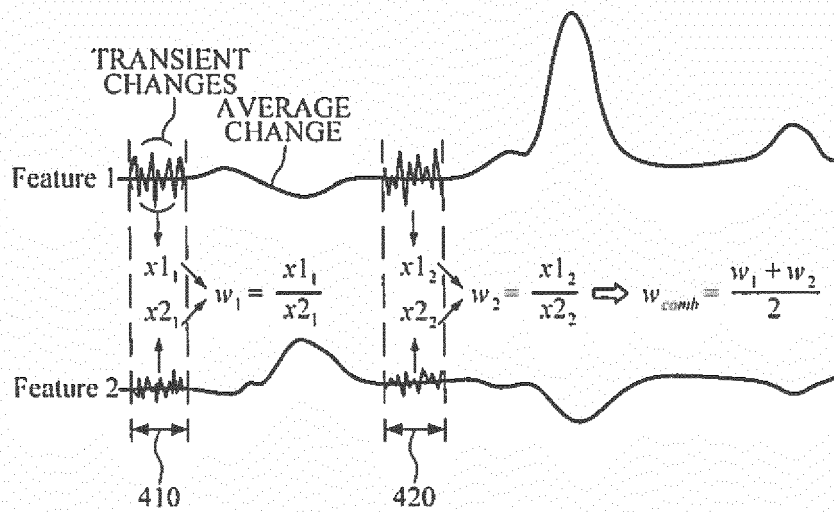


FIG. 8

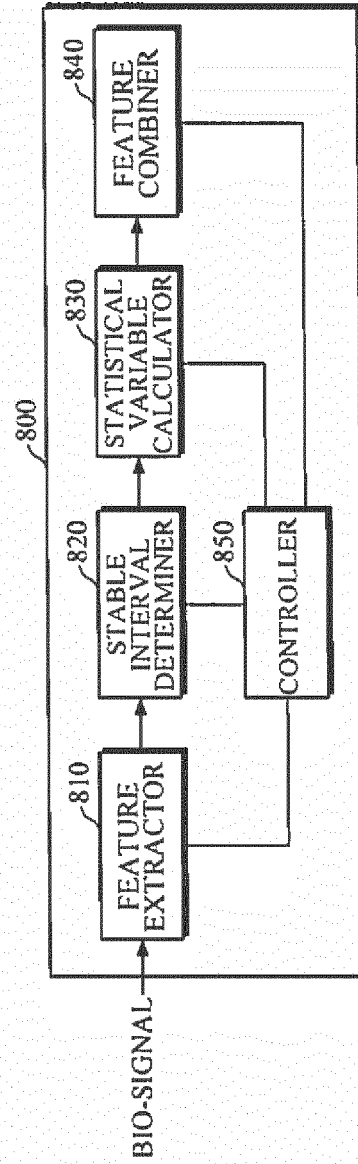


FIG. 9

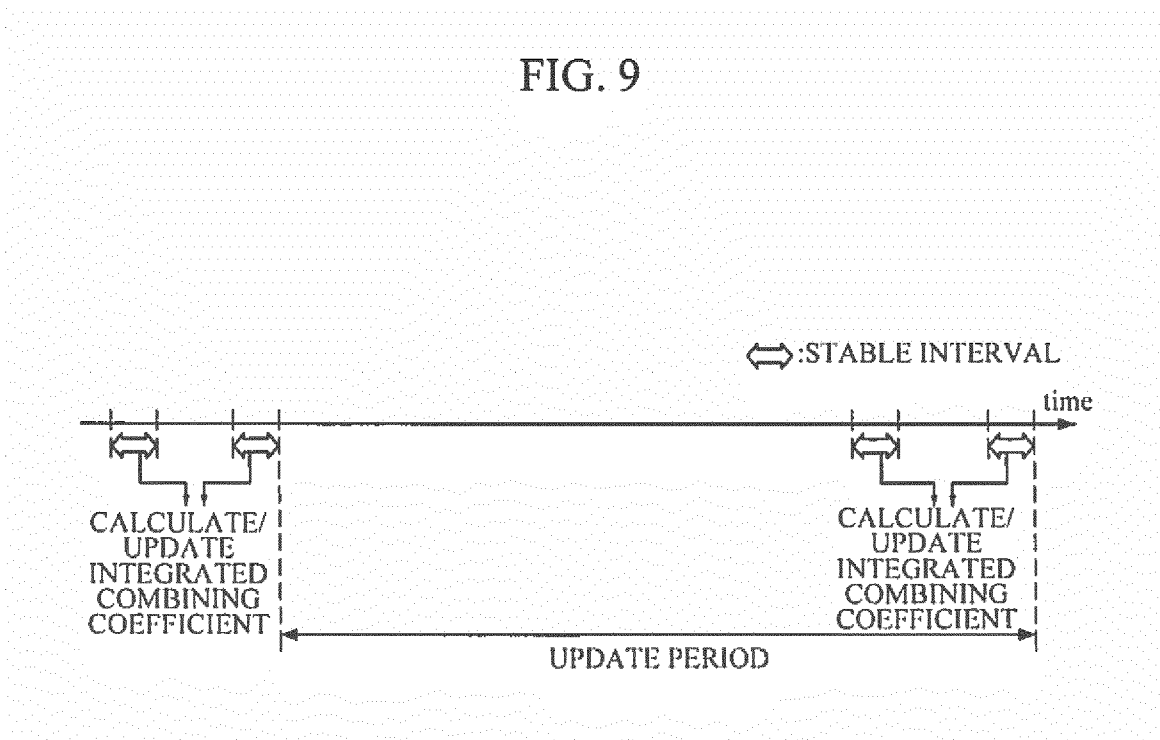


FIG. 10

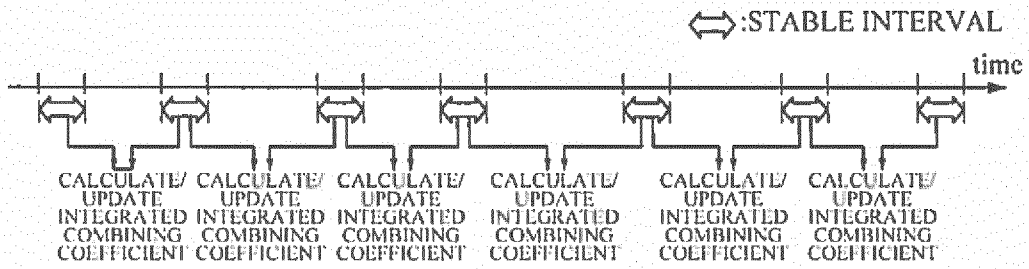


FIG. 11

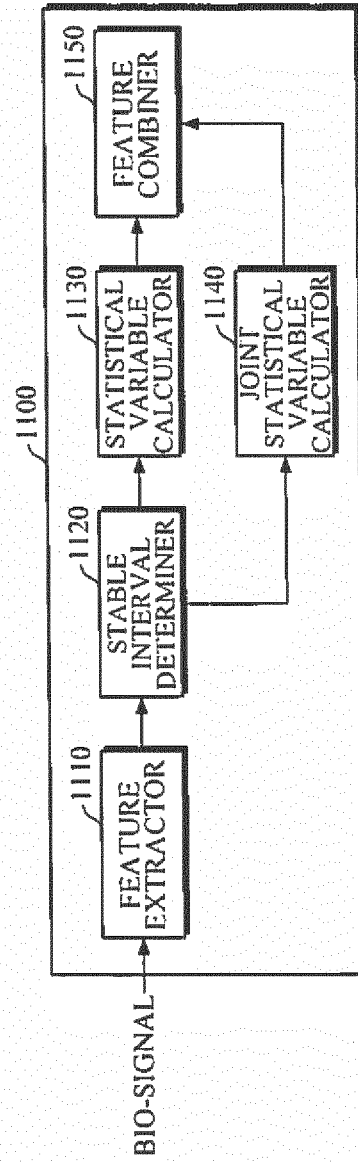


FIG. 12

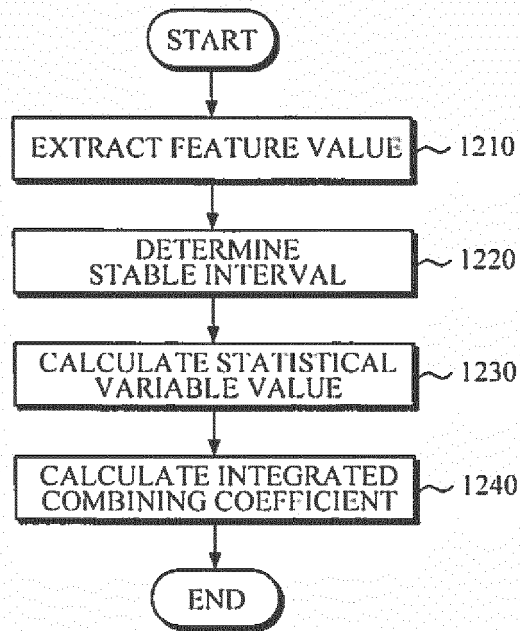


FIG. 13

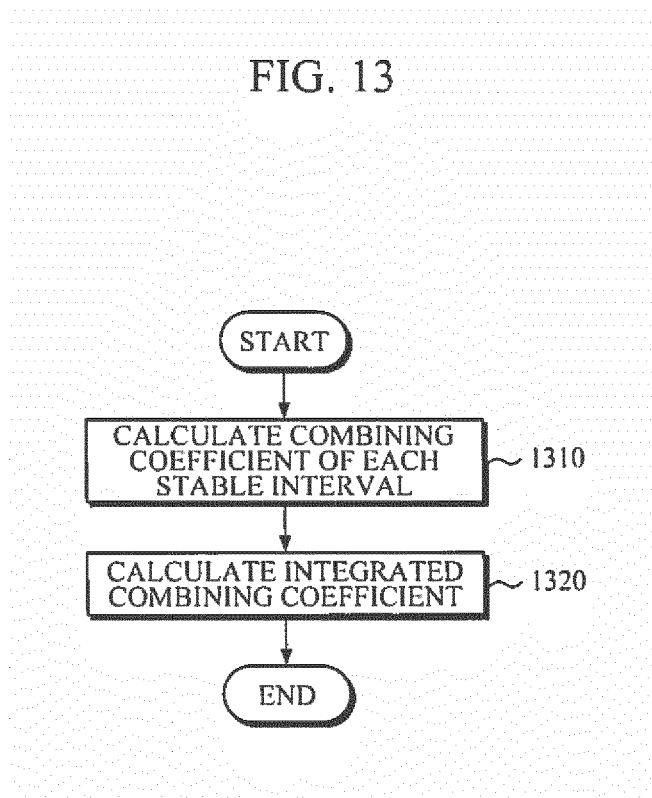


FIG. 14

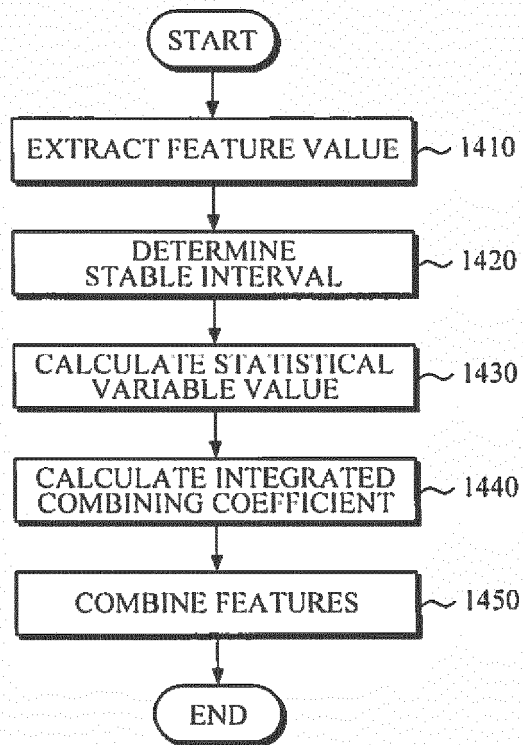


FIG. 15

