US 20160192884A1

(19) **United States**

(12) **Patent Application Publication**

Levant et al.

(10) **Pub. No.: US 2016/0192884 A1**

(43) **Pub. Date: Jul. 7, 2016**

(54) **POSITIONING A MEDICAL DEVICE BASED ON OXYGEN SATURATION MEASUREMENTS**

(71) Applicant: **LifeWatch Technologies, Ltd.**, Rehovot (IL)

(72) Inventors: **Anna Levant**, Rehovot (IL); **Zohar Brachia Halevi**, Ramat Gan (IL); **Mordehay Amirim**, Rehovot (IL)

(21) Appl. No.: **14/696,513**

(22) Filed: **Apr. 27, 2015**

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/590,149, filed on Jan. 6, 2015.

Publication Classification

(51) **Int. Cl.**

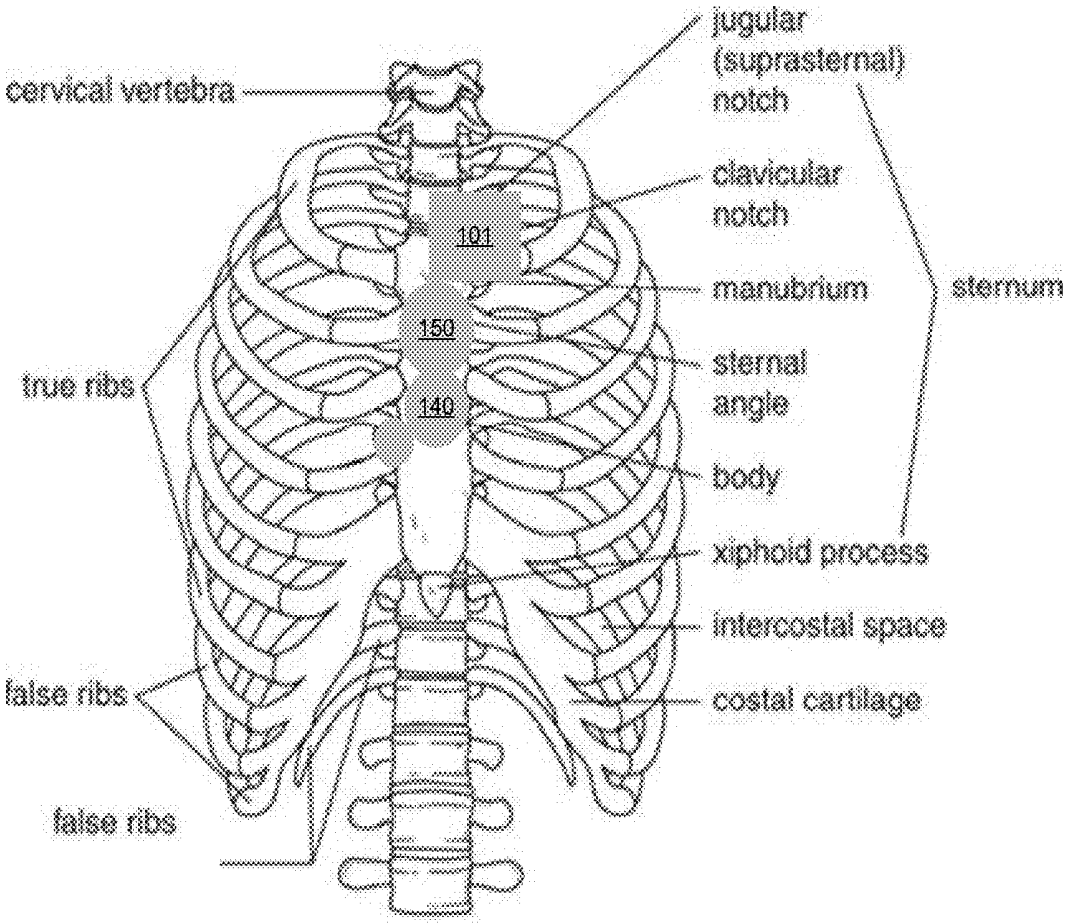
A61B 5/00	(2006.01)
A61B 5/1455	(2006.01)
A61B 5/0402	(2006.01)

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

CPC ***A61B 5/6823*** (2013.01); ***A61B 5/0402*** (2013.01); ***A61B 5/14551*** (2013.01); ***A61B 5/725*** (2013.01); ***A61B 5/7246*** (2013.01)

(57) **ABSTRACT**

A method that includes receiving, by a computerized device, first detection signals generated as a result of an illumination, by infrared pulses, of a current portion of a sternum of a user; receiving, by the computerized device, second detection signals generated as a result of an illumination, by visible light pulses, of the current portion of the sternum of the user; and evaluating, by the computerized device, a quality of the first and second detection signals; and determining whether the current portion of the sternum of the user is the sternal angle of the user; wherein the determining is responsive to the quality of the first and second detection signals.



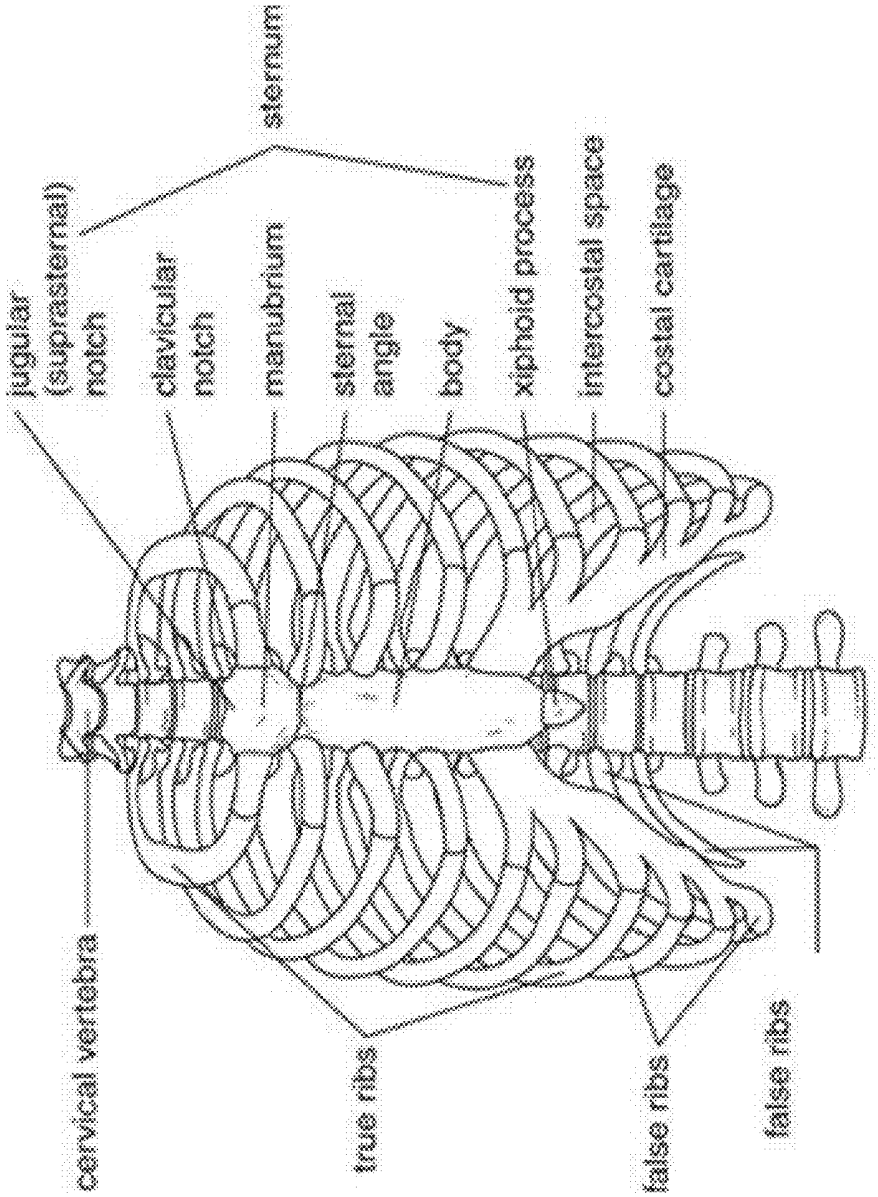

jugular (suprasternal) notch
clavicular notch
manubrium
sternal angle
body
xiphoid process
intercostal space
costal cartilage
sternum
cervical vertebra
true ribs
false ribs
false ribs
10

FIG. 1

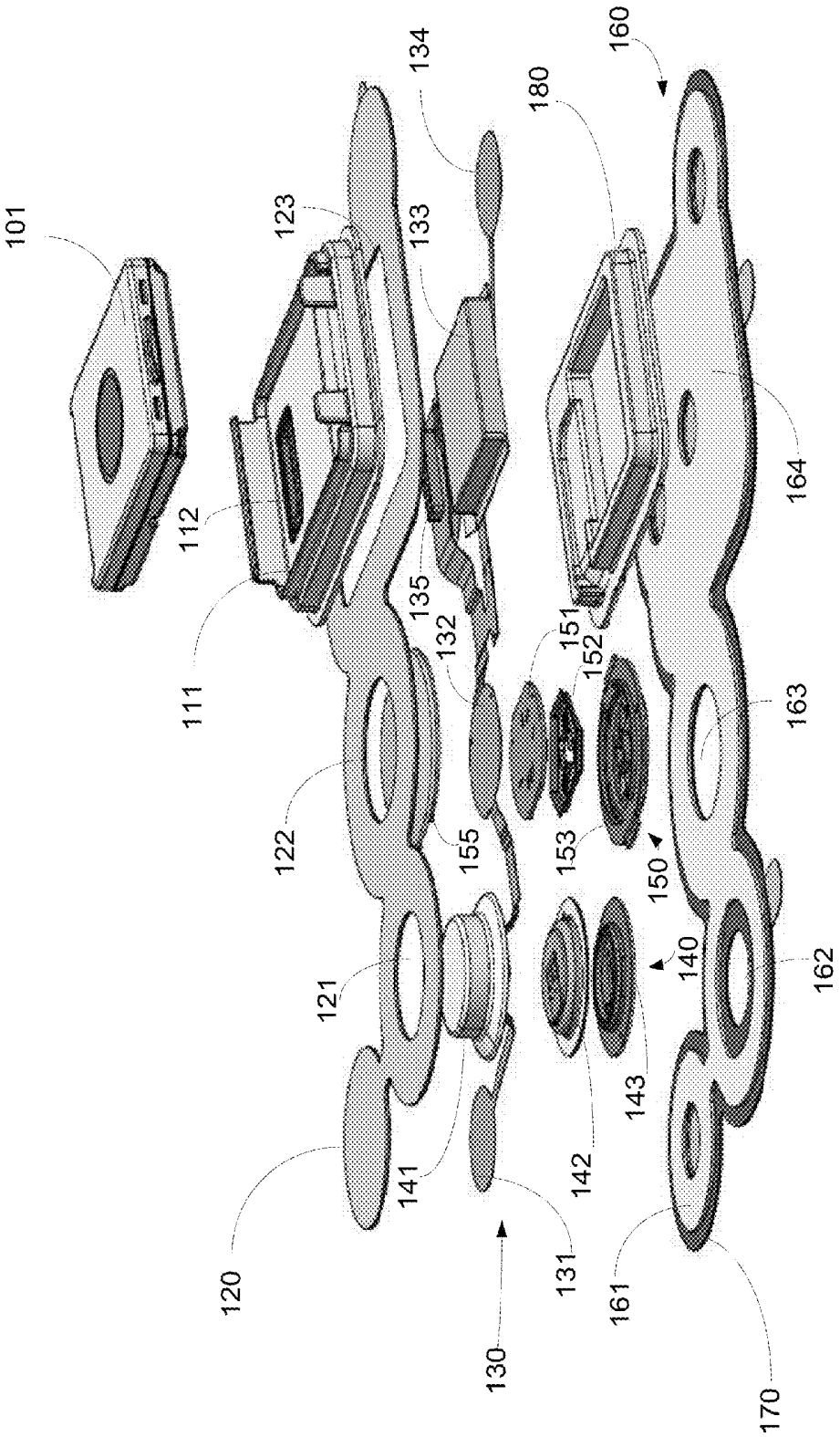

101
112
111
123
133
134
135
132
122
155
121
141
120
131
130
142
143
153
151
152
150
140
160
180
164
163
162
161
170
100

FIG. 2

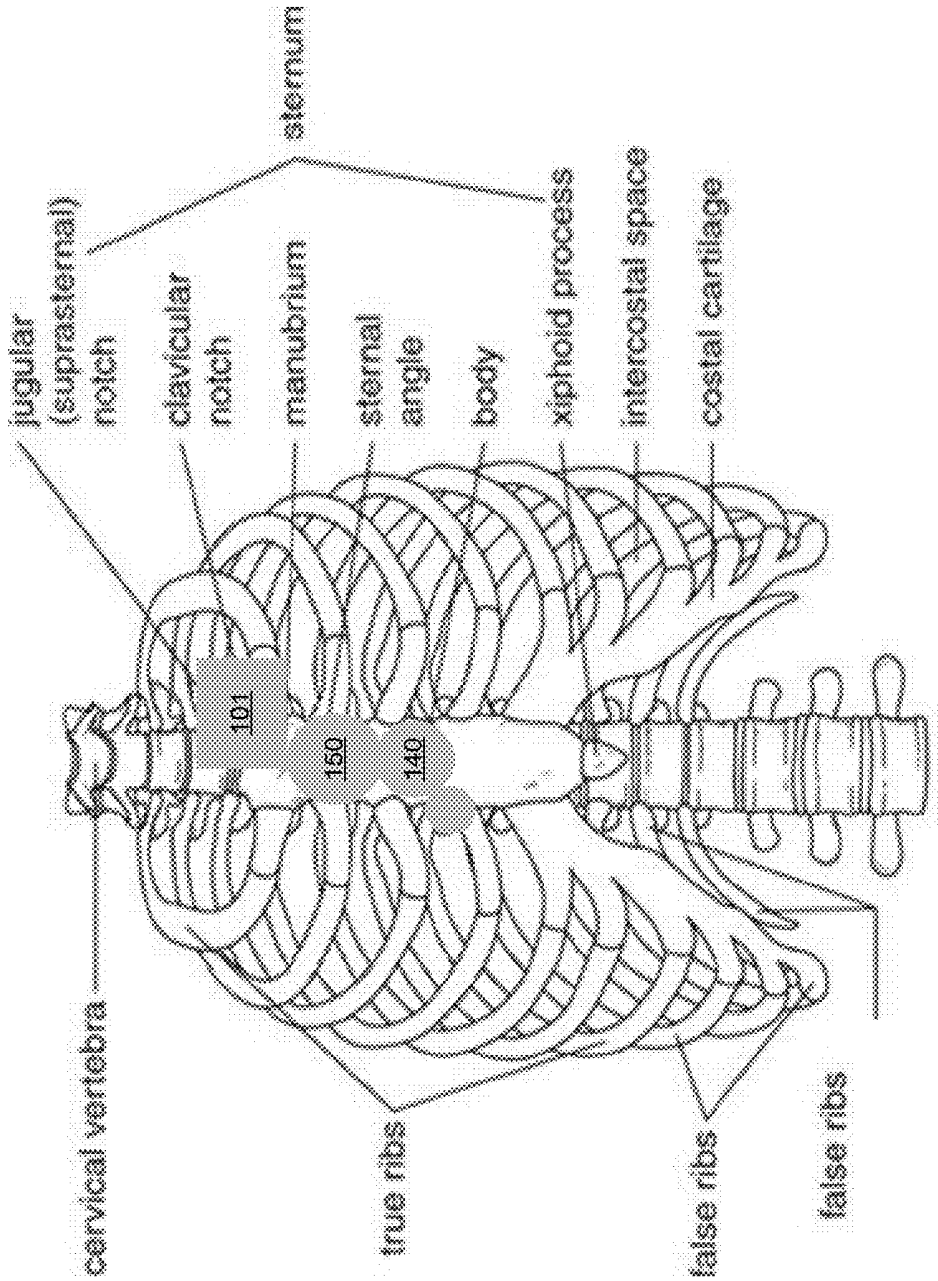

jugular (suprasternal) notch
clavicular notch
manubrium
sternal angle
body
xiphoid process
intercostal space
costal cartilage
sternum
cervical vertebra
true ribs
false ribs
false ribs
101
150
140

