US 20190125276A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2019/0125276 A1**

Seale et al. (43) **Pub. Date: May 2, 2019**

(54) **APPARATUS AND METHODS FOR DETECTING CARDIAC ARREST**

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(21) Appl. No.: **15/801,186**

(22) Filed: **Nov. 1, 2017**

Publication Classification

(51) **Int. Cl.**

A61B 5/00 (2006.01)

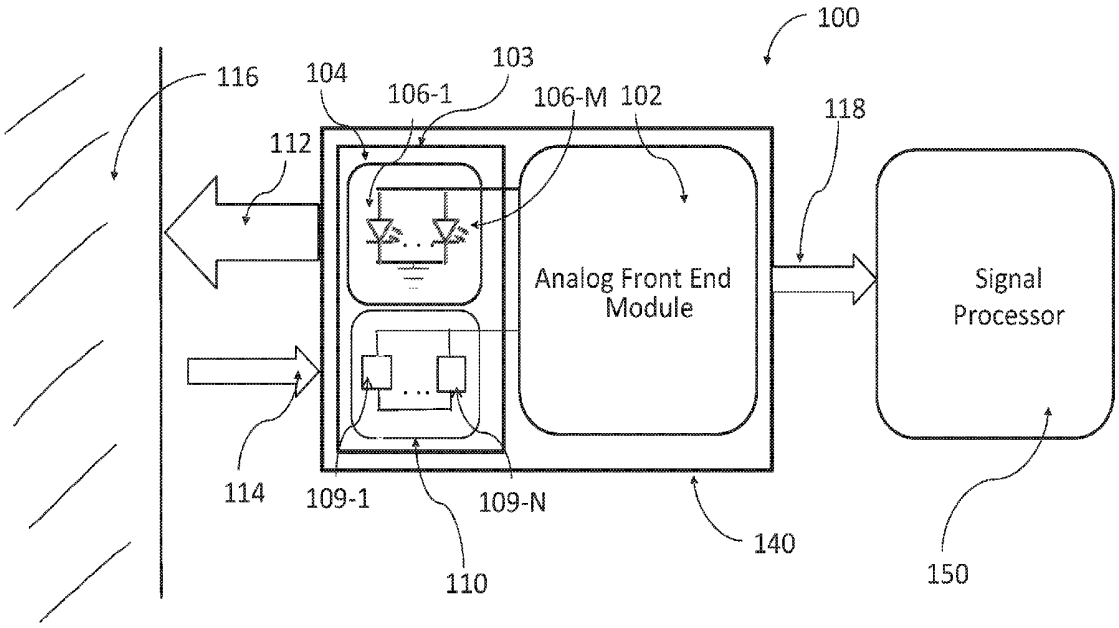
A61B 5/024 (2006.01)

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

CPC ***A61B 5/7282*** (2013.01); ***A61B 5/746*** (2013.01); *A61B 2560/0209* (2013.01); *A61B 2562/0219* (2013.01); ***A61B 5/02416*** (2013.01)

(57) **ABSTRACT**

Apparatus and methods for detecting onset of cardiac arrest utilizing a perfusion monitor. Detecting cardiac arrest comprises transmitting a signal toward a user to interact with the skin of the user, receiving a reflection of the signal, generating a photoplethysmogram, and processing the photoplethysmogram to detect whether the user is experiencing cardiac arrest.