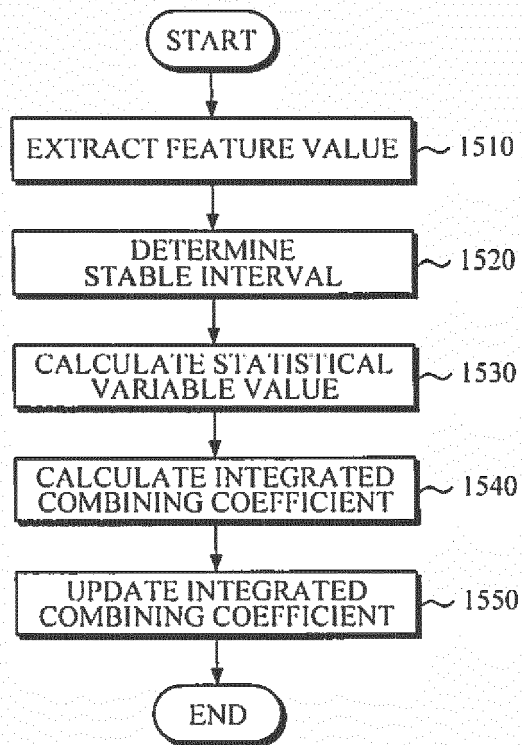


FIG. 16

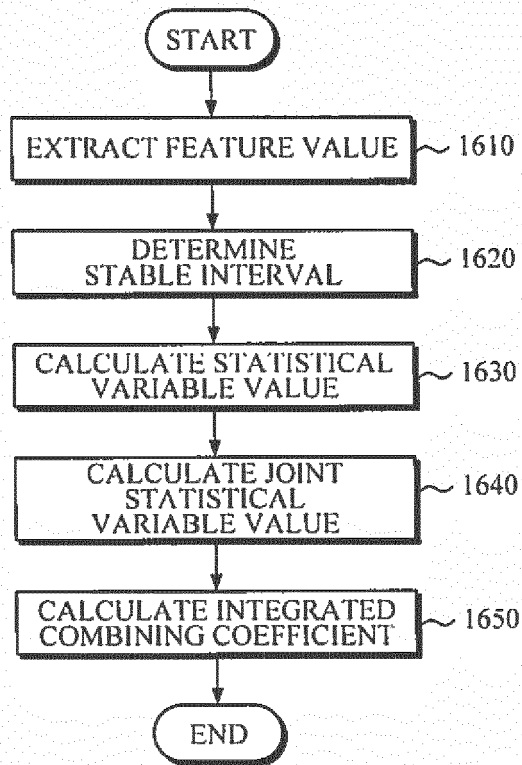


FIG. 17

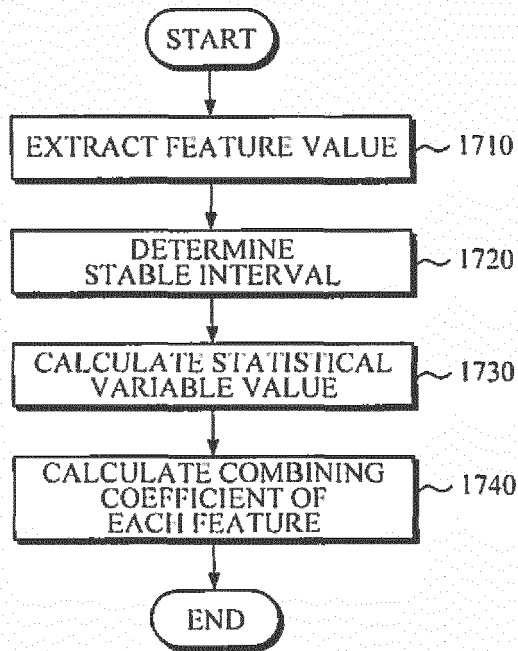


FIG. 18

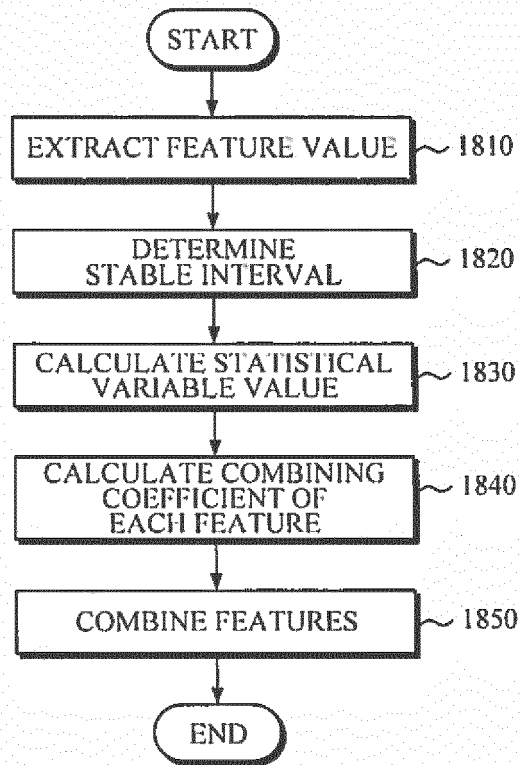


FIG. 19

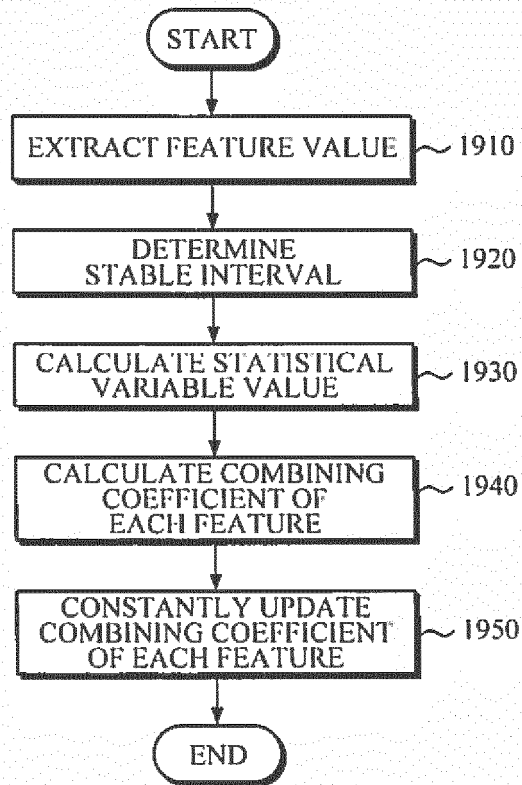


FIG. 20

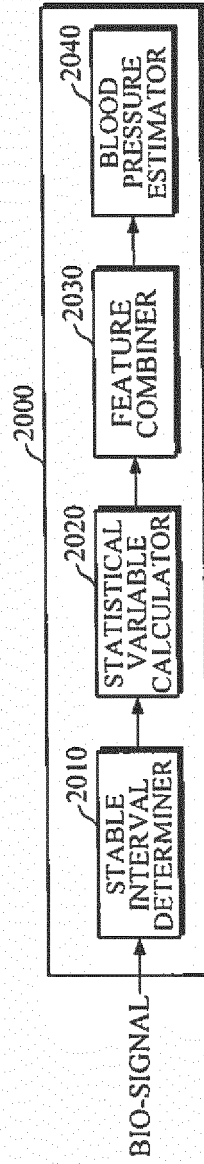
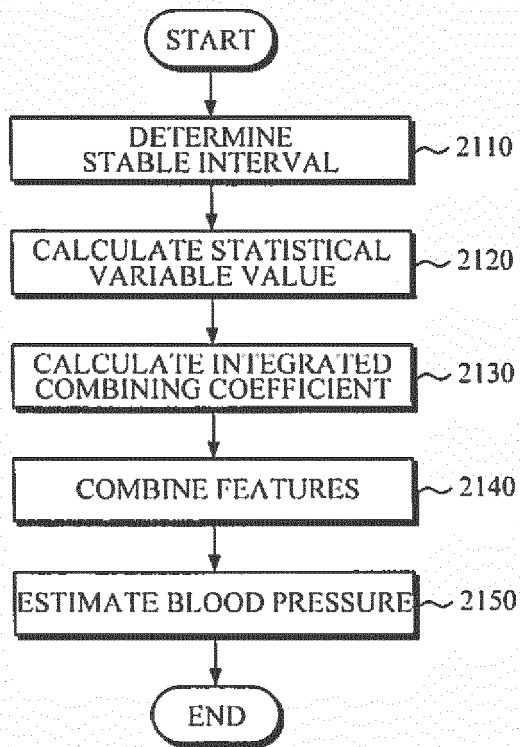


FIG. 21





EUROPEAN SEARCH REPORT

Application Number
EP 17 21 0907