FIG. 3

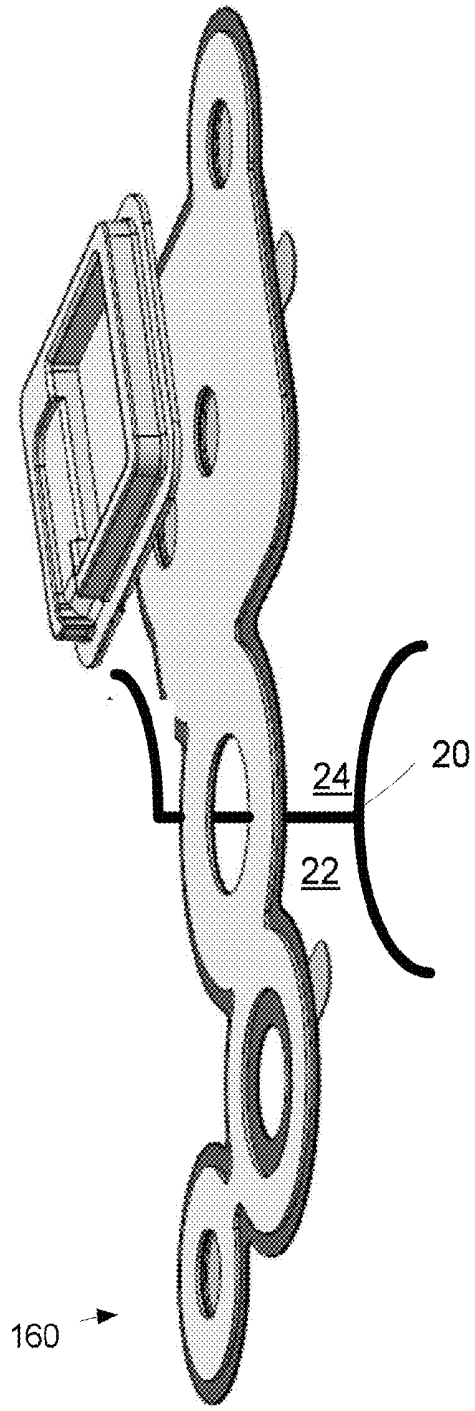


FIG. 4

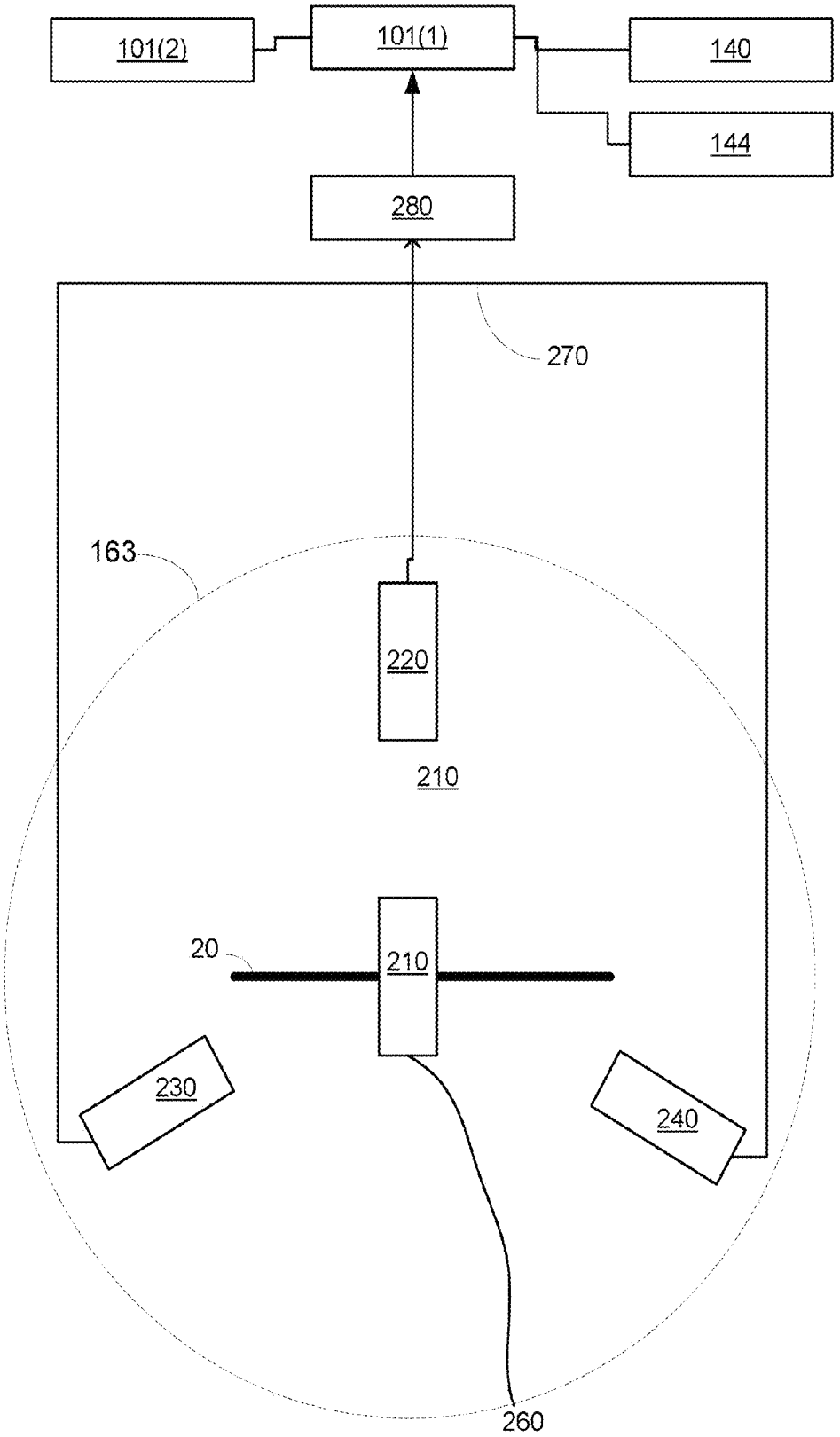


FIG. 5

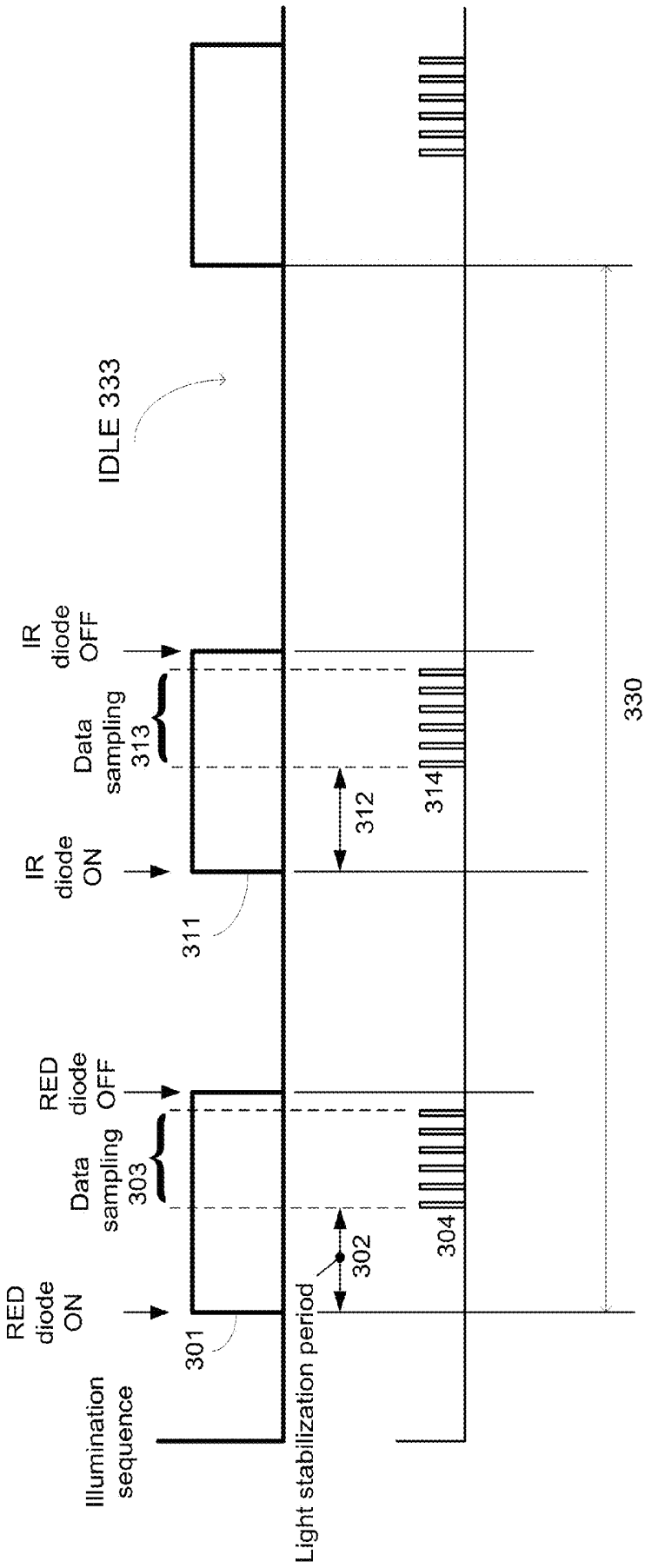

IDLE 333
IR diode OFF
Data sampling 313
IR diode ON
311
312
314
330
RED diode OFF
Data sampling 303
RED diode ON
301
302
304
300
Illumination sequence
Light stabilization period

FIG. 6

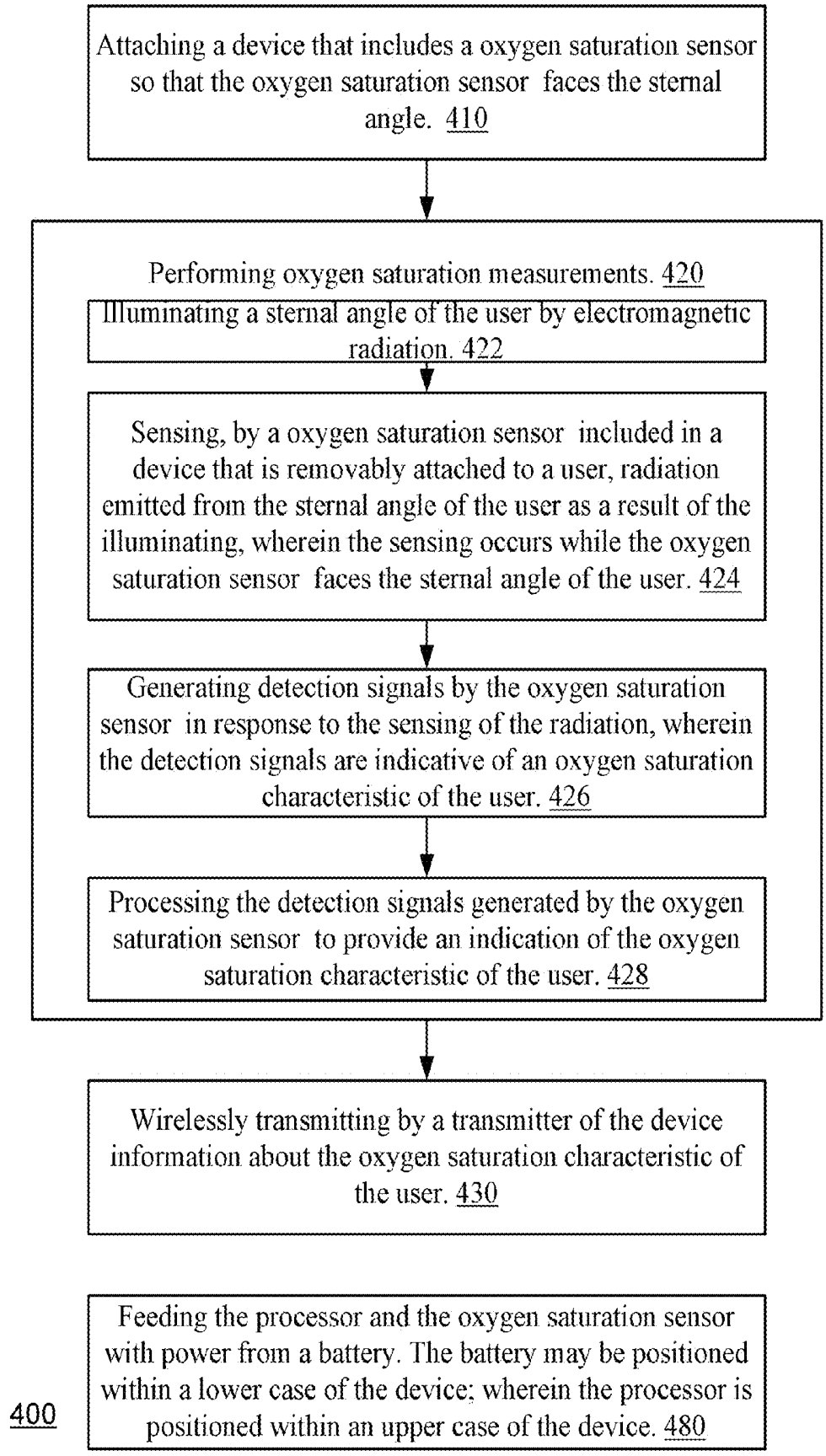
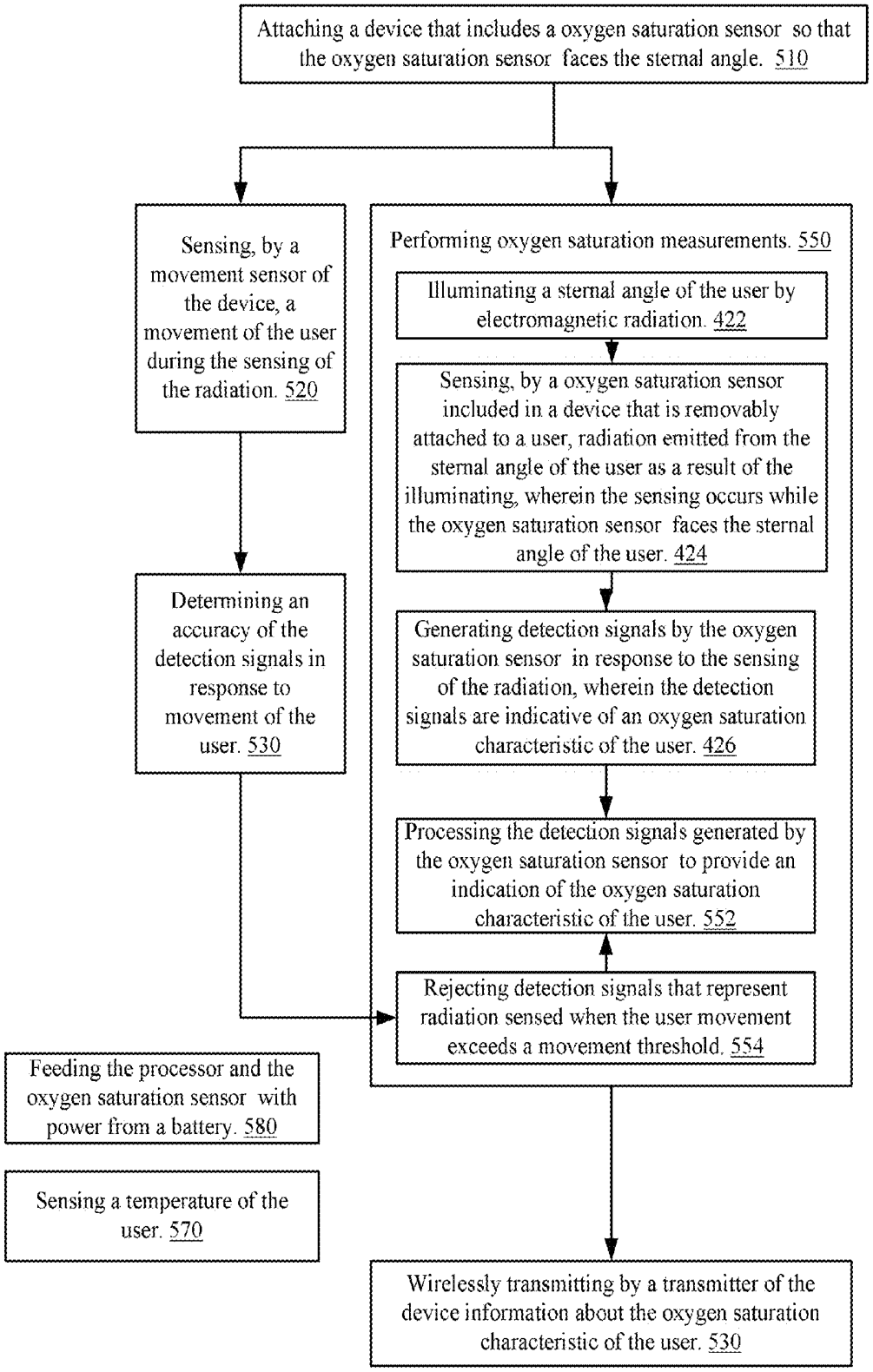
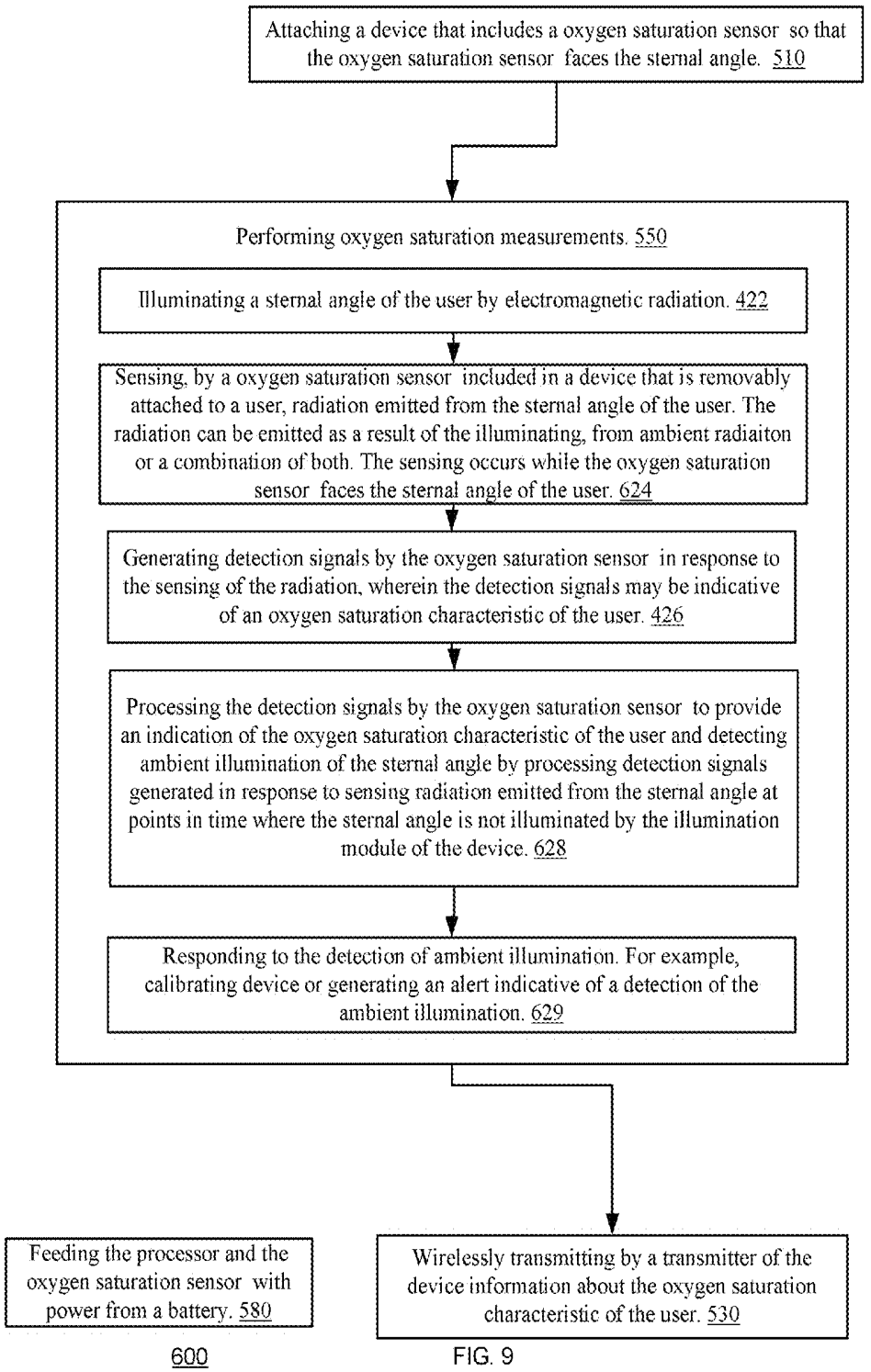