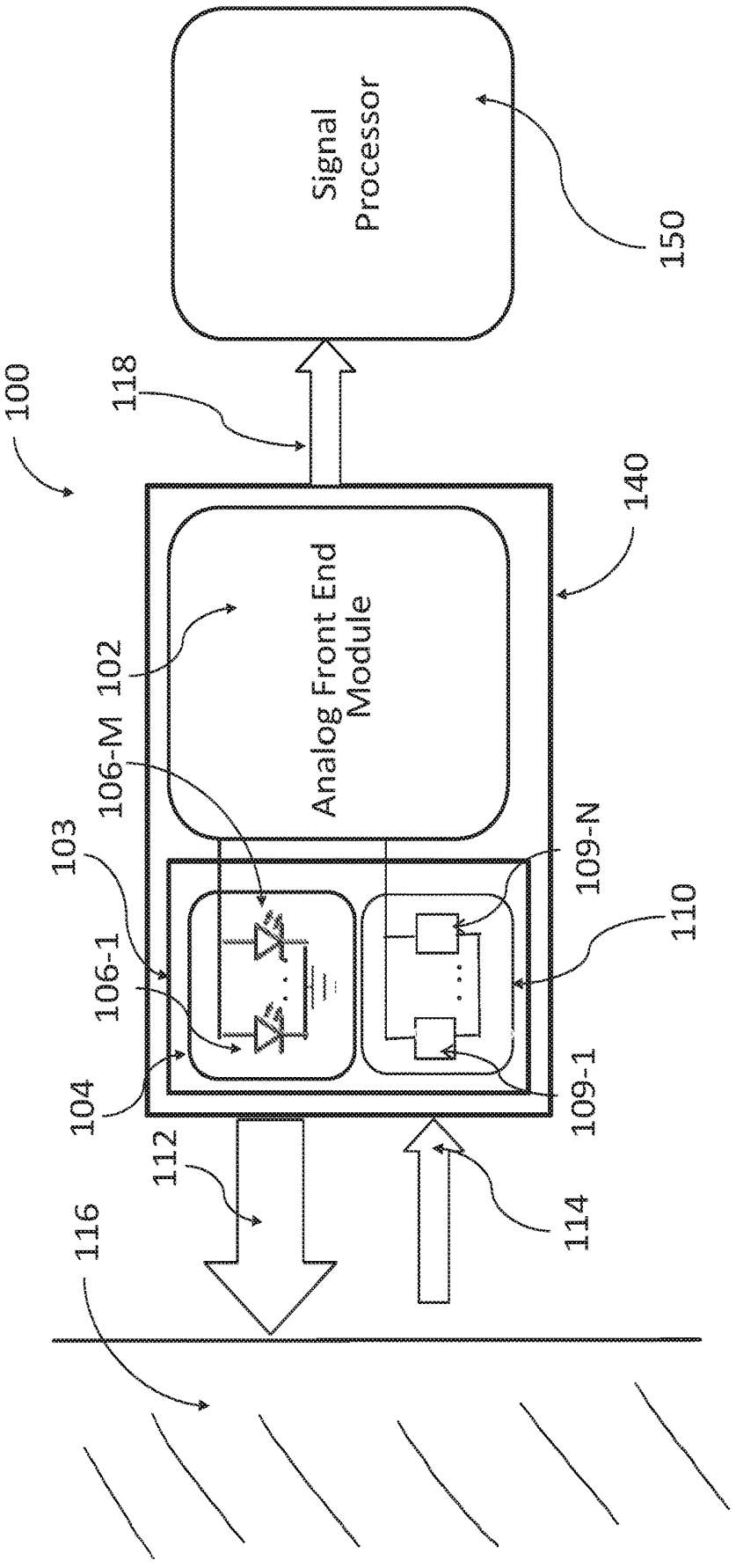

Signal Processor
150
100
118
140
Analog Front End Module
102
106-M
103
106-1
104
109-N
110
109-1
112
114
116