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2012/103296 A2 (UNIV LELAND STANFORD JUNIOR [US]; WIARD RICHARD M [US]; GIOVANGRANDI L) 2 August 2012 (2012-08-02) * page 2, lines 3, 26, 28 * * page 16, line 12 * * page 17, lines 29-31 * * page 18, line 2 * * page 21, line 1 * * page 24, lines 12-14 * * page 28, lines 6, 26 * * page 31, lines 2, 11, 20, 22, 24, 26-28 * * page 32, lines 2, 3 * * page 35, lines 5, 6 * * page 38, lines 8-13 *	1-15	INV. A61B5/00 A61B5/02 A61B5/0205 A61B5/021 A61B5/026 A61B5/029 A61B5/0402 A61B5/0488 A61B5/11
A	MILLASSEAU SANDRINE C ET AL: "Contour analysis of the photoplethysmographic pulse measured at the finger", JOURNAL OF HYPERTENSION, LIPPINCOTT WILLIAMS & WILKINS, LTD, GB, vol. 24, no. 8, 1 August 2006 (2006-08-01), pages 1449-1456, XP002673731, ISSN: 0263-6352, DOI: 10.1097/01.HJH.0000239277.05068.87 * figures 3, 4 * * Chapter "Applications"; page 1453 *	3,8,9	TECHNICAL FIELDS SEARCHED (IPC) A61B
A	US 2014/275854 A1 (VENKATRAMAN SUBRAMANIAM [US] ET AL) 18 September 2014 (2014-09-18) * the whole document *	1-15	
A	WO 2016/135583 A1 (KONINKLIJKE PHILIPS NV [NL]) 1 September 2016 (2016-09-01) * the whole document *	1-15	
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 April 2018	Examiner Meyer, Wolfgang
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)