Attaching a device that includes a oxygen saturation sensor so that the oxygen saturation sensor faces the sternal angle. 410
Performing oxygen saturation measurements. 420
Illuminating a sternal angle of the user by electromagnetic radiation. 422
Sensing, by a oxygen saturation sensor included in a device that is removably attached to a user, radiation emitted from the sternal angle of the user as a result of the illuminating, wherein the sensing occurs while the oxygen saturation sensor faces the sternal angle of the user. 424
Generating detection signals by the oxygen saturation sensor in response to the sensing of the radiation, wherein the detection signals are indicative of an oxygen saturation characteristic of the user. 426
Processing the detection signals generated by the oxygen saturation sensor to provide an indication of the oxygen saturation characteristic of the user. 428
Wirelessly transmitting by a transmitter of the device information about the oxygen saturation characteristic of the user. 430
Feeding the processor and the oxygen saturation sensor with power from a battery. The battery may be positioned within a lower case of the device; wherein the processor is positioned within an upper case of the device. 480
400

FIG. 7


Attaching a device that includes a oxygen saturation sensor so that the oxygen saturation sensor faces the sternal angle. 510
Sensing, by a movement sensor of the device, a movement of the user during the sensing of the radiation. 520
Determining an accuracy of the detection signals in response to movement of the user. 530
Performing oxygen saturation measurements. 550
Illuminating a sternal angle of the user by electromagnetic radiation. 422
Sensing, by a oxygen saturation sensor included in a device that is removably attached to a user, radiation emitted from the sternal angle of the user as a result of the illuminating, wherein the sensing occurs while the oxygen saturation sensor faces the sternal angle of the user. 424
Generating detection signals by the oxygen saturation sensor in response to the sensing of the radiation, wherein the detection signals are indicative of an oxygen saturation characteristic of the user. 426
Processing the detection signals generated by the oxygen saturation sensor to provide an indication of the oxygen saturation characteristic of the user. 552
Rejecting detection signals that represent radiation sensed when the user movement exceeds a movement threshold. 554
Feeding the processor and the oxygen saturation sensor with power from a battery. 580
Sensing a temperature of the user. 570
Wirelessly transmitting by a transmitter of the device information about the oxygen saturation characteristic of the user. 530

500

FIG. 8


Attaching a device that includes a oxygen saturation sensor so that the oxygen saturation sensor faces the sternal angle. 510
Performing oxygen saturation measurements. 550
Illuminating a sternal angle of the user by electromagnetic radiation. 422
Sensing, by a oxygen saturation sensor included in a device that is removably attached to a user, radiation emitted from the sternal angle of the user. The radiation can be emitted as a result of the illuminating, from ambient radiaiton or a combination of both. The sensing occurs while the oxygen saturation sensor faces the sternal angle of the user. 624
Generating detection signals by the oxygen saturation sensor in response to the sensing of the radiation, wherein the detection signals may be indicative of an oxygen saturation characteristic of the user. 426
Processing the detection signals by the oxygen saturation sensor to provide an indication of the oxygen saturation characteristic of the user and detecting ambient illumination of the sternal angle by processing detection signals generated in response to sensing radiation emitted from the sternal angle at points in time where the sternal angle is not illuminated by the illumination module of the device. 628
Responding to the detection of ambient illumination. For example, calibrating device or generating an alert indicative of a detection of the ambient illumination. 629
Feeding the processor and the oxygen saturation sensor with power from a battery. 580
Wirelessly transmitting by a transmitter of the device information about the oxygen saturation characteristic of the user. 530

600

FIG. 9

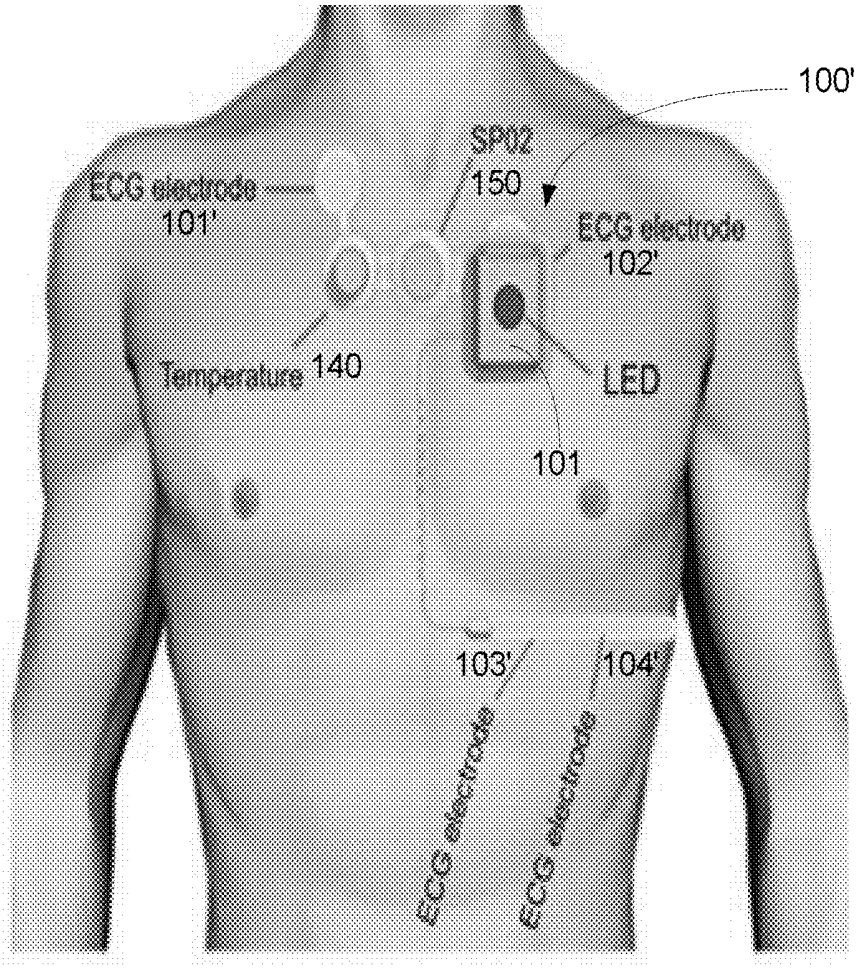

100'
SP02
150
ECG electrode
101'
ECG electrode
102'
Temperature
140
LED
101
103'
104'
ECG electrode
ECG electrode

FIG. 10

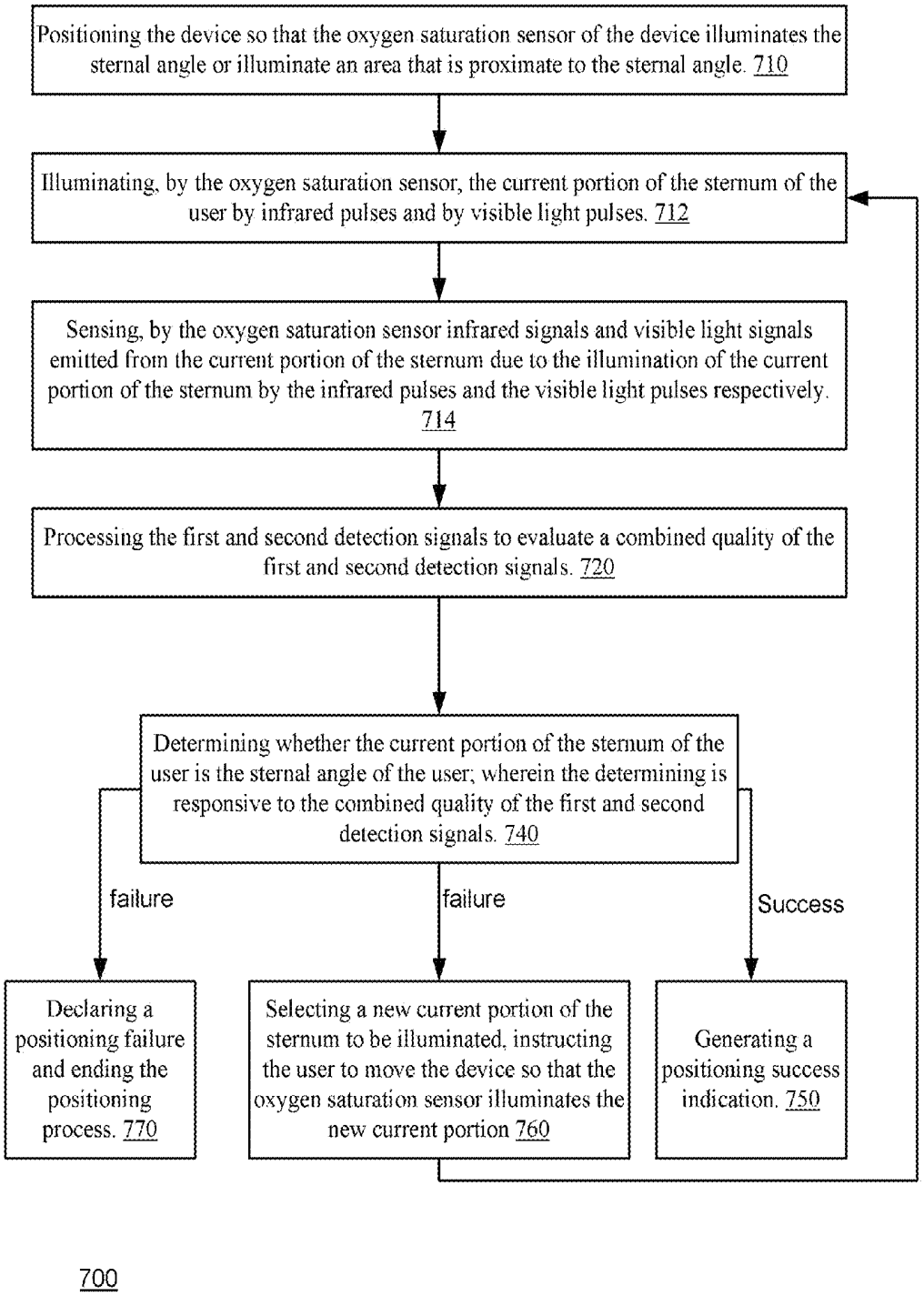

Positioning the device so that the oxygen saturation sensor of the device illuminates the sternal angle or illuminate an area that is proximate to the sternal angle. 710
Illuminating, by the oxygen saturation sensor, the current portion of the sternum of the user by infrared pulses and by visible light pulses. 712
Sensing, by the oxygen saturation sensor infrared signals and visible light signals emitted from the current portion of the sternum due to the illumination of the current portion of the sternum by the infrared pulses and the visible light pulses respectively. 714
Processing the first and second detection signals to evaluate a combined quality of the first and second detection signals. 720
Determining whether the current portion of the sternum of the user is the sternal angle of the user; wherein the determining is responsive to the combined quality of the first and second detection signals. 740
failure
failure
Success
Declaring a positioning failure and ending the positioning process. 770
Selecting a new current portion of the sternum to be illuminated, instructing the user to move the device so that the oxygen saturation sensor illuminates the new current portion 760
Generating a positioning success indication. 750
700

FIG. 11

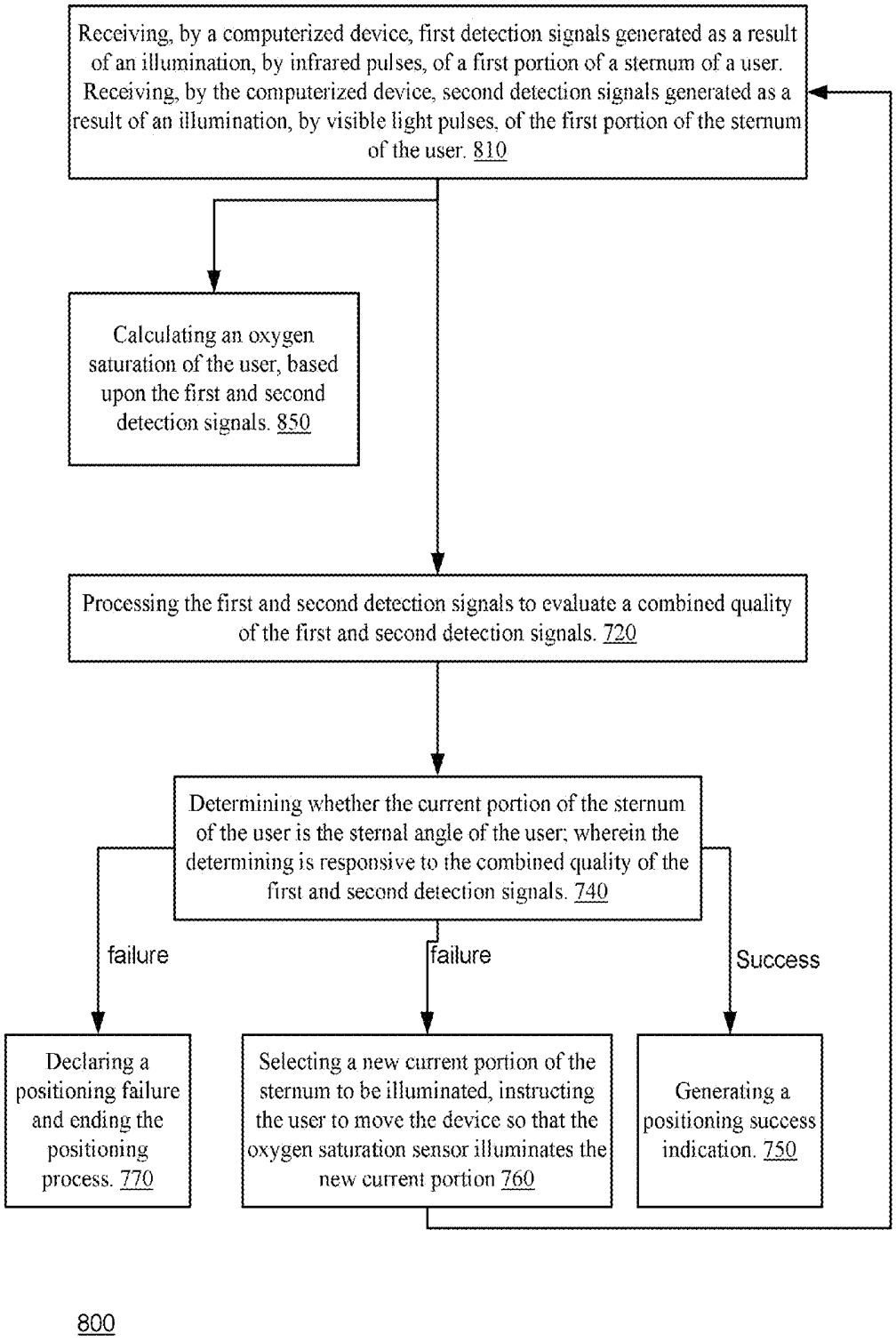

Receiving, by a computerized device, first detection signals generated as a result of an illumination, by infrared pulses, of a first portion of a sternum of a user. Receiving, by the computerized device, second detection signals generated as a result of an illumination, by visible light pulses, of the first portion of the sternum of the user. 810
Calculating an oxygen saturation of the user, based upon the first and second detection signals. 850
Processing the first and second detection signals to evaluate a combined quality of the first and second detection signals. 720
Determining whether the current portion of the sternum of the user is the sternal angle of the user; wherein the determining is responsive to the combined quality of the first and second detection signals. 740
failure
failure
Success
Declaring a positioning failure and ending the positioning process. 770
Selecting a new current portion of the sternum to be illuminated, instructing the user to move the device so that the oxygen saturation sensor illuminates the new current portion 760
Generating a positioning success indication. 750
800