FIG. 1

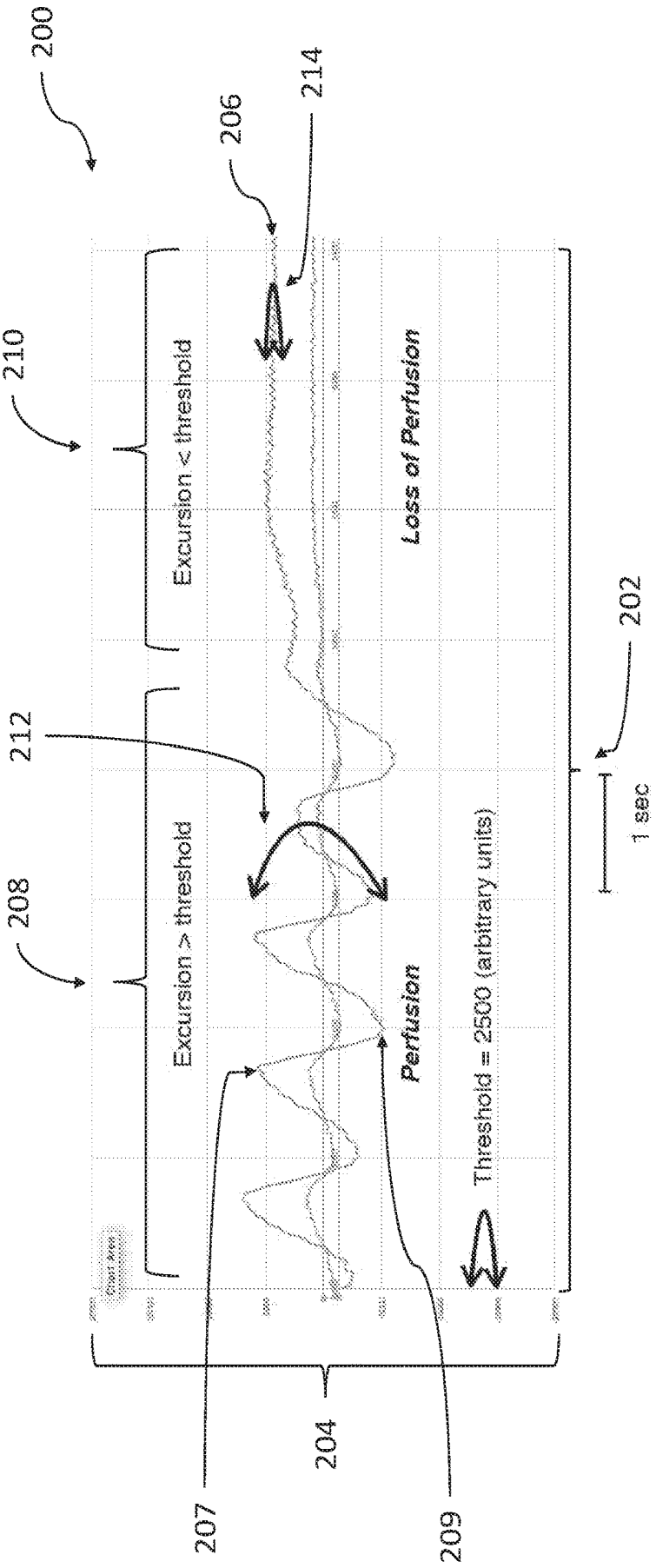

200
206
214
210
Excursion < threshold
Loss of Perfusion
212
202
208
Excursion > threshold
Perfusion
Threshold = 2500 (arbitrary units)
1 sec
204
207
209