EUROPEAN SEARCH REPORT

Application Number
EP 17 21 0907

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2016/123484 A1 (WORCESTER POLYTECH INST [US]) 4 August 2016 (2016-08-04) * the whole document * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 April 2018	Examiner Meyer, Wolfgang
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

1
EPO FORM 1503 03.02 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 17 21 0907

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

26-04-2018

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012103296 A2	02-08-2012	AU 2012211300 A1	09-05-2013
		CA 2825405 A1	02-08-2012
		EP 2667769 A2	04-12-2013
		JP 5955341 B2	20-07-2016
		JP 6130474 B2	17-05-2017
		JP 2014507213 A	27-03-2014
		JP 2016101504 A	02-06-2016
		US 2013310700 A1	21-11-2013
		US 2015282718 A1	08-10-2015
		US 2016095522 A1	07-04-2016
		WO 2012103296 A2	02-08-2012
US 2014275854 A1	18-09-2014	US 2014275854 A1	18-09-2014
		US 2014276119 A1	18-09-2014
		US 2014288436 A1	25-09-2014
		US 2014288438 A1	25-09-2014
		US 2015196256 A1	16-07-2015
		US 2017027523 A1	02-02-2017
WO 2016135583 A1	01-09-2016	AU 2016225134 A1	12-10-2017
		CN 107257654 A	17-10-2017
		EP 3261520 A1	03-01-2018
		JP 2018505737 A	01-03-2018
		US 2018028080 A1	01-02-2018
		WO 2016135583 A1	01-09-2016
WO 2016123484 A1	04-08-2016	US 2016220188 A1	04-08-2016
		WO 2016123484 A1	04-08-2016

专利名称(译)	自适应生物信号特征组合装置和方法		
公开(公告)号	EP3342332A1	公开(公告)日	2018-07-04
申请号	EP2017210907	申请日	2017-12-28
[标]申请(专利权)人(译)	三星电子株式会社		
申请(专利权)人(译)	SAMSUNG ELECTRONICS CO. , LTD.		
当前申请(专利权)人(译)	SAMSUNG ELECTRONICS CO. , LTD.		
[标]发明人	PARK CHANG SOON KWON UI KUN JANG DAE GEUN KIM YOUNG SOO		
发明人	PARK, CHANG SOON KWON, UI KUN JANG, DAE GEUN KIM, YOUNG SOO		
IPC分类号	A61B5/00 A61B5/02 A61B5/0205 A61B5/021 A61B5/026 A61B5/029 A61B5/0402 A61B5/0488 A61B5/11		
CPC分类号	A61B5/021 A61B5/72 A61B5/7235 A61B5/02007 A61B5/02028 A61B5/0205 A61B5/02108 A61B5/0261 A61B5/029 A61B5/0402 A61B5/0488 A61B5/1102 A61B5/1118 A61B5/721 A61B5/7239 A61B5/7264 A61B2505/07 A61B2562/0219 G16H50/20 A61B5/7232 A61B5/7246 A61B5/7278		
审查员(译)	MEYER , WOLFGANG		
优先权	1020160181373 2016-12-28 KR 1020170169187 2017-12-11 KR		
外部链接	Espacenet		

摘要(译)

一种自适应生物信号特征组合装置，包括：特征提取器，被配置为从对象的生物信号中提取第一特征值和第二特征值；稳定间隔确定器，被配置为确定生物信号中的至少一个稳定间隔；统计变量计算器，被配置为基于从所述至少一个稳定区间提取的第一和第二特征值，针对所述至少一个稳定区间中的每一个计算第一特征的统计变量值和第二特征的统计变量值；和特征组合器，被配置为基于第一特征的统计变量值和第二特征的统计变量值，计算用于组合第一特征和第二特征的综合组合系数，

FIG. 2