FIG. 12

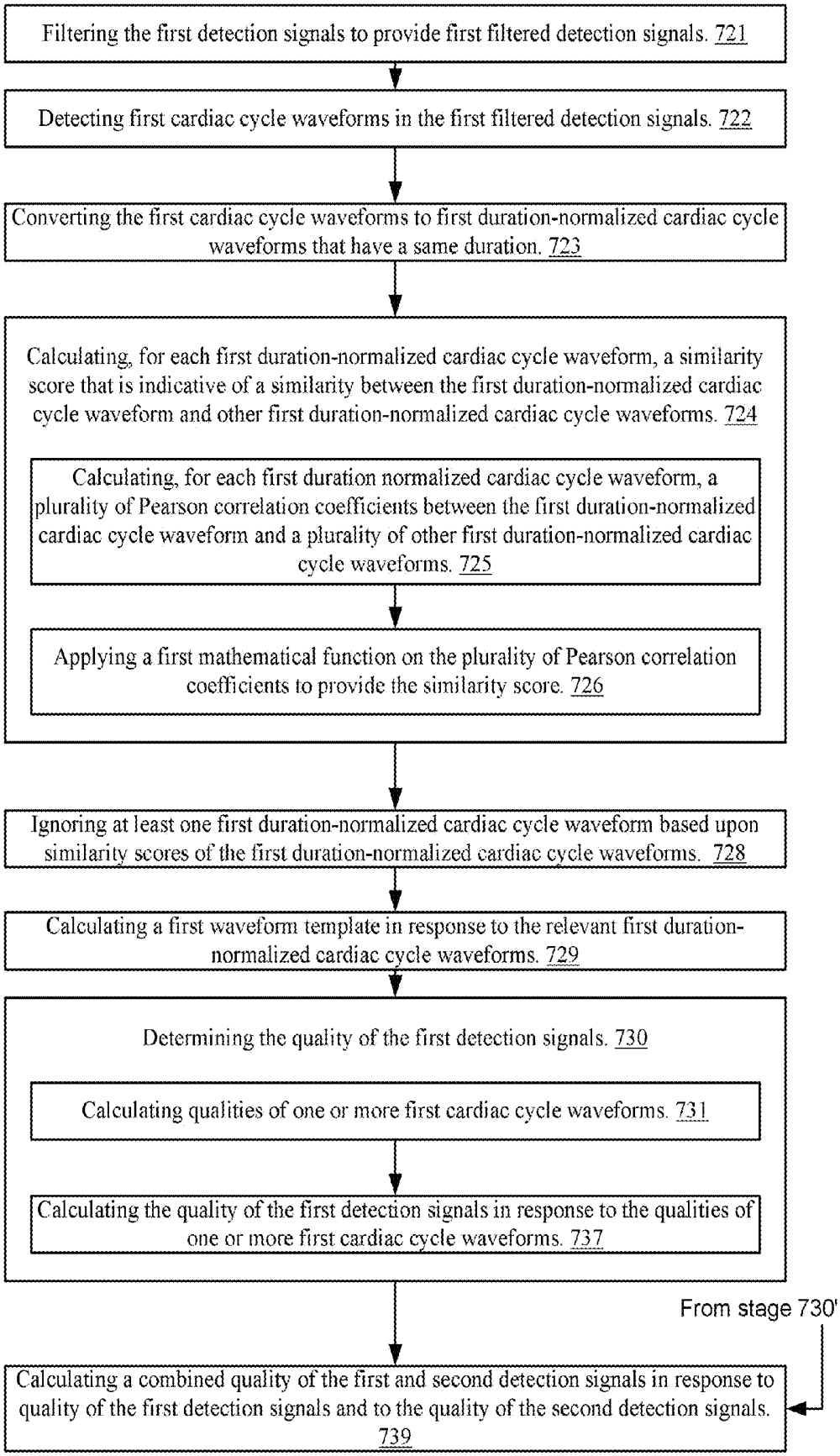

Filtering the first detection signals to provide first filtered detection signals. 721
Detecting first cardiac cycle waveforms in the first filtered detection signals. 722
Converting the first cardiac cycle waveforms to first duration-normalized cardiac cycle waveforms that have a same duration. 723
Calculating, for each first duration-normalized cardiac cycle waveform, a similarity score that is indicative of a similarity between the first duration-normalized cardiac cycle waveform and other first duration-normalized cardiac cycle waveforms. 724
Calculating, for each first duration normalized cardiac cycle waveform, a plurality of Pearson correlation coefficients between the first duration-normalized cardiac cycle waveform and a plurality of other first duration-normalized cardiac cycle waveforms. 725
Applying a first mathematical function on the plurality of Pearson correlation coefficients to provide the similarity score. 726
Ignoring at least one first duration-normalized cardiac cycle waveform based upon similarity scores of the first duration-normalized cardiac cycle waveforms. 728
Calculating a first waveform template in response to the relevant first duration-normalized cardiac cycle waveforms. 729
Determining the quality of the first detection signals. 730
Calculating qualities of one or more first cardiac cycle waveforms. 731
Calculating the quality of the first detection signals in response to the qualities of one or more first cardiac cycle waveforms. 737
From stage 730'
Calculating a combined quality of the first and second detection signals in response to quality of the first detection signals and to the quality of the second detection signals. 739

FIG. 13

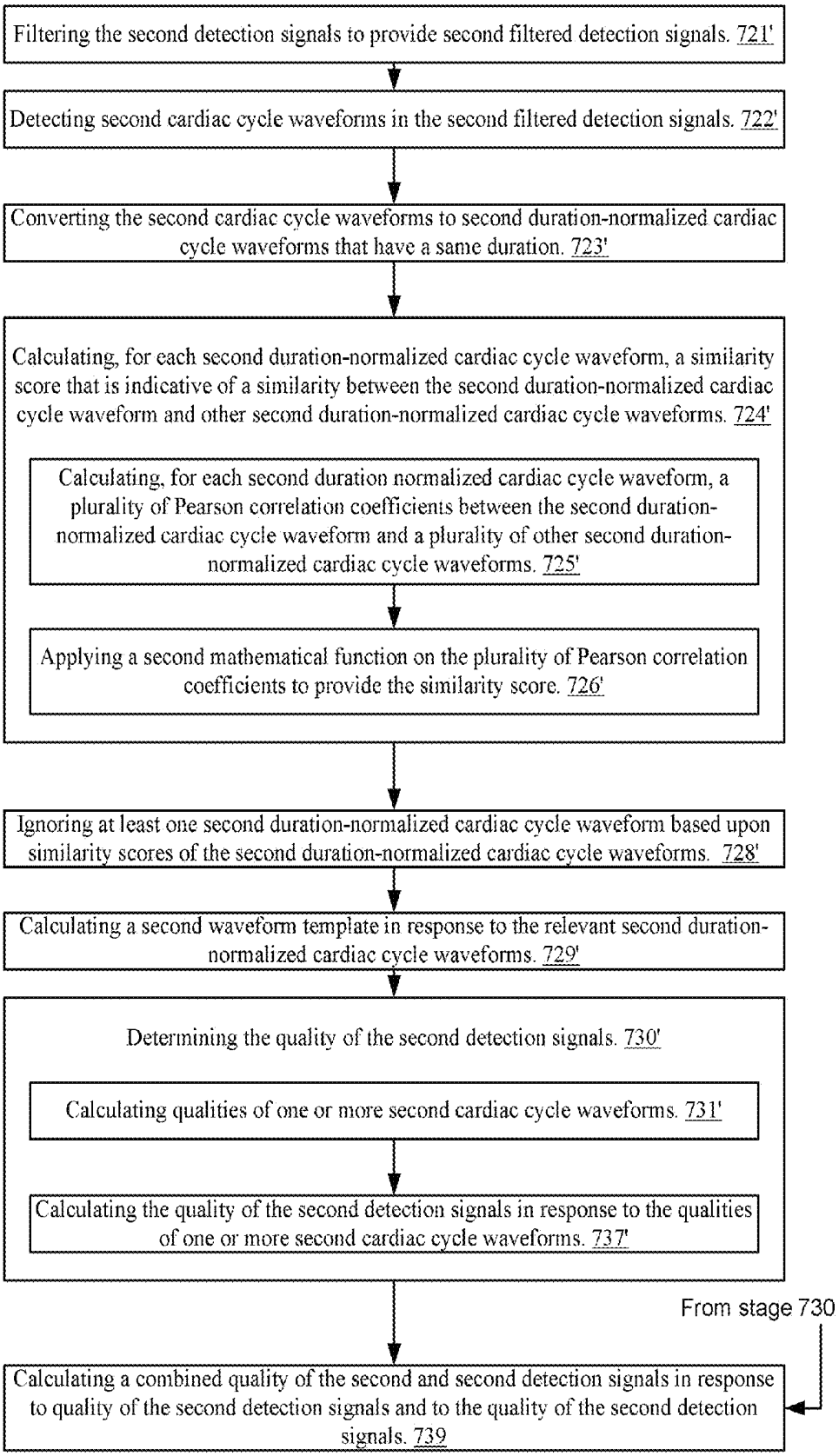

Filtering the second detection signals to provide second filtered detection signals. 721'
Detecting second cardiac cycle waveforms in the second filtered detection signals. 722'
Converting the second cardiac cycle waveforms to second duration-normalized cardiac cycle waveforms that have a same duration. 723'
Calculating, for each second duration-normalized cardiac cycle waveform, a similarity score that is indicative of a similarity between the second duration-normalized cardiac cycle waveform and other second duration-normalized cardiac cycle waveforms. 724'
Calculating, for each second duration normalized cardiac cycle waveform, a plurality of Pearson correlation coefficients between the second duration-normalized cardiac cycle waveform and a plurality of other second duration-normalized cardiac cycle waveforms. 725'
Applying a second mathematical function on the plurality of Pearson correlation coefficients to provide the similarity score. 726'
Ignoring at least one second duration-normalized cardiac cycle waveform based upon similarity scores of the second duration-normalized cardiac cycle waveforms. 728'
Calculating a second waveform template in response to the relevant second duration-normalized cardiac cycle waveforms. 729'
Determining the quality of the second detection signals. 730'
Calculating qualities of one or more second cardiac cycle waveforms. 731'
Calculating the quality of the second detection signals in response to the qualities of one or more second cardiac cycle waveforms. 737'
From stage 730
Calculating a combined quality of the second and second detection signals in response to quality of the second detection signals and to the quality of the second detection signals. 739

FIG. 14

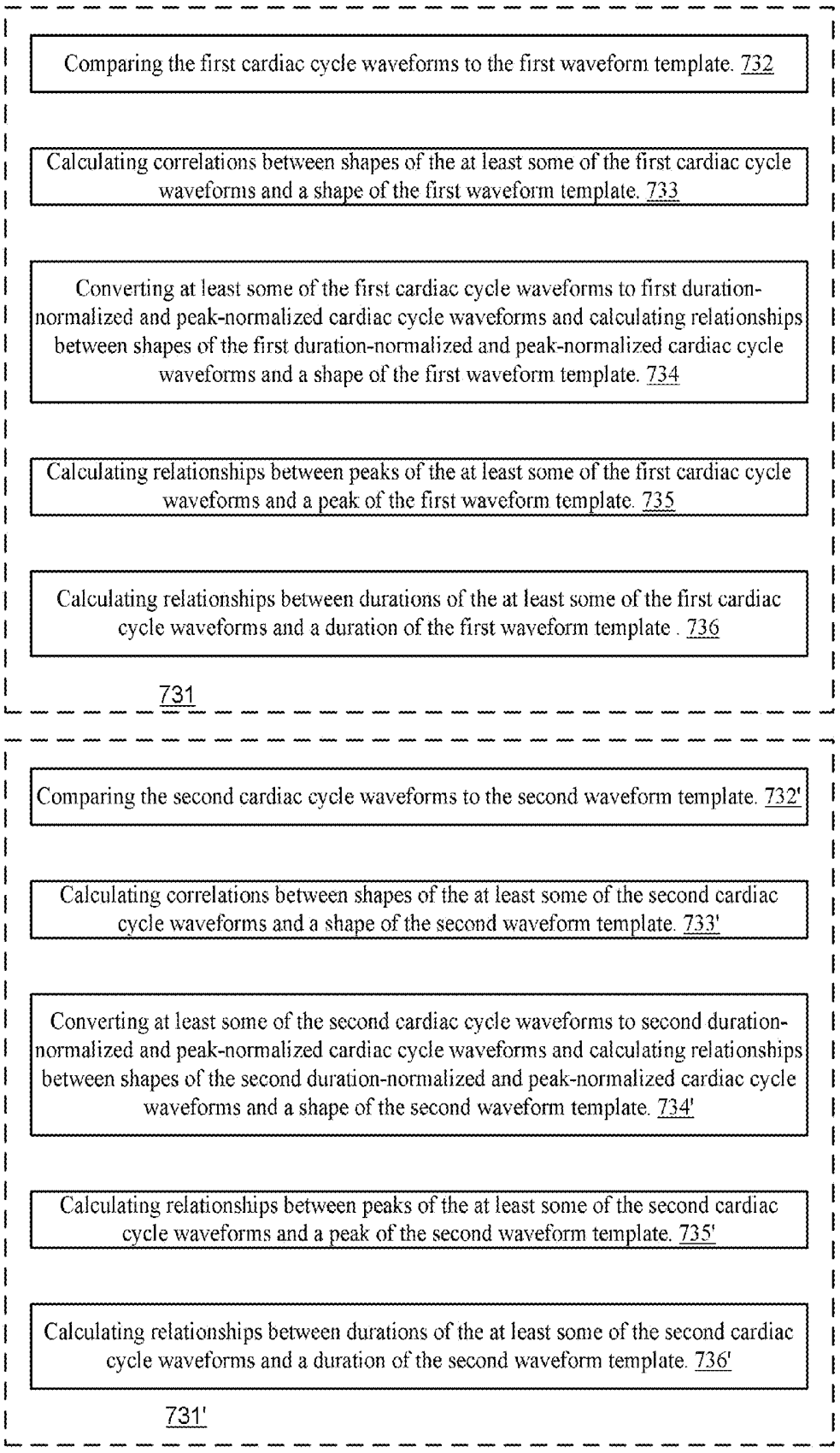

Comparing the first cardiac cycle waveforms to the first waveform template. 732
Calculating correlations between shapes of the at least some of the first cardiac cycle waveforms and a shape of the first waveform template. 733
Converting at least some of the first cardiac cycle waveforms to first duration-normalized and peak-normalized cardiac cycle waveforms and calculating relationships between shapes of the first duration-normalized and peak-normalized cardiac cycle waveforms and a shape of the first waveform template. 734
Calculating relationships between peaks of the at least some of the first cardiac cycle waveforms and a peak of the first waveform template. 735
Calculating relationships between durations of the at least some of the first cardiac cycle waveforms and a duration of the first waveform template . 736
731
Comparing the second cardiac cycle waveforms to the second waveform template. 732'
Calculating correlations between shapes of the at least some of the second cardiac cycle waveforms and a shape of the second waveform template. 733'
Converting at least some of the second cardiac cycle waveforms to second duration-normalized and peak-normalized cardiac cycle waveforms and calculating relationships between shapes of the second duration-normalized and peak-normalized cardiac cycle waveforms and a shape of the second waveform template. 734'
Calculating relationships between peaks of the at least some of the second cardiac cycle waveforms and a peak of the second waveform template. 735'
Calculating relationships between durations of the at least some of the second cardiac cycle waveforms and a duration of the second waveform template. 736'
731'

FIG. 15

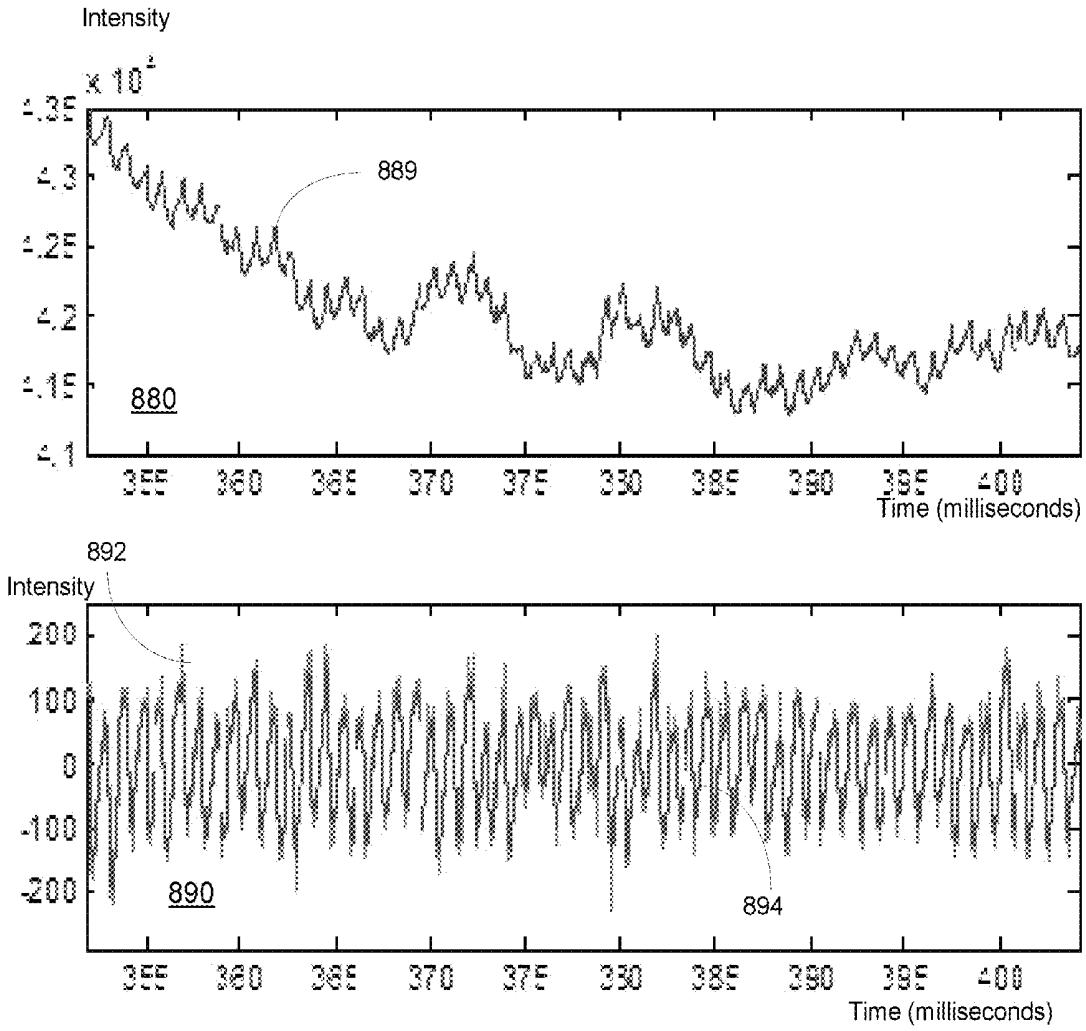

Intensity
x 10^2
889
880
Time (milliseconds)
892
Intensity
200
100
0
-100
-200
890
894
Time (milliseconds)