FIG. 2

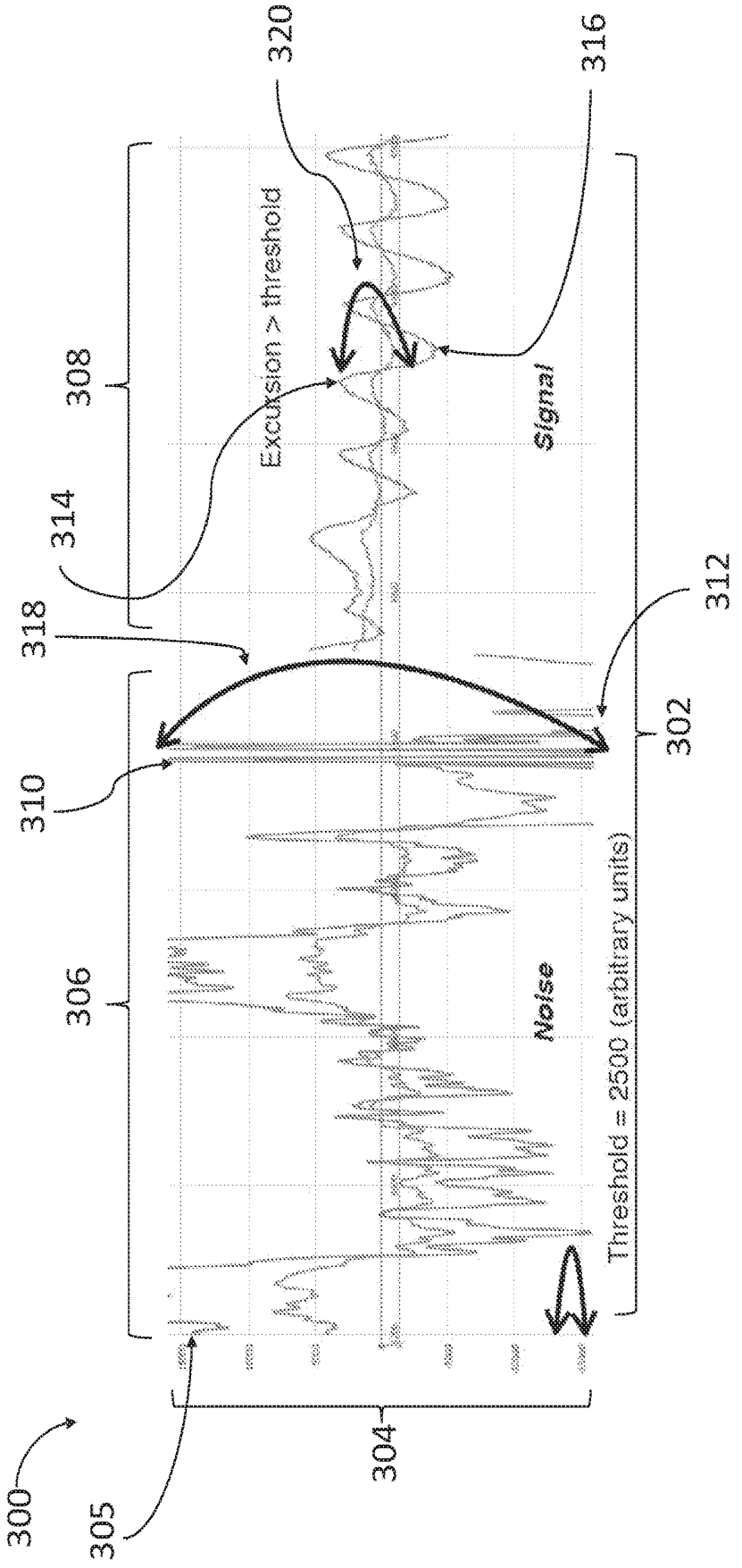

300
305
304
306
310
318
308
314
320
316
312
302
Excursion > threshold
Signal
Noise
Threshold = 2500 (arbitrary units)