FIG. 16

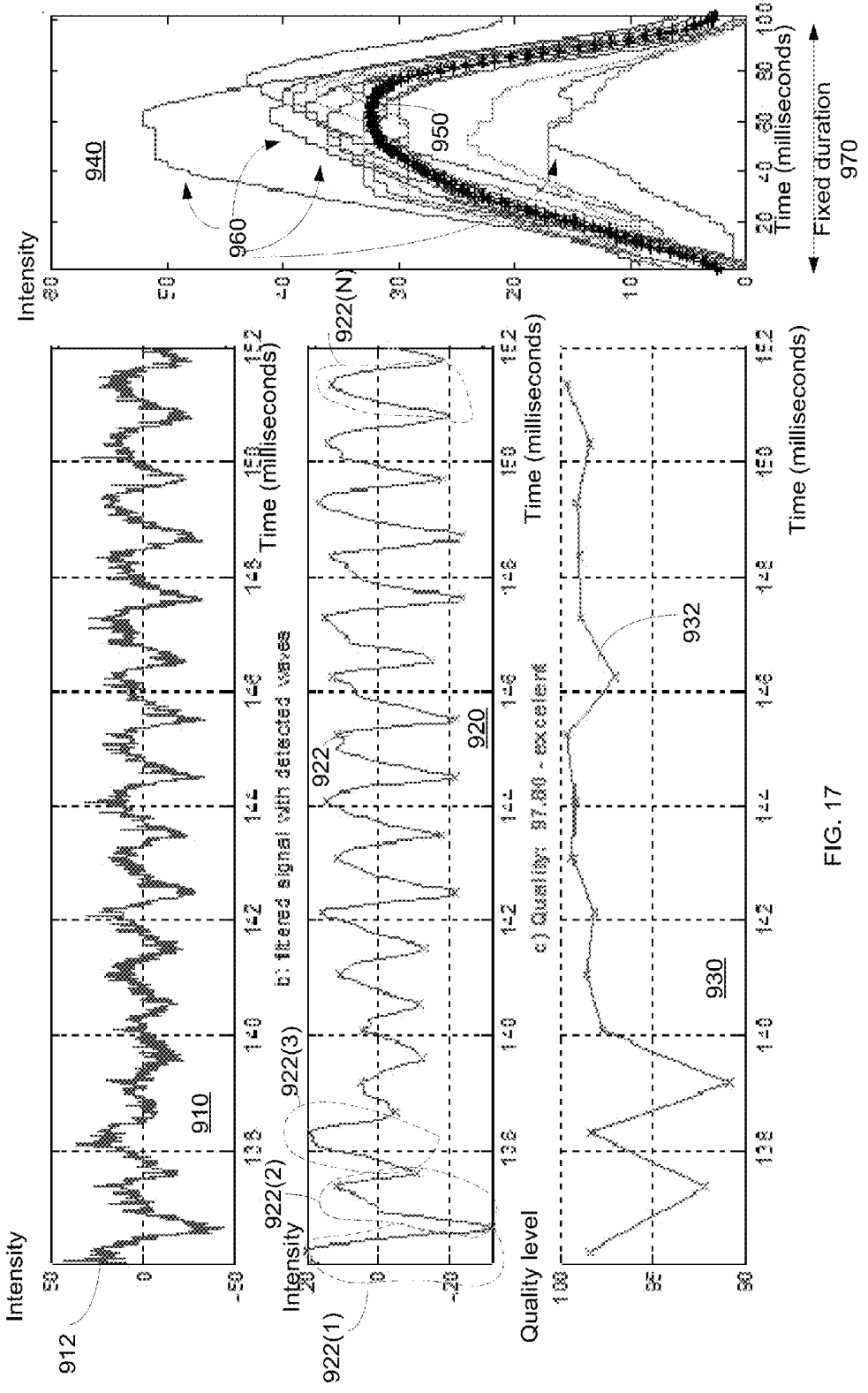

Intensity
940
960
950
Time (milliseconds)
Fixed duration
970
Intensity
910
912
Time (milliseconds)
b: filtered signal with detected waves
Intensity
920
922
922(1)
922(2)
922(3)
922(N)
Time (milliseconds)
c) Quality: 97.80 - excellent
Quality level
930
932
Time (milliseconds)

FIG. 17

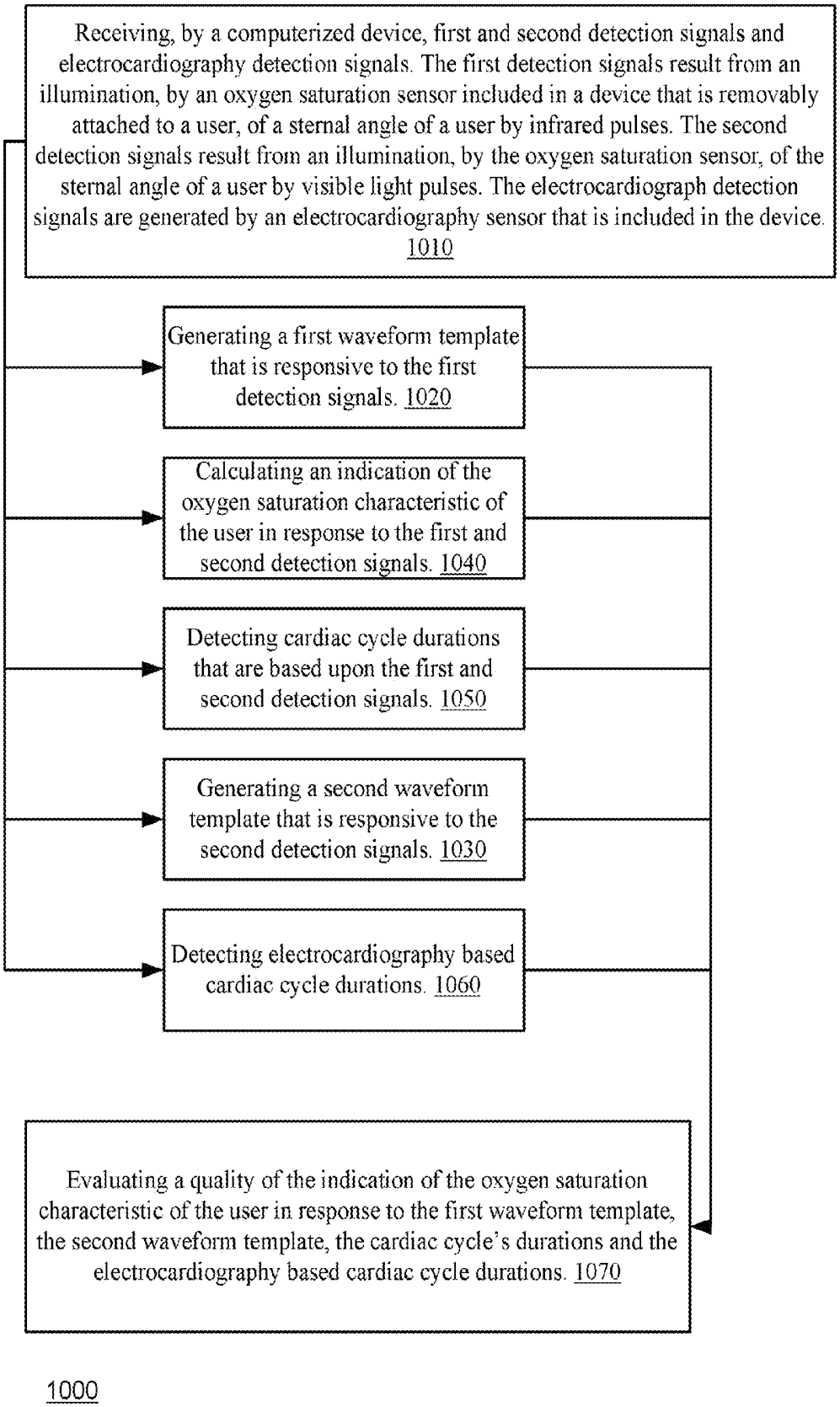

Receiving, by a computerized device, first and second detection signals and electrocardiography detection signals. The first detection signals result from an illumination, by an oxygen saturation sensor included in a device that is removably attached to a user, of a sternal angle of a user by infrared pulses. The second detection signals result from an illumination, by the oxygen saturation sensor, of the sternal angle of a user by visible light pulses. The electrocardiograph detection signals are generated by an electrocardiography sensor that is included in the device. 1010
Generating a first waveform template that is responsive to the first detection signals. 1020
Calculating an indication of the oxygen saturation characteristic of the user in response to the first and second detection signals. 1040
Detecting cardiac cycle durations that are based upon the first and second detection signals. 1050
Generating a second waveform template that is responsive to the second detection signals. 1030
Detecting electrocardiography based cardiac cycle durations. 1060
Evaluating a quality of the indication of the oxygen saturation characteristic of the user in response to the first waveform template, the second waveform template, the cardiac cycle's durations and the electrocardiography based cardiac cycle durations. 1070
1000

FIG. 18

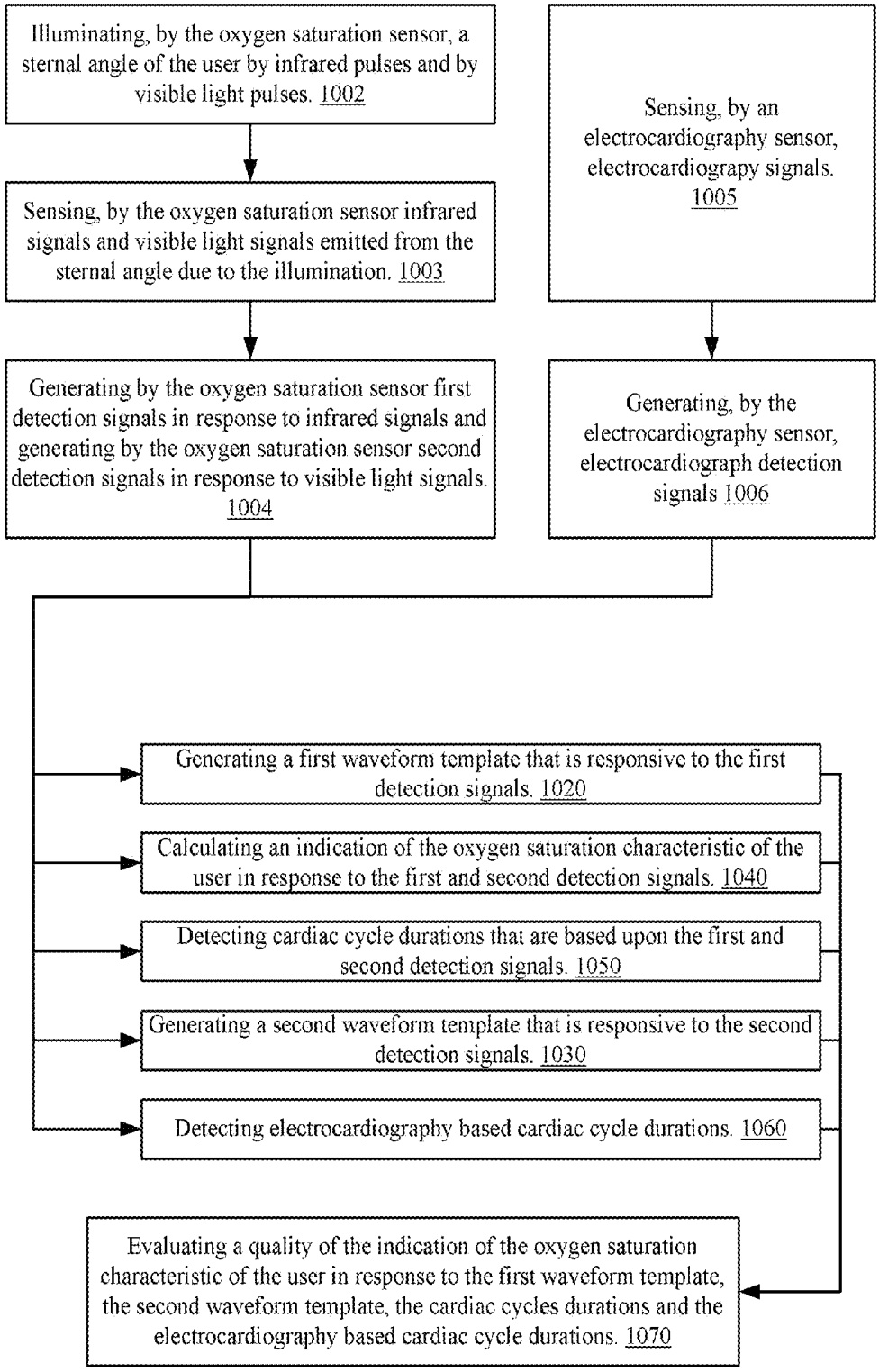
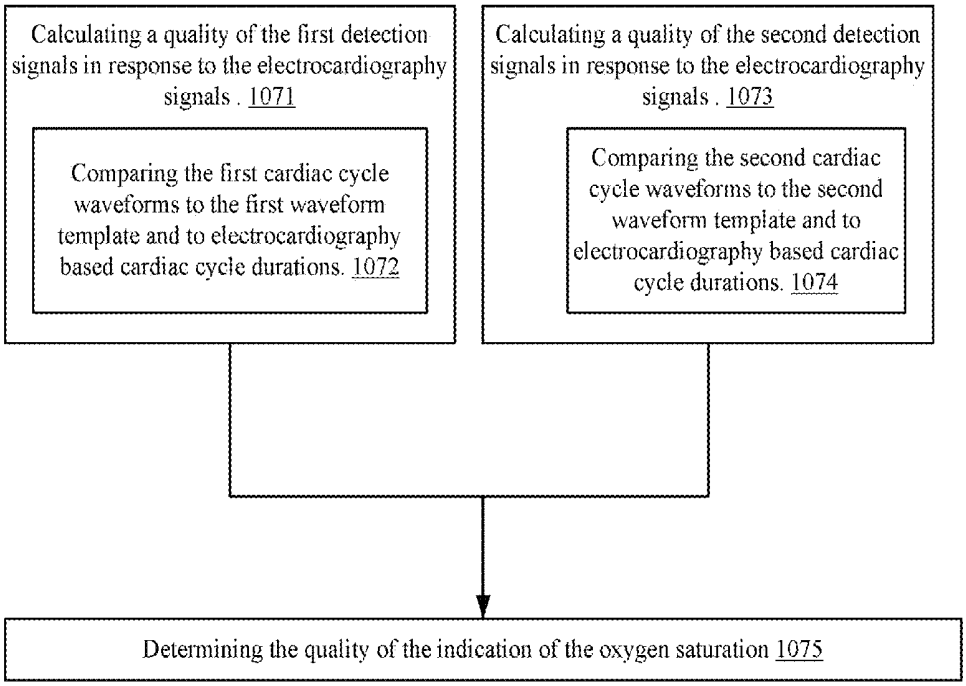
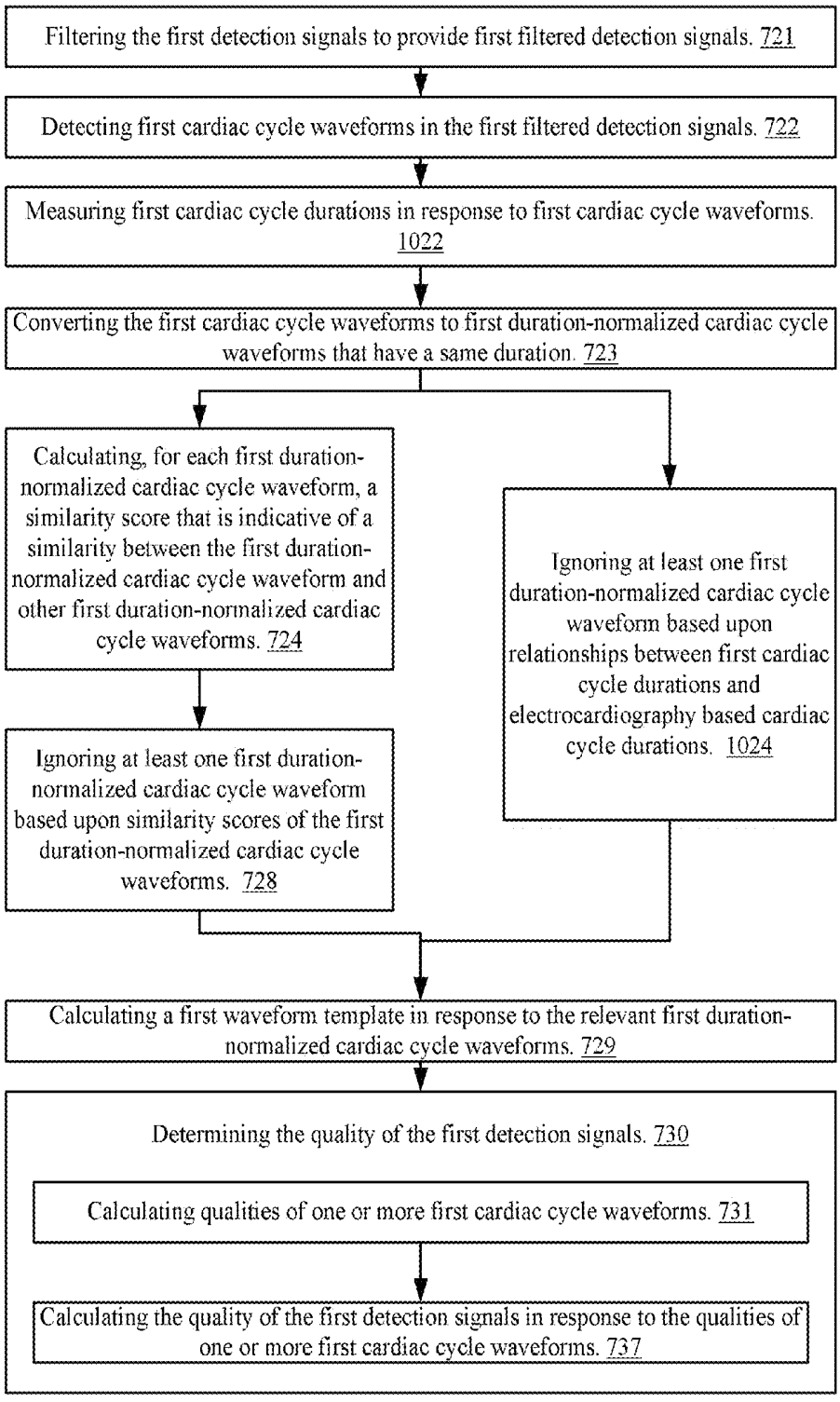

Illuminating, by the oxygen saturation sensor, a sternal angle of the user by infrared pulses and by visible light pulses. 1002
Sensing, by the oxygen saturation sensor infrared signals and visible light signals emitted from the sternal angle due to the illumination. 1003
Generating by the oxygen saturation sensor first detection signals in response to infrared signals and generating by the oxygen saturation sensor second detection signals in response to visible light signals. 1004
Sensing, by an electrocardiography sensor, electrocardiograpy signals. 1005
Generating, by the electrocardiography sensor, electrocardiograph detection signals 1006
Generating a first waveform template that is responsive to the first detection signals. 1020
Calculating an indication of the oxygen saturation characteristic of the user in response to the first and second detection signals. 1040
Detecting cardiac cycle durations that are based upon the first and second detection signals. 1050
Generating a second waveform template that is responsive to the second detection signals. 1030
Detecting electrocardiography based cardiac cycle durations. 1060
Evaluating a quality of the indication of the oxygen saturation characteristic of the user in response to the first waveform template, the second waveform template, the cardiac cycles durations and the electrocardiography based cardiac cycle durations. 1070
1000'

FIG. 19


Calculating a quality of the first detection signals in response to the electrocardiography signals . 1071
Comparing the first cardiac cycle waveforms to the first waveform template and to electrocardiography based cardiac cycle durations. 1072
Calculating a quality of the second detection signals in response to the electrocardiography signals . 1073
Comparing the second cardiac cycle waveforms to the second waveform template and to electrocardiography based cardiac cycle durations. 1074
Determining the quality of the indication of the oxygen saturation 1075

1070

FIG. 20


Filtering the first detection signals to provide first filtered detection signals. 721
Detecting first cardiac cycle waveforms in the first filtered detection signals. 722
Measuring first cardiac cycle durations in response to first cardiac cycle waveforms. 1022
Converting the first cardiac cycle waveforms to first duration-normalized cardiac cycle waveforms that have a same duration. 723
Calculating, for each first duration-normalized cardiac cycle waveform, a similarity score that is indicative of a similarity between the first duration-normalized cardiac cycle waveform and other first duration-normalized cardiac cycle waveforms. 724
Ignoring at least one first duration-normalized cardiac cycle waveform based upon similarity scores of the first duration-normalized cardiac cycle waveforms. 728
Ignoring at least one first duration-normalized cardiac cycle waveform based upon relationships between first cardiac cycle durations and electrocardiography based cardiac cycle durations. 1024
Calculating a first waveform template in response to the relevant first duration-normalized cardiac cycle waveforms. 729
Determining the quality of the first detection signals. 730
Calculating qualities of one or more first cardiac cycle waveforms. 731
Calculating the quality of the first detection signals in response to the qualities of one or more first cardiac cycle waveforms. 737

1071

FIG. 21

POSITIONING A MEDICAL DEVICE BASED ON OXYGEN SATURATION MEASUREMENTS

RELATED APPLICATIONS

[0001] This application is a continuation in part of U.S. patent application Ser. No. 14/590,149 filing date Jan. 6, 2015 which is incorporated in reference.

BACKGROUND OF THE INVENTION

[0002] Oxygen saturation measurements provide highly valuable information about the state of a user. Results of oxygen saturation measurements depend upon the location of measurement and may be required to be taken over relatively long periods.

[0003] There is a growing need to provide methods for accurate oxygen saturation measurements that can be easily taken over long periods of time.

SUMMARY OF THE INVENTION

[0004] According to an embodiment of the invention there may be provided a method that may include receiving, by a computerized device, first detection signals generated as a result of an illumination, by infrared pulses, of a current portion of a sternum of a user; receiving, by the computerized device, second detection signals generated as a result of an illumination, by visible light pulses, of the current portion of the sternum of the user; and evaluating, by the computerized device, a quality of the first and second detection signals; and determining whether the current portion of the sternum of the user may be a sternal angle of the user; wherein the determining may be responsive to the quality of the first and second detection signals. The computerized device may be a server, a laptop computer, a desktop computer, a mobile phone, a personal data assistant, a medical monitor or any type of computerized system that has one or more hardware component.

[0005] The method may include illuminating the current portion of the sternum of the user by the infrared pulses and by the visible light pulses.

[0006] The illuminating may be executed by an oxygen saturation sensor that belongs to the computerized device.

[0007] The receiving of the first and second detection signals may include receiving the first and second detection signals from a device that differs from the computerized device.

[0008] The method may include determining that the current portion of the sternum of the user may be the sternal angle of the user when the quality of the first and second detection signals exceeds a predetermined quality threshold.

[0009] The evaluating of the quality of the first and second detection signals may include generating a first waveform template in response to the first detection signals.

[0010] The evaluating of the quality of the first and second detection signals may include detecting first cardiac cycle waveforms and generating a first waveform template in response to the first cardiac cycle waveforms.

[0011] The generating of the first waveform template may be followed by determining relationships between one or more first cardiac cycle waveform and the first waveform template.

[0012] The generating of the first waveform template may include: filtering the first detection signals to provide first filtered detection signals; and detecting first cardiac cycle waveforms in the first filtered detection signals.

[0013] The generating of the first waveform template may include converting the first cardiac cycle waveforms to first duration-normalized cardiac cycle waveforms that have a same duration.

[0014] The converting may be followed by calculating, for each first duration-normalized cardiac cycle waveform, a similarity score that may be indicative of a similarity between the first duration-normalized cardiac cycle waveform and other first duration-normalized cardiac cycle waveforms.

[0015] The method may include calculating, for each first duration-normalized cardiac cycle waveform, the similarity score by calculating a plurality of Pearson correlation coefficients between the first duration-normalized cardiac cycle waveform and a plurality of other first duration-normalized cardiac cycle waveforms.

[0016] The calculating a plurality of Pearson correlation coefficients may be followed by applying a first mathematical function on the plurality of Pearson correlation coefficients to provide the similarity score of the first duration-normalized cardiac cycle waveform.

[0017] The generating of the first waveform template may include ignoring at least one first duration-normalized cardiac cycle waveform based upon similarity scores of the first duration-normalized cardiac cycle waveforms to provide relevant first duration-normalized cardiac cycle waveforms.

[0018] The generating of the first waveform template may be responsive to the relevant first duration-normalized cardiac cycle waveforms.

[0019] The method may include calculating qualities of at least some of the first cardiac cycle waveforms; and wherein the quality of the first and second detection signals may be responsive to the qualities of at least some of the first cardiac cycle waveforms.

[0020] The calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms may include comparing the first cardiac cycle waveform to the first waveform template.

[0021] The calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms may include comparing calculating a correlation between a shape of the first cardiac cycle waveform and a shape of the first waveform template.

[0022] The calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms may include converting the first cardiac cycle waveform to a first duration-normalized and peak-normalized cardiac cycle waveform and calculating a relationship between a shape of the first duration-normalized and peak-normalized cardiac cycle waveform and a shape of the first waveform template.

[0023] The calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms may include comparing a relationship between a peak of the first cardiac cycle waveform and a peak of the first waveform template.

[0024] The method wherein a calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms may include calculating a relationship between a peak of the first cardiac cycle waveform and a peak of the first waveform template.

[0025] According to an embodiment of the invention there may be provided a a non-transitory computer readable

medium that stores instructions that once executed by a computerized device cause the computerized device to execute the steps of: receiving, by a computerized device, first detection signals generated as a result of an illumination, by infrared pulses, of a first portion of a sternum of a user; receiving, by the computerized device, second detection signals generated as a result of an illumination, by visible light pulses, of the first portion of the sternum of the user; evaluating, by the computerized device, a quality of the first and second detection signals; and determining whether the first portion of the sternum of the user may be a sternal angle of the user; wherein the determining may be responsive to the quality of the first and second detection signals.

[0026] According to an embodiment of the invention there may be provided a device that may be removably attached to a user and may include an oxygen saturation sensor, wherein the oxygen saturation sensor may be configured to: generate first detection signals responsive to an illumination, by infrared pulses, of a first portion of a sternum of a user; generate second detection signals responsive to an illumination, by visible light pulses, of the first portion of the sternum of a user; and evaluate a quality of the first and second detection signals; and determine whether the first portion of the sternum of the user may be the sternal angle of the user, in response to the quality of the first and second detection signals.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with objects, features, and advantages thereof may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

[0028] FIG. **1** illustrates the sternum and the ribs of a person;

[0029] FIG. **2** is an exploded view of a device according to an embodiment of the invention;

[0030] FIG. **3** illustrates a placement of the device of FIG. **2** on a chest of a user according to an embodiment of the invention;

[0031] FIG. **4** illustrates a placement of the device of FIG. **2** on a chest of a user according to an embodiment of the invention;

[0032] FIG. **5** is a schematic diagram of various components of the device of FIG. **2** according to an embodiment of the invention;

[0033] FIG. **6** is a timing diagram according to an embodiment of the invention;

[0034] FIG. **7** illustrates a method according to an embodiment of the invention;

[0035] FIG. **8** illustrates a method according to an embodiment of the invention;

[0036] FIG. **9** illustrates a method according to an embodiment of the invention;

[0037] FIG. **10** illustrates a device that is removably attached to a person according to an embodiment of the invention;

[0038] FIG. **11** illustrates a method for positioning the device according to an embodiment of the invention;

[0039] FIG. **12** illustrates a method according to an embodiment of the invention;

[0040] FIGS. **13-15** illustrate a stage of processing the first and second detection signals to evaluate a quality of the first and second detection signals according to an embodiment of the invention;

[0041] FIG. **16** illustrates first detection signals and first filtered detection signals according to an embodiment of the invention;

[0042] FIG. **17** illustrates first detection signals, first filtered detection signals, first cardiac cycle waveforms, first waveform template, first duration-normalized cardiac cycle waveforms of a fixed duration, and first cardiac cycle waveform quality scores **932** according to an embodiment of the invention;

[0043] FIG. **18** illustrates a method according to an embodiment of the invention;

[0044] FIG. **19** illustrates a method according to an embodiment of the invention;

[0045] FIG. **20** illustrates a stage according to an embodiment of the invention; and

[0046] FIG. **21** illustrates a stage for calculating a quality of the first detection signals in response to the electrocardiography signals according to an embodiment of the invention.

[0047] It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION OF THE DRAWINGS

[0048] The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with objects, features, and advantages thereof, may best be understood by reference to the following detailed description when read with the accompanying drawings.

[0049] In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known methods, procedures, and components have not been described in detail so as not to obscure the present invention. It has been surprisingly found that measuring oxygen saturation by illuminating the sternal angle of a user provides reliable results. The sternal angle is easy to find by the user (or third parties) so that users can easily and accurately position the sensor to face sternal angle. This greatly increases the repetitiveness of the oxygen saturation results. Furthermore—placing the device in this position reduces the breath induced movements that the device experiences and further increases the accuracy of this measurement. In addition-placing the device at that position is relatively easy as the sternum is relatively flat.

[0050] FIG. **1** illustrates the sternum and the ribs of a person **10**. The sternum angle is located between the manubrium bone and the body of the sternum.

[0051] FIG. **2** is an exploded view of a device **100** according to an embodiment of the invention.

[0052] Device **100** includes:

[0053] 1. Processor and transceiver (collectively denoted **101**).

[0054] 2. An upper elastic layer **120** that include first, second and third openings **121**, **122** and **123**.

[0055] 3. Intermediate layer **130** that includes conductors **131**, **132** and **134** and socket **135** for conveying power from battery **133**.

[0056] 4. Temperature sensor **140** that includes temperature sensor cover **141**, temperature sensor electrical board **142** and temperature sensor case **143**.

[0057] 5. Oxygen saturation sensor **150** that includes oxygen saturation sensor electrical board **151**, **151**, oxygen saturation sensor shield **152** and oxygen saturation sensor case **153**.

[0058] 6. A lower elastic layer **160** that include first, second and third openings **161**, **162** and **163** and an addition portion **164** to be contacted by lower case **180**. The lower elastic layer **160** has an underside provided with a self-adhesive. Removable cover **170** shields the self-adhesive and is removed before attaching the device **100** to a user.

[0059] 7. Upper case **111** having socket **112**.

[0060] 8. Lower case **180**.

[0061] The temperature sensor cover **141** is shaped and positioned to pass through the first opening **121** of the upper elastic layer **120**. Cover **155** is arranged to seal the second opening **122** of the upper elastic layer **120**. Cover **155** is positioned between the upper elastic layer **120** and conductor **132** of the intermediate layer **130**. Conductor **132** is positioned above the oxygen saturation sensor electrical board **151**.

[0062] The temperature sensor case **143** is positioned directly above the first opening **162** of the lower elastic layer **160**.

[0063] The oxygen saturation sensor **150** is positioned directly above the second opening **163** of the lower elastic layer **160**. It may contact the sternum angle during measurements but may be positioned slightly (few millimeters) above the sternum angle without contacting the sternum angle.

[0064] Battery **133** is placed within lower case **180** and its upper facet supports a lower facet of upper case **111** that is connected to the processor and transceiver **101**.

[0065] Device **100** is illustrated as including a temperature sensor **140** and oxygen saturation sensor **150**. It is noted that other sensor (or sensors) can be provided instead (or in addition) to the temperature sensor **140**. Alternatively, the only sensor included in device **100** may be the oxygen saturation sensor **150**. For an example (illustrated in FIG. **6**), the device **100** may include a movement sensor **144**, a temperature sensor **140** and the oxygen saturation sensor **150**.

[0066] The device **100** may be very compact and light weight. Its transceiver (denoted **101**(**2**) in FIG. **6**) may be arranged to perform short range and/or long range transmissions.

[0067] FIG. **3** illustrates device **100** as being positioned on a user wherein the oxygen saturation sensor **150** is positioned directly above the sternum angle, the temperature sensor **140** is positioned below the sternum angle and the processor and transceiver **101** is positioned above the sternum angle.

[0068] FIG. **4** illustrates the lower elastic layer **160** of device **100** as being positioned on a user wherein the third opening **163** (that the oxygen saturation sensor **150** is positioned directly above) is positioned directly above the sternum angle **22**, the temperature sensor **140** is positioned directly above the body **24** of the sternum and the lower case **180** faces the manubrium bone.

[0069] FIG. **5** is a schematic diagram of various components of the device **100** of FIG. **2** according to an embodiment of the invention.

[0070] FIG. **5** illustrates the oxygen saturation sensor **150** as including three radiation sensing elements **220**, **230** and **240**, illumination module **210** (illustrated as being positioned directly above the sternum angle **20** and within third opening **163** of the lower elastic layer **160**), intermediate module **260** (that may include an analog amplifier, an analog to digital converter or a combination of both), processor **101**(**1**) of processor/transducer **101**, transducer **101**(**2**), temperature sensor **140** and movement sensor **144**.

[0071] The illumination module **210** may be arranged to illuminate the sternum angle with infrared pulses and visible light pulses. The radiation sensing elements **220**, **230** and **240** may sense radiation reflected and/or scattered from the sternum angle in the infrared and visible light ranges and send detection signals towards intermediate module **260**.

[0072] Pulses of energy are provided to the illumination module **210** via conductor **270**.

[0073] Radiation sensing elements **220**, **230** and **240** are coupled in parallel to each other via conductor **270** but may be coupled in a serial manner to each other.

[0074] Processor **101**(**1**) may receive detection signals from temperature sensor **140** and movement sensor **144**. It may be arranged to disregard detection signals obtained when the user moves in a manner that may reduce the reliability of the detection signals below a predefined threshold.

[0075] FIG. **6** is a timing diagram **300** according to an embodiment of the invention. It illustrates a cyclic illumination pattern having a period of **330**. Each cycle includes an activation window **301** of a red diode (delimited between RED diode ON and RED diode OFF) and an activation window **313** of an infrared diode (delimited between IR diode ON and IR diode OFF) that are followed by an idle period **333**. Each activation window includes a stabilization period (**302** and **312** respectively) in which the emitted light (red or infrared) is stabilized that is followed by a measurement period (**303** and **313**) in which the light pulses (**304** and **314** respectively) can be used for oxygen saturation measurements. The activation windows may be of the same length (for example 0.5 millisecond) or of different lengths. The cyclic illumination pattern may have a cycle **330** that is longer and even much longer than the duration of the activation windows (for example—13 millisecond).

[0076] Detection signals generated during idle period **333** may be indicative of unwanted ambient light.

[0077] FIG. **7** illustrates method **400** according to an embodiment of the invention.

[0078] Method **400** may start by stage **410** of attaching a device that includes an oxygen saturation sensor so that the oxygen saturation sensor faces the sternal angle. This may, for example, positioning device **100** (or any other device that has an oxygen saturation sensor for sensing oxygen saturation characteristics) on a user. The device can be attached using a self-adhesive material, using a belt and the like.

[0079] Stage **410** may be followed by stage **420** of performing oxygen saturation measurements. Multiple oxygen saturation measurements can be performed over short or long periods of time-minutes, hours, days and even more.

[0080] An oxygen saturation measurement may include a detection signal acquisition phase and a processing phase. The detection signal acquisition phase is executed by the device attached to the client. The processing stage can be

executed in full by the device, can be partially executed by the device or can be executed by another device or system not attached to the device.

[0081] The detection signal acquisition stage includes:

[0082] 1. Illuminating (stage **422**) a sternal angle of the user by electromagnetic radiation.

[0083] 2. Sensing (stage **424**) by an oxygen saturation sensor included in a device that is removably attached to a user, radiation emitted from the sternal angle of the user. The radiation detected can result from the illuminating of the sternal angle. The sensing occurs while the oxygen saturation sensor faces the sternal angle of the user.

[0084] 3. Generating detection signals (stage **426**) by the oxygen saturation sensor in response to the sensing of the radiation, wherein the detection signals are indicative of an oxygen saturation characteristic of the user.

[0085] Stage **422** may include illuminating the sternal angle of the user by a diode that emits visible light pulses and infrared pulses in an interleaved manner.