FIG. 3

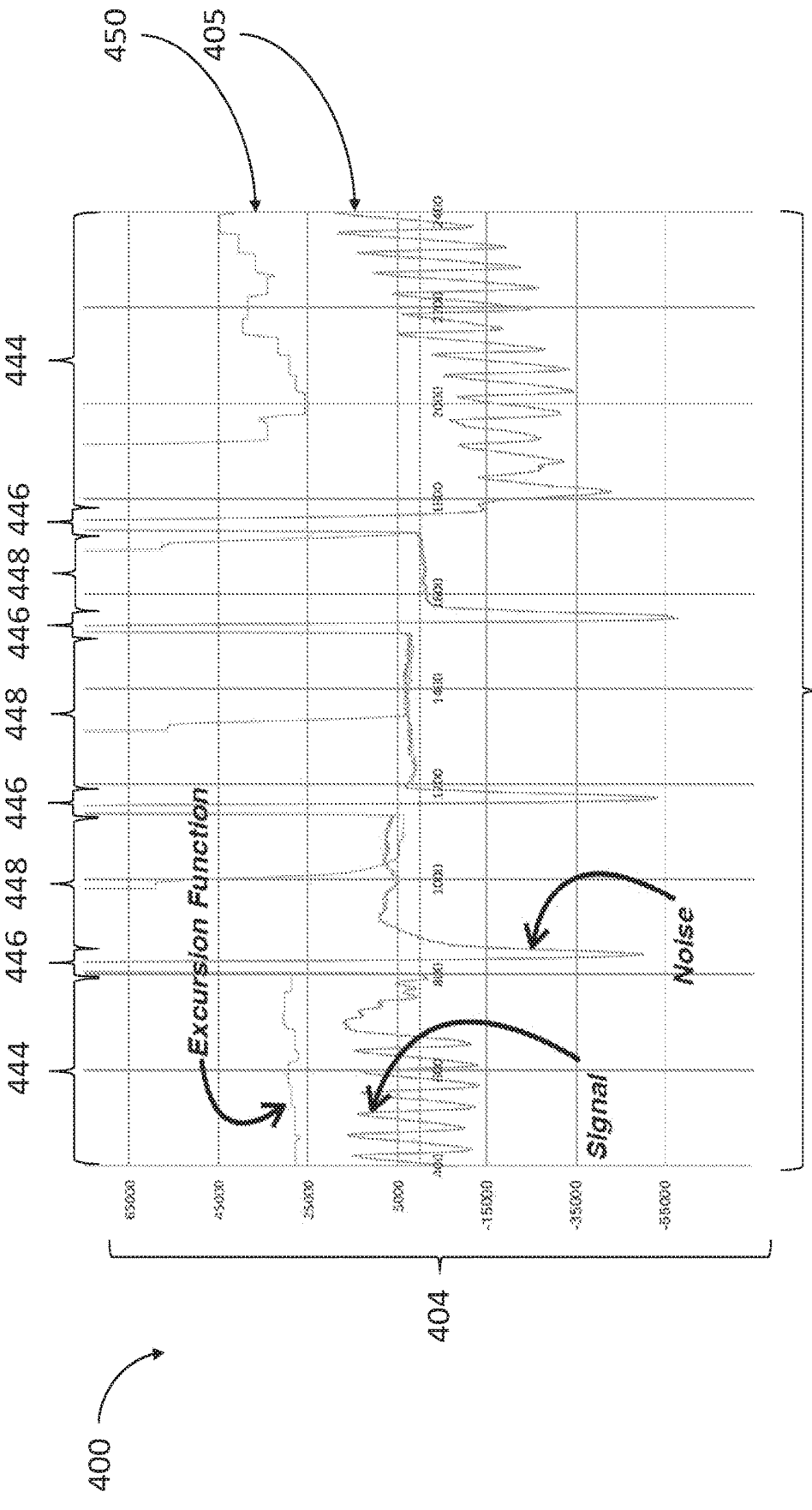

450
405
444
446
448
446
448
446
448
446
444
Excursion Function
Noise
Signal
402
404
400