[0086] Stage **422** may be executed by an illumination module of the device.

[0087] Stage **424** may include sensing the radiation by one or more sensing elements such as photodiodes. If there are multiple sensing elements the sensing elements may be coupled to each other in parallel, in serial or a combination thereof.

[0088] Stage **424** may include sensing the radiation by a plurality of photodiodes that are arranged in a radially symmetrical manner.

[0089] The processing phase includes processing (stage **428**) the detection signals generated by the oxygen saturation sensor to provide an indication of the oxygen saturation characteristic of the user.

[0090] If the processing is performed by a processor of the device then stage **428** is preceded (or includes) sending the detection signals to the processor of the device. If the processing is executed by a processor that does not belong to the device then the method includes transmitting the detection signals towards that processor.

[0091] Stage **420** may be followed by stage **430** of wirelessly transmitting by a transmitter of the device information about the oxygen saturation characteristic of the user.

[0092] Method **400** may also include stage **480** of feeding the processor and the oxygen saturation sensor with power from a battery. The battery may be positioned within a lower case of the device. The processor may be positioned within an upper case of the device.

[0093] FIG. **8** illustrates method **500** according to an embodiment of the invention.

[0094] Method **500** starts by stage **510** of attaching a device that includes an oxygen saturation sensor so that the oxygen saturation sensor faces the sternal angle.

[0095] Stage **510** may be followed by stages **520** and **550**.

[0096] Stage **520** may include sensing, by a movement sensor of the device, a movement of the user during the sensing of the radiation.

[0097] Stage **520** may be followed by stage **530** of determining an accuracy of the detection signals in response to movement of the user.

[0098] Stage **550** may include of performing oxygen saturation measurements. Multiple oxygen saturation measurements can be performed over short or long periods of time-minutes, hours, days and even more.

[0099] Stage **550** may include stages **422**, **424** and **426**. Stage **550** may also include stage **552** of processing the detection signals by the oxygen saturation sensor to provide an indication of the oxygen saturation characteristic of the user and stage **554** of rejecting detection signals that represent radiation sensed when the user movement exceeds a movement threshold.

[0100] If the processing is performed by a processor of the device then stage **552** is preceded (or includes) sending the detection signals to the processor of the device. If the processing is executed by a processor that does not belong to the device then the method includes transmitting the detection signals towards that processor.

[0101] Stage **550** may be followed by stage **560** of wirelessly transmitting by a transmitter of the device information about the oxygen saturation characteristic of the user.

[0102] Method **500** may also include stage **580** of feeding the processor and the oxygen saturation sensor with power from a battery. The battery may be positioned within a lower case of the device. The processor may be positioned within an upper case of the device.

[0103] FIG. **8** also illustrates method **500** as sensing (**570**) a temperature of the user by a temperature sensor of the device. It is noted that this stage can include performing any further sensing operation by any other type of sensor.

[0104] FIG. **9** illustrates method **600** according to an embodiment of the invention.

[0105] Method **600** may start by stage **610** of attaching a device that includes an oxygen saturation sensor so that the oxygen saturation sensor faces the sternal angle.

[0106] Stage **610** may be followed by stage **620** of performing oxygen saturation measurements.

[0107] An oxygen saturation measurement may include a detection signal acquisition phase and a processing phase. The detection signal acquisition phase is executed by the device attached to the client. The processing stage can be executed in full by the device, can be partially executed by the device or can be executed by another device or system not attached to the device.

[0108] The detection signal acquisition stage includes:

[0109] 1. Illuminating (stage **422**) a sternal angle of the user by electromagnetic radiation.

[0110] 2. Sensing (stage **624**), by an oxygen saturation sensor included in a device that is removably attached to a user, radiation emitted from the sternal angle of the user. The radiation detected can result of the illuminating of the sternal angle, from ambient illumination of from a combination thereof. The sensing occurs while the oxygen saturation sensor faces the sternal angle of the user.

[0111] 3. Generating detection signals (stage **426**) by the oxygen saturation sensor in response to the sensing of the radiation, wherein the detection signals are indicative of an oxygen saturation characteristic of the user.

[0112] Stage **424** may include sensing the radiation by one or more sensing elements such as photodiodes. If there are multiple sensing elements the sensing elements may be coupled to each other in parallel, in serial or a combination thereof.

[0113] The processing phase includes processing (stage **628**) the detection signals by the oxygen saturation sensor to provide an indication of the oxygen saturation characteristic of the user.

[0114] Stage **628** may include detecting ambient illumination of the sternal angle by processing detection signals generated (during stage **426**) in response to sensing radiation emitted from the sternal angle at points in time where the sternal angle is not illuminated by the illumination module of the device. See, for example, generation of detection signals that sense ambient radiation sensed during idle period **333** of FIG. **5**.

[0115] Stage **628** may be followed by stage **629** of responding to the detection of ambient illumination.

[0116] For example, calibrating device or generating an alert indicative of a detection of the ambient illumination. The calibrating may include estimating the ambient light and compensating the oxygen saturation measurements in response to the ambient light. For example-reducing from detected radiation (detected when illuminating the sternum angle by IR or light pulse) the estimated value of the ambient light (IR component or light component respectively).

[0117] The alert may signal the user that he should re-attach the device in order to reduce or eliminate ambient radiation from reaching the sternum angle.

[0118] If the processing is performed by a processor of the device then stage **628** is preceded (or includes) sending the detection signals to the processor of the device. If the processing is executed by a processor that does not belong to the device then the method includes transmitting the detection signals towards that processor.

[0119] Stage **620** may be followed by stage **630** of wirelessly transmitting by a transmitter of the device information about the oxygen saturation characteristic of the user.

[0120] Method **600** may also include stage **680** of feeding the processor and the oxygen saturation sensor with power from a battery. The battery may be positioned within a lower case of the device. The processor may be positioned within an upper case of the device.

[0121] FIG. **10** illustrates a device **100'** that is removably attached to a person according to an embodiment of the invention.

[0122] The device **100'** has a temperature sensor **140**, an oxygen saturation sensor **150**, processor and transceiver **101** and may be the device (denoted **100**) that was illustrated in previous figures—but may differ from device **100**.

[0123] Device **100'** may include one or multiple electrocardiography (ECG) electrodes such as electrodes **101'**, **102'**, **103'** and **104'**.

[0124] It is desirable to aim the oxygen saturation sensor of the device **100'** to illuminate the sternal angle of the person. This can be done by performing a positioning process.

[0125] FIG. **11** illustrates a method **700** for positioning the device according to an embodiment of the invention.

[0126] Method **700** may start by stage **710** of positioning the device so that the oxygen saturation sensor of the device illuminates the sternal angle or illuminates an area that is proximate (for example by less than 10 centimeters) to the sternal angle. It may be assumed that the device is positioned so that the oxygen saturation sensor illuminates a current portion of the sternum of the user.

[0127] During a first execution of stage **710** the current portion is a first portion.

[0128] Stage **710** is followed by stage **712** of illuminating, by the oxygen saturation sensor, the current portion of the sternum of the user by infrared pulses and by visible light pulses. Pulses of different wavelength (infrared and visible light) may be transmitted towards the current portion of the sternum in a non-overlapping manner (at different points of time).

[0129] Stage **712** may be followed by stage **714** of sensing, by the oxygen saturation sensor, infrared signals and visible light signals emitted from the current portion of the sternum due to the illumination of the current portion of the sternum by the infrared pulses and the visible light pulses respectively.

[0130] Stage **714** may be followed by stage **716** of generating first and second detection signals, by the oxygen saturation sensor, in response to the sensing of the, infrared signals and visible light signals. The first and second detection signals are indicative of an oxygen saturation characteristic of the user.

[0131] The first detection signals are responsive to the infrared signals and the second detection signals are responsive to the visible light signals.

[0132] Stage **716** may be followed by stage **720** of processing the first and second detection signals to evaluate a quality of the first and second detection signals.

[0133] Stage **720** may be followed by stage **740** of determining whether the current portion of the sternum of the user is the sternal angle of the user; wherein the determining is responsive to the quality of the first and second detection signals.

[0134] Stage **740** may include determining that the current portion of the sternum of the user is the sternal angle of the user if the quality of the first and second detection signals exceeds a predetermined quality threshold.

[0135] Stage **720** and/or step **740** may be executed by the oxygen saturation sensor, by a computerized device that includes the oxygen saturation sensor, or by a computerized device that does not include the oxygen saturation sensor or may be executed in part by the oxygen saturation sensor and in part by the computerized device that does not include the oxygen saturation sensor.

[0136] If it is determined that the current portion of the sternum of the user is the sternal angle of the user than stage **740** may be followed by stage **750** of generating a positioning success indication.

[0137] The positioning success indication may be sent to the user, to a user device or to a third party. The aim of the positioning success indication is to notify the user or a third party that the device should be positioned so that the oxygen saturation sensor illuminates the sternal angle of the user. The positioning may include peeling a protective element and detachably connecting the device to the user.

[0138] If it is determined that the current portion of the sternum of the user is not the sternal angle of the user than stage **740** may be followed by stage **760** of selecting a new current portion of the sternum to be illuminated, instructing the user to move the device so that the oxygen saturation sensor illuminates the new current portion and repeating stages **712**, **714**, **716**, **720** and **740** for the new current portion.

[0139] It is also noted that if it is determined that the current portion of the sternum of the user is not the sternal angle of the user then stage **740** may be followed by stage **770** of declaring a positioning failure and ending the positioning process.

[0140] According to another embodiment of the invention stages **712**, **714**, **716**, **720**, **740** and **760** are repeated multiple times to find one or more current portions of the sternum that are valid candidates of a sternal angle—and selecting the best current portions of the one or more valid candidates—for example selecting the valid candidate with the highest qual-

ity. Each valid candidate may have a quality that exceeds a valid candidate quality threshold. The valid candidate quality threshold may not exceed the predetermined quality threshold.

[0141] FIG. **12** illustrates a method **800** according to an embodiment of the invention.

[0142] Method **800** is executed by a computerized device.

[0143] Method **800** starts by stage **810** of (a) receiving, by a computerized device, first detection signals generated as a result of an illumination, by infrared pulses, of a first portion of a sternum of a user; and (b) receiving, by the computerized device, second detection signals generated as a result of an illumination, by visible light pulses, of the first portion of the sternum of the user;

[0144] Stage **810** is followed by stage **720** of processing the first and second detection signals to evaluate a quality of the first and second detection signals.

[0145] Stage **720** may be followed by stage **740** of determining whether the current portion of the sternum of the user is the sternal angle of the user. The determining may be responsive to the quality of the first and second detection signals. Stage **740** may be followed by stage **750**, **760** or **770**.

[0146] Stage **810** may be followed by stage **850** of calculating an oxygen saturation of the user, based upon the first and second detection signals.

[0147] Differences between amplitudes of infrared signals and visible light signals emitted from the user are indicative of the oxygen saturation of the user. Especially—the ratio between the amplitudes of infrared signals and the visible light signals detected by the oxygen saturation sensor is indicative of the oxidation level of the blood of the user.

[0148] FIGS. **13-15** illustrate stage **720** of processing the first and second detection signals to evaluate a quality of the first and second detection signals according to an embodiment of the invention.

[0149] Stage **720** may include at least one of the following stages. For simplicity of explanation it is assumed that stage **720** includes all of the following stages, although stage **720** may include only one or some of the following stages.

[0150] Stage **720** may start by stages **721** and **721'**.

[0151] Stage **721** may include filtering the first detection signals to provide first filtered detection signals. The filtering may include high-pass filtering and low-pass filtering or applying bandpass filtering. The low-pass filtering may be bilateral filtering, any other edge preserving filtering or any other filtering.

[0152] Stage **721** may be followed by stage **722** of detecting first cardiac cycle waveforms in the first filtered detection signals.

[0153] Stage **722** may be followed by stage **723** of converting the first cardiac cycle waveforms to first duration-normalized cardiac cycle waveforms that have a same duration.

[0154] Stage **723** may be followed by stage **724** of calculating, for each first duration-normalized cardiac cycle waveform, a similarity score that is indicative of a similarity between the first duration-normalized cardiac cycle waveform and other first duration-normalized cardiac cycle waveforms.

[0155] Stage **724** may include stage **725** of calculating, for each first duration normalized cardiac cycle waveform, a plurality of Pearson correlation coefficients between the first duration-normalized cardiac cycle waveform and a plurality of other first duration-normalized cardiac cycle waveforms. The plurality of other first duration-normalized cardiac cycle waveforms may include all of the first duration-normalized cardiac cycle waveforms that differ from the first duration normalized cardiac cycle waveform or only some of these other first duration-normalized cardiac cycle waveforms.

[0156] For example, a Pearson correlation coefficient (Rij) between an i'th first duration-normalized cardiac cycle waveform (wi) and a j'th first duration-normalized cardiac cycle waveform (wj) may be expressed by the following equation:

$$Ri,j=\text{covariance}(wi, wj)/\text{std}(wi)*\text{std}(wj).$$

[0157] Wherein "std" stands for a standard deviation.

[0158] Stage **725** may be followed by stage **726** (may also be included in stage **724**) of applying a first mathematical function on the plurality of Pearson correlation coefficients to provide the similarity score. The applying may include, for example, summing the plurality of Pearson correlation coefficients to provide the similarity score.

[0159] Stage **724** may be followed by stage **728** of ignoring at least one first duration-normalized cardiac cycle waveform based upon similarity scores of the first duration-normalized cardiac cycle waveforms. Stage **728** provides relevant first duration-normalized cardiac cycle waveforms (those first duration-normalized cardiac cycle waveform that were not ignored of).

[0160] Stage **728** may include, for example, ignoring one or more first duration-normalized cardiac cycle waveform that have a similarity score that is below a similarity score threshold, ignoring a preset number of first duration-normalized cardiac cycle waveforms that have the lowest similarity scores, and the like.

[0161] Stage **728** may be followed by stage **729** of calculating a first waveform template in response to the relevant first duration-normalized cardiac cycle waveforms. This stage may include applying a second mathematical function on the relevant first duration-normalized cardiac cycle waveforms. The second mathematical function may be any mathematical function. If may be, for example. A weighted averaging function, an averaging function and the like.

[0162] Stage **729** may be followed by stage **730** of determining the quality of the first detection signals.

[0163] Stage **730** may include stage **731** of calculating qualities of one or more first cardiac cycle waveforms. These one or more first cardiac cycle waveforms may include all the first cardiac cycle waveforms detected during stage **722** or only some of the first cardiac cycle waveforms detected during stage **722**. For example—the one or more first cardiac cycle waveforms may correspond to the relevant first duration-normalized cardiac cycle waveforms.

[0164] Stage **731** may include at least one out of stages **732**, **733**, **734**, **735** and **736**. For example, stage **731** may include stages **734**, **735** and **736**.

[0165] Stage **732** may include comparing the first cardiac cycle waveforms to the first waveform template.

[0166] Stage **733** may include calculating correlations between shapes of the at least some of the first cardiac cycle waveforms and a shape of the first waveform template.

[0167] Stage **734** may include converting at least some of the first cardiac cycle waveforms to first duration-normalized and peak-normalized cardiac cycle waveforms and calculating relationships between shapes of the first duration-normalized and peak-normalized cardiac cycle waveforms and a shape of the first waveform template. The first duration-nor-

malized and peak-normalized cardiac cycle waveforms are a same duration and a same peak value as the first waveform template.

[0168] Stage **735** may include calculating relationships between peaks of the at least some of the first cardiac cycle waveforms and a peak of the first waveform template.

[0169] Stage **736** may include calculating relationships between durations of the at least some of the first cardiac cycle waveforms and a duration of the first waveform template quality of the first detection signals.

[0170] Stage **730** may include stage **737** of calculating the quality of the first detection signals in response to the qualities (calculated during stage **731**) of one or more first cardiac cycle waveforms.

[0171] Stage **721'** may include filtering the second detection signals to provide second filtered detection signals. The filtering may include high-pass filtering and low-pass filtering or applying bandpass filtering. The low-pass filtering may be bilateral filtering, any other edge preserving filtering or any other filtering.

[0172] Stage **721'** may be followed by stage **722'** of detecting second cardiac cycle waveforms in the second filtered detection signals.

[0173] Stage **722'** may be followed by stage **723'** of converting the second cardiac cycle waveforms to second duration-normalized cardiac cycle waveforms that have a same duration.

[0174] Stage **723'** may be followed by stage **724'** of calculating, for each second duration-normalized cardiac cycle waveform, a similarity score that is indicative of a similarity between the second duration-normalized cardiac cycle waveform and other second duration-normalized cardiac cycle waveforms.

[0175] Stage **724'** may include stage **725'** of calculating, for each second duration normalized cardiac cycle waveform, a plurality of Pearson correlation coefficients between the second duration-normalized cardiac cycle waveform and a plurality of other second duration-normalized cardiac cycle waveforms. The plurality of other second duration-normalized cardiac cycle waveforms may include all of the second duration-normalized cardiac cycle waveforms that differ from the second duration normalized cardiac cycle waveform or only some of these other second duration-normalized cardiac cycle waveforms.

[0176] Stage **725'** may be followed by stage **726'** (may also be included in stage **724'**) of applying a first mathematical function on the plurality of Pearson correlation coefficients to provide the similarity score. The applying may include, for example, summing the plurality of Pearson correlation coefficients to provide the similarity score.

[0177] Stage **724'** may be followed by stage **728'** of ignoring at least one second duration-normalized cardiac cycle waveform based upon similarity scores of the second duration-normalized cardiac cycle waveforms. Stage **728'** provides relevant second duration-normalized cardiac cycle waveforms (those second duration-normalized cardiac cycle waveform that were not ignored of).

[0178] Stage **728'** may include, for example, ignoring one or more second duration-normalized cardiac cycle waveform that have a similarity score that is below a similarity score threshold, ignoring a preset number of second duration-normalized cardiac cycle waveforms that have the lowest similarity scores, and the like.

[0179] Stage **728'** may be followed by stage **729'** of calculating a second waveform template in response to the relevant second duration-normalized cardiac cycle waveforms. This stage may include applying a second mathematical function on the relevant second duration-normalized cardiac cycle waveforms. The second mathematical function may be any mathematical function. If may be, for example. A weighted averaging function, an averaging function and the like.

[0180] Stage **729'** may be followed by stage **730'** of determining the quality of the second detection signals.

[0181] Stage **730'** may include stage **731'** of calculating qualities of one or more second cardiac cycle waveforms. These one or more second cardiac cycle waveforms may include all the second cardiac cycle waveforms detected during stage **722'** or only some of the second cardiac cycle waveforms detected during stage **722'**. For example—the one or more second cardiac cycle waveforms may correspond to the relevant second duration-normalized cardiac cycle waveforms.

[0182] Stage **731'** may include at least one out of stages **732'**, **733'**, **734'**, **735'** and **736'**. For example, stage **731'** may include stages **734**, **735'** and **736'**.

[0183] Stage **732'** may include comparing the second cardiac cycle waveforms to the second waveform template.

[0184] Stage **733'** may include calculating correlations between shapes of the at least some of the second cardiac cycle waveforms and a shape of the second waveform template.

[0185] Stage **734'** may include converting at least some of the second cardiac cycle waveforms to second duration-normalized and peak-normalized cardiac cycle waveforms and calculating relationships between shapes of the second duration-normalized and peak-normalized cardiac cycle waveforms and a shape of the second waveform template. The second duration-normalized and peak-normalized cardiac cycle waveforms are a same duration and a same peak value as the second waveform template.

[0186] Stage **735'** may include calculating relationships between peaks of the at least some of the second cardiac cycle waveforms and a peak of the second waveform template.

[0187] Stage **736'** may include calculating relationships between durations of the at least some of the second cardiac cycle waveforms and a duration of the second waveform template quality of the second detection signals.

[0188] Stage **730'** may include stage **737'** of calculating the quality of the second detection signals in response to the qualities (calculated during stage **731'**) of one or more second cardiac cycle waveforms.

[0189] Stages **730** and **730'** may be followed by stage **739** of calculating a quality of the first and second detection signals in response to quality of the first detection signals and to the quality of the second detection signals. Stage **739** may include summing, weighted summing, averaging or applying any function on the quality of the first detection signals and the quality of the second detection signals.

[0190] FIG. **16** illustrates first detection signals **882** and first filtered detection signals according to an embodiment of the invention.

[0191] Graph **880** of FIG. **16** illustrates first detection signals **882**.

[0192] Graph **890** of FIG. **16** illustrates first filtered detection signals **892** and **894**. First filtered detection signals **892** were filtered only by a high-pass filter (a Butterworth high-

pass filter) while first filtered detection signals **894** were filtered using both a high-pass filter and a low-pass (Bilateral) filter.

[0193] The x-axis of graphs **880** and **890** represent time while the y-axis of graphs **880** and **890** represent intensity.

[0194] FIG. **17** illustrates first detection signals **912**, first filtered detection signals **922**, first cardiac cycle waveforms **922**(**1**)-**922**(N), first waveform template **950** and first duration-normalized cardiac cycle waveforms **960** of a fixed duration **970**, and first cardiac cycle waveform quality scores **932** according to an embodiment of the invention.

[0195] Graph **910** of FIG. **17** illustrates first detection signals **912**.

[0196] Graph **920** of FIG. **17** illustrates first filtered detection signals **922** that include first cardiac cycle waveforms **922**(**1**)-**922**(N).

[0197] Graph **930** of FIG. **17** illustrates first cardiac cycle waveform quality scores **932** of first cardiac cycle waveforms **922**(**1**)-**922**(N).

[0198] Graph **940** of FIG. **17** illustrates first waveform template **950**, first duration-normalized cardiac cycle waveforms **960** of a fixed duration **970**. The first cardiac cycle waveforms were converted to become the first duration-normalized cardiac cycle waveforms **960**.

[0199] The x-axis of graphs **910**, **920**, **930** and **940** represent time while the y-axis of graphs **910**, **920** and **940** represent intensity.

[0200] FIG. **18** illustrates method **1000** according to an embodiment of the invention.

[0201] Method **1000** may start by stage **1010** of receiving, by a computerized device, first and second detection signals and electrocardiograph signals. The first detection signals result from an illumination, by an oxygen saturation sensor included in a device that is removably attached to a user, of a sternal angle of a user by infrared pulses. The second detection signals result from an illumination, by the oxygen saturation sensor, of the sternal angle of a user by visible light pulses. The electrocardiograph signals are detected by an electrocardiography sensor that is included in the device.

[0202] Stage **1010** may be followed by stages **1020**, **1030**, **1040**, **1050** and **1060**.

[0203] Stage **1020** may include generating a first waveform template that is responsive to the first detection signals.

[0204] Stage **1020** may include at least one of stages **721**-**726**, **728** and **729** of FIG. **13**.

[0205] Stage **1030** may include generating a second waveform template that is responsive to the second detection signals.

[0206] Stage **1030** may include at least one of stages **721'**-**726'**, **728'** and **729'** of FIG. **14**.

[0207] Stage **1040** may include calculating an indication of the oxygen saturation characteristic of the user in response to the first and second detection signals.

[0208] Stage **1050** may include detecting cardiac cycle durations that are based upon the first and second detection signals.

[0209] Stage **1050** may include stages **721**, **722**, **721'** and **722'** of FIGS. **13** and **14**.

[0210] Stage **1060** may include detecting electrocardiography based cardiac cycle durations.

[0211] Stages **1020**, **1030**, **1040**, **1050** and **1060** may be followed by stage **1070** of evaluating a quality of the indication of the oxygen saturation characteristic of the user in response to the first waveform template, the second waveform template, the cardiac cycle's durations and the electrocardiography based cardiac cycle durations.

[0212] Stage **1070** may include at least one of stages **730**, **731**, **732**, **733**, **734**, **735**, **736**, **737**, **730'**, **731'**, **732'**, **733'**, **734'**, **735'**, **736'**, **737'** and **739'**.

[0213] FIG. **19** illustrates method **1000'** according to an embodiment of the invention.

[0214] Method **1000'** may start by stages **1002** and **1005**.

[0215] Stage **1002** may include illuminating, by the oxygen saturation sensor, a sternal angle of the user by infrared pulses and by visible light pulses.

[0216] Stage **1002** may be followed by stage **1003** of sensing, by the oxygen saturation sensor infrared signals and visible light signals emitted from the sternal angle due to the illumination.

[0217] Stage **1003** may be followed by stage **1004** of generating by the oxygen saturation sensor first detection signals in response to infrared signals and generating by the oxygen saturation sensor second detection signals in response to visible light signals.

[0218] Stage **1005** may include sensing, by an electrocardiography sensor, electrocardiography signals.

[0219] Stage **1005** may be followed by stage **1006** of generating, by the electrocardiography sensor, electrocardiograph detection signals.

[0220] Stages **1004** and **1002** may be executed in parallel to each other, in a partially overlapping manner or in a non-overlapping manner. The method can benefit from sensing the same cardiac cycles by the oxygen saturation sensor and the electrocardiography sensor.

[0221] Stage **1004** and stage **1006** may be followed by stages **1020**, **1030**, **1040**, **1050** and **1060**.

[0222] Stage **1020** may include generating a first waveform template that is responsive to the first detection signals.

[0223] Stage **1030** may include generating a second waveform template that is responsive to the second detection signals.

[0224] Stage **1040** may include calculating an indication of the oxygen saturation characteristic of the user in response to the first and second detection signals.

[0225] Stage **1050** may include detecting cardiac cycle durations that are based upon the first and second detection signals.

[0226] Stage **1060** may include detecting electrocardiography based cardiac cycle durations.

[0227] Stages **1020**, **1030**, **1040**, **1050** and **1060** may be followed by stage **1070** of evaluating a quality of the indication of the oxygen saturation characteristic of the user in response to the first waveform template, the second waveform template, the cardiac cycle's durations and the electrocardiography based cardiac cycle durations.

[0228] FIG. **20** illustrates stage **1070** according to an embodiment of the invention.

[0229] Stage **1070** may start by stages **1071** and **1073**.

[0230] Stage **1071** may include calculating a quality of the first detection signals in response to the electrocardiography signals.

[0231] Stage **1071** may include stage **1072** of comparing the first cardiac cycle waveforms to the first waveform template and to electrocardiography based cardiac cycle durations.

[0232] Stage **1073** may include calculating a quality of the second detection signals in response to the electrocardiography signals.

[0233] Stage **1073** may include stage **1074** may include comparing the second cardiac cycle waveforms to the second waveform template and to electrocardiography based cardiac cycle durations.

[0234] Stage **1071** and **1073** may be followed by stage **1075** of determining the quality of the indication of the oxygen saturation. This may include applying any function on the quality of the first detection signals and (b) the quality of the second detection signals.

[0235] FIG. **21** illustrates a stage **1071** for calculating a quality of the first detection signals in response to the electrocardiography signals according to an embodiment of the invention.

[0236] Stage **721** may include filtering the first detection signals to provide first filtered detection signals. The filtering may include high-pass filtering and low-pass filtering or applying bandpass filtering. The low-pass filtering may be bilateral filtering, any other edge preserving filtering or any other filtering.

[0237] Stage **721** may be followed by stage **722** of detecting first cardiac cycle waveforms in the first filtered detection signals.

[0238] Stage **722** may be followed by stage **723** of converting the first cardiac cycle waveforms to first duration-normalized cardiac cycle waveforms that have a same duration.

[0239] Stage **723** may be followed by one or more branches. A first branch (also shown in FIG. **13**) includes stages **724** and **728** and a second branch includes stage **1024**. Both branches are followed by stage **729**.

[0240] Stage **1024** may include ignoring at least one first duration-normalized cardiac cycle waveform based upon relationships between first cardiac cycle durations and electrocardiography based cardiac cycle durations.

[0241] Stage **724** may include calculating, for each first duration-normalized cardiac cycle waveform, a similarity score that is indicative of a similarity between the first duration-normalized cardiac cycle waveform and other first duration-normalized cardiac cycle waveforms.

[0242] Stage **724** may include stages (not shown) such as stages **725** and **726** of FIG. **13**.

[0243] Stage **724** may be followed by stage **728** of ignoring at least one first duration-normalized cardiac cycle waveform based upon similarity scores of the first duration-normalized cardiac cycle waveforms. Stage **728** provides relevant first duration-normalized cardiac cycle waveforms (those first duration-normalized cardiac cycle waveform that were not ignored of).

[0244] Stage **728** may include, for example, ignoring one or more first duration-normalized cardiac cycle waveform that have a similarity score that is below a similarity score threshold, ignoring a preset number of first duration-normalized cardiac cycle waveforms that have the lowest similarity scores, and the like.

[0245] Stage **729** may include calculating a first waveform template in response to the relevant first duration-normalized cardiac cycle waveforms. This stage may include applying a second mathematical function on the relevant first duration-normalized cardiac cycle waveforms. The second mathematical function may be any mathematical function. If may be, for example. A weighted averaging function, an averaging function and the like.

[0246] Stage **729** may be followed by stage **730** of determining the quality of the first detection signals.

[0247] Stage **730** may include stage **731** of calculating qualities of one or more first cardiac cycle waveforms. These one or more first cardiac cycle waveforms may include all the first cardiac cycle waveforms detected during stage **722** or only some of the first cardiac cycle waveforms detected during stage **722**. For example—the one or more first cardiac cycle waveforms may correspond to the relevant first duration-normalized cardiac cycle waveforms.

[0248] Stage **731** may include at least one out of stages (not shown in FIG. **21** but illustrated in FIGS. **13**) **732**, **733**, **734**, **735** and **736**.

[0249] Stage **730** may include stage **737** of calculating the quality of the first detection signals in response to the qualities (calculated during stage **731**) of one or more first cardiac cycle waveforms.

[0250] While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will now occur to those of ordinary skill in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

1. A method, comprising:

receiving, by a computerized device, first detection signals generated as a result of an illumination, by infrared pulses, of a current portion of a sternum of a user;

receiving, by the computerized device, second detection signals generated as a result of an illumination, by visible light pulses, of the current portion of the sternum of the user; and

evaluating, by the computerized device, a quality of the first and second detection signals; and determining whether the current portion of the sternum of the user is a sternal angle of the user; wherein the determining is responsive to the quality of the first and second detection signals.

2. The method according to claim **1**, further comprising illuminating the current portion of the sternum of the user by the infrared pulses and by the visible light pulses.

3. The method according to claim **2**, wherein the illuminating is executed by an oxygen saturation sensor that belongs to the computerized device.

4. The method according to claim **1** wherein the receiving of the first and second detection signals comprises receiving the first and second detection signals from a device that differs from the computerized device.

5. The method according to claim **1** comprising determining that the current portion of the sternum of the user is the sternal angle of the user when the quality of the first and second detection signals exceeds a predetermined quality threshold.

6. The method according to claim **1** wherein the evaluating of the quality of the first and second detection signals comprises generating a first waveform template in response to the first detection signals.

7. The method according to claim **1** wherein the evaluating of the quality of the first and second detection signals comprises detecting first cardiac cycle waveforms and generating a first waveform template in response to the first cardiac cycle waveforms.

8. The method according to claim **7** wherein the generating of the first waveform template is followed by determining relationships between one or more first cardiac cycle waveform and the first waveform template.

9. The method according to claim **7** wherein the generating of the first waveform template comprises: filtering the first detection signals to provide first filtered detection signals; and detecting first cardiac cycle waveforms in the first filtered detection signals.

10. The method according to claim **9** wherein the generating of the first waveform template comprises converting the first cardiac cycle waveforms to first duration-normalized cardiac cycle waveforms that have a same duration.

11. The method according to claim **10** wherein the converting is followed by calculating, for each first duration-normalized cardiac cycle waveform, a similarity score that is indicative of a similarity between the first duration-normalized cardiac cycle waveform and other first duration-normalized cardiac cycle waveforms.

12. The method according to claim **11** comprising calculating, for each first duration-normalized cardiac cycle waveform, the similarity score by calculating a plurality of Pearson correlation coefficients between the first duration-normalized cardiac cycle waveform and a plurality of other first duration-normalized cardiac cycle waveforms.

13. The method according to claim **12** wherein the calculating a plurality of Pearson correlation coefficients is followed by applying a first mathematical function on the plurality of Pearson correlation coefficients to provide the similarity score of the first duration-normalized cardiac cycle waveform.

14. The method according to claim **13** wherein the generating of the first waveform template further comprises ignoring at least one first duration-normalized cardiac cycle waveform based upon similarity scores of the first duration-normalized cardiac cycle waveforms to provide relevant first duration-normalized cardiac cycle waveforms.

15. The method according to claim **14** wherein the generating of the first waveform template is responsive to the relevant first duration-normalized cardiac cycle waveforms.

16. The method according to claim **7** comprising calculating qualities of at least some of the first cardiac cycle waveforms; and wherein the quality of the first and second detection signals is responsive to the qualities of at least some of the first cardiac cycle waveforms.

17. The method according to claim **16** wherein a calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms comprises comparing the first cardiac cycle waveform to the first waveform template.

18. The method according to claim **16** wherein a calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms comprises comparing calculating a correlation between a shape of the first cardiac cycle waveform and a shape of the first waveform template.

19. The method according to claim **16** wherein a calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms comprises converting the first cardiac cycle waveform to a first duration-normalized and peak-normalized cardiac cycle waveform and calculating a relationship between a shape of the first duration-normalized and peak-normalized cardiac cycle waveform and a shape of the first waveform template.

20. The method according to claim **16** wherein a calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms comprises comparing a relationship between a peak of the first cardiac cycle waveform and a peak of the first waveform template.

21. The method according to claim **16** wherein a calculating of a quality of a first cardiac cycle waveform out of the at least some of the first cardiac cycle waveforms comprises calculating a relationship between a peak of the first cardiac cycle waveform and a peak of the first waveform template.

22. A non-transitory computer readable medium that stores instructions that once executed by a computerized device cause the computerized device to execute the steps of:

receiving, by a computerized device, first detection signals generated as a result of an illumination, by infrared pulses, of a first portion of a sternum of a user;

receiving, by the computerized device, second detection signals generated as a result of an illumination, by visible light pulses, of the first portion of the sternum of the user;

evaluating, by the computerized device, a quality of the first and second detection signals; and

determining whether the first portion of the sternum of the user is a sternal angle of the user; wherein the determining is responsive to the quality of the first and second detection signals.

23. A device that is removably attached to a user and comprises an oxygen saturation sensor, wherein the oxygen saturation sensor is configured to: generate first detection signals responsive to an illumination, by infrared pulses, of a first portion of a sternum of a user; generate second detection signals responsive to an illumination, by visible light pulses, of the first portion of the sternum of a user; and evaluate a quality of the first and second detection signals; and determine whether the first portion of the sternum of the user is a sternal angle of the user, in response to the quality of the first and second detection signals.

* * * * *

专利名称(译)	根据氧饱和度测量定位医疗设备		
公开(公告)号	US20160192884A1	公开(公告)日	2016-07-07
申请号	US14/696513	申请日	2015-04-27
申请(专利权)人(译)	LIFEWATCH TECHNOLOGIES，LTD.		
当前申请(专利权)人(译)	LIFEWATCH TECHNOLOGIES，LTD.		
[标]发明人	LEVANT ANNA HALEVI ZOHAR BRACHIA AMIRIM MORDEHAY		
发明人	LEVANT, ANNA HALEVI, ZOHAR BRACHIA AMIRIM, MORDEHAY		
IPC分类号	A61B5/00 A61B5/1455 A61B5/0402		
CPC分类号	A61B5/6823 A61B5/0402 A61B5/7246 A61B5/725 A61B5/14551 A61B5/14552 A61B5/6833 A61B5/721		
外部链接	Espacenet USPTO		

摘要(译)

一种方法，包括由计算机化设备接收由于用户胸骨的当前部分的红外脉冲照射而产生的第一检测信号;由计算机化设备接收由于用户胸骨的当前部分的可见光脉冲照射而产生的第二检测信号;并通过计算机化设备评估第一和第二检测信号的质量;确定用户胸骨的当前部分是否是用户的胸骨角;其中，所述确定响应于第一和第二检测信号的质量。