FIG. 4A

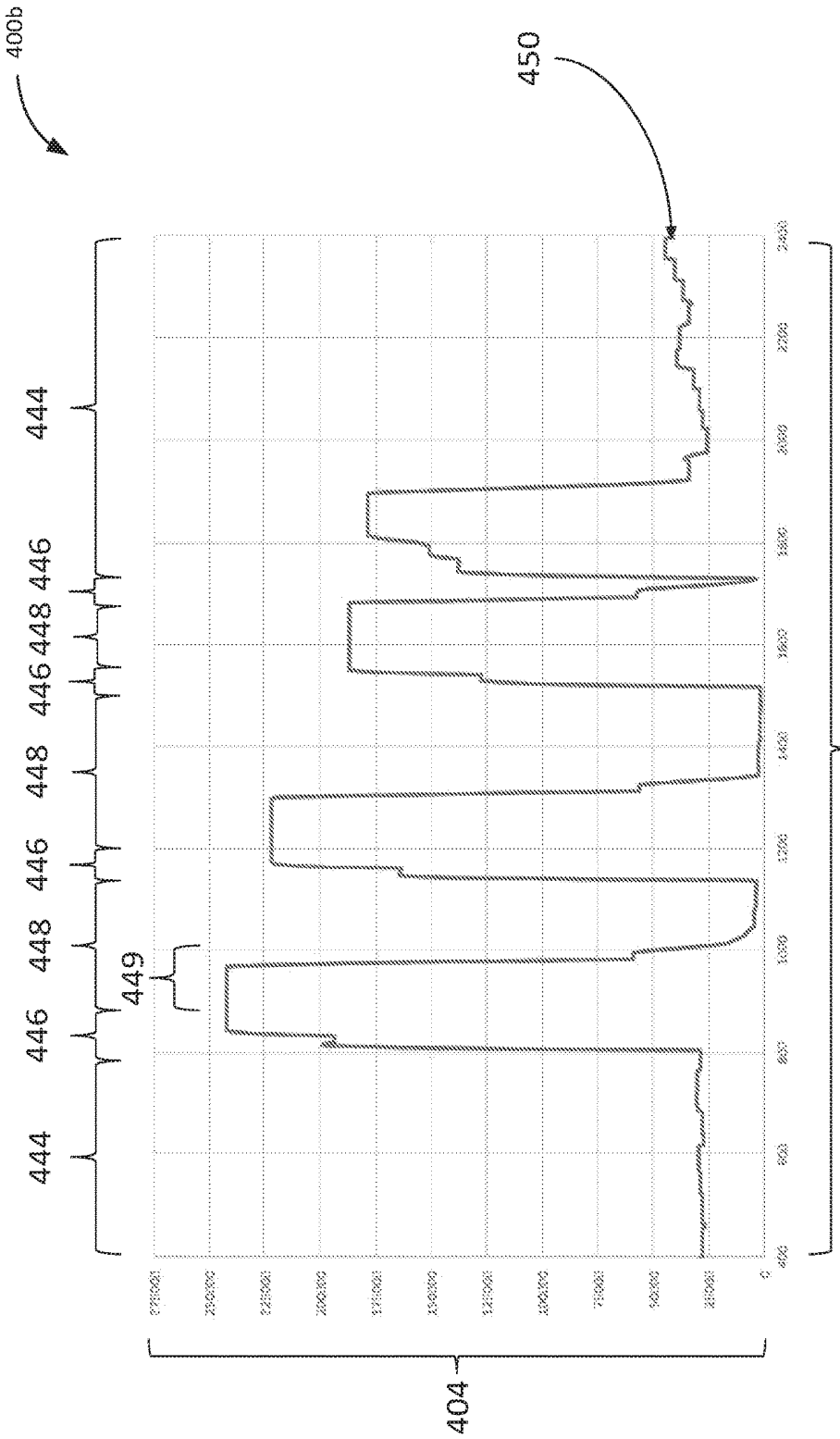


FIG. 4B

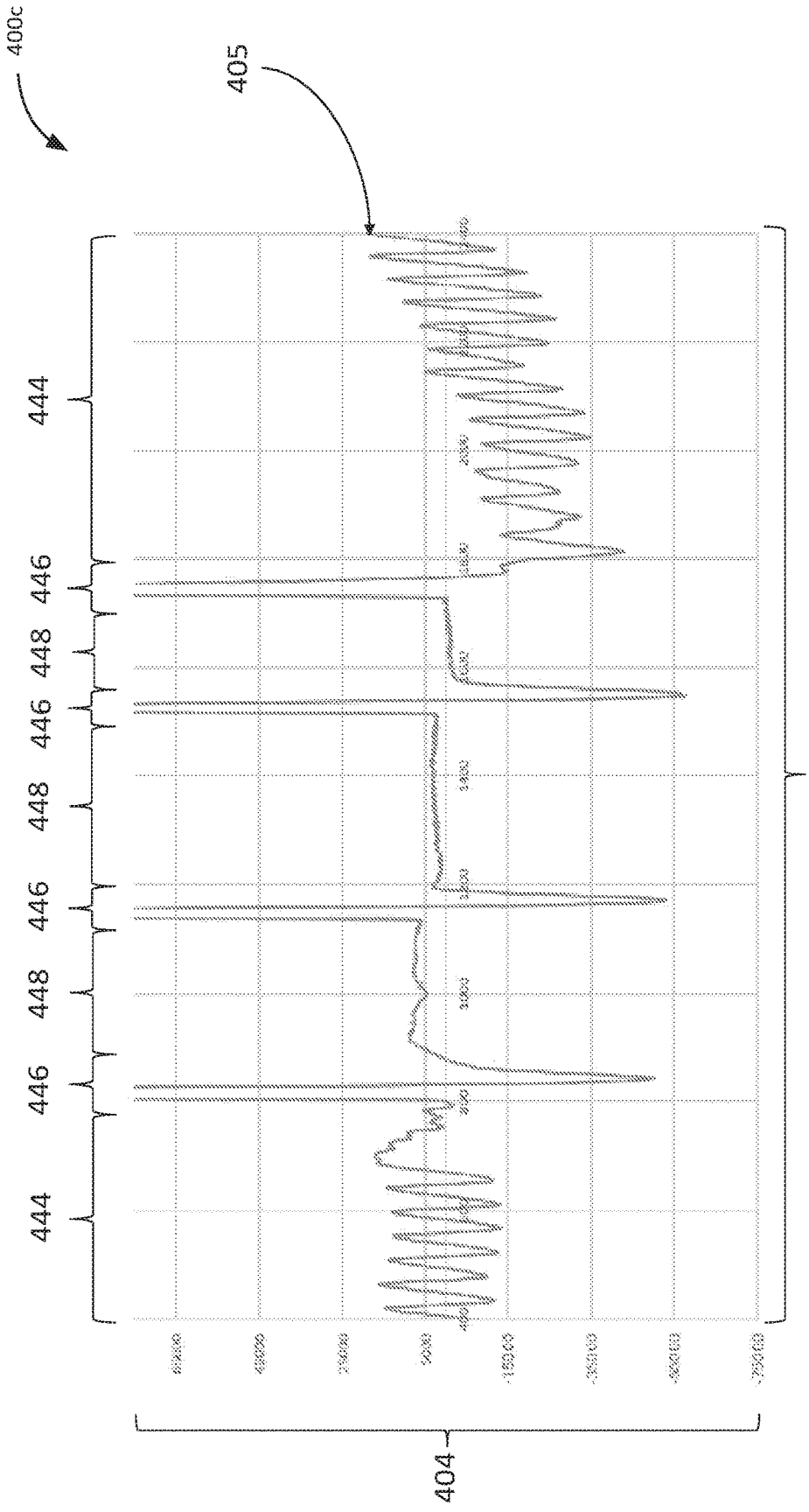


FIG. 4C

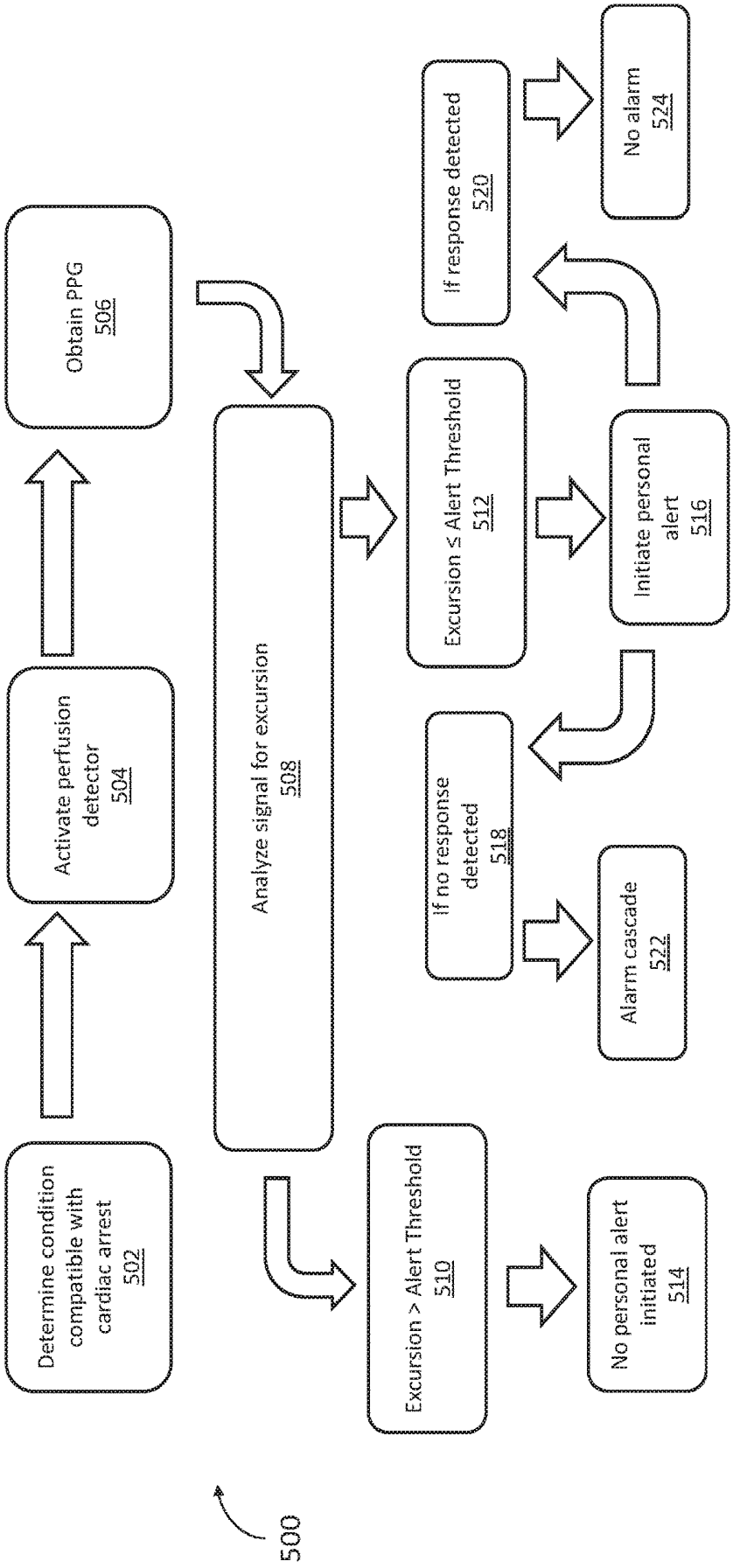

Determine condition compatible with cardiac arrest 502
Activate perfusion detector 504
Obtain PPG 506
Analyze signal for excursion 508
Excursion > Alert Threshold 510
No personal alert initiated 514
Excursion ≤ Alert Threshold 512
If no response detected 518
Alarm cascade 522
Initiate personal alert 516
If response detected 520
No alarm 524
500

FIG. 5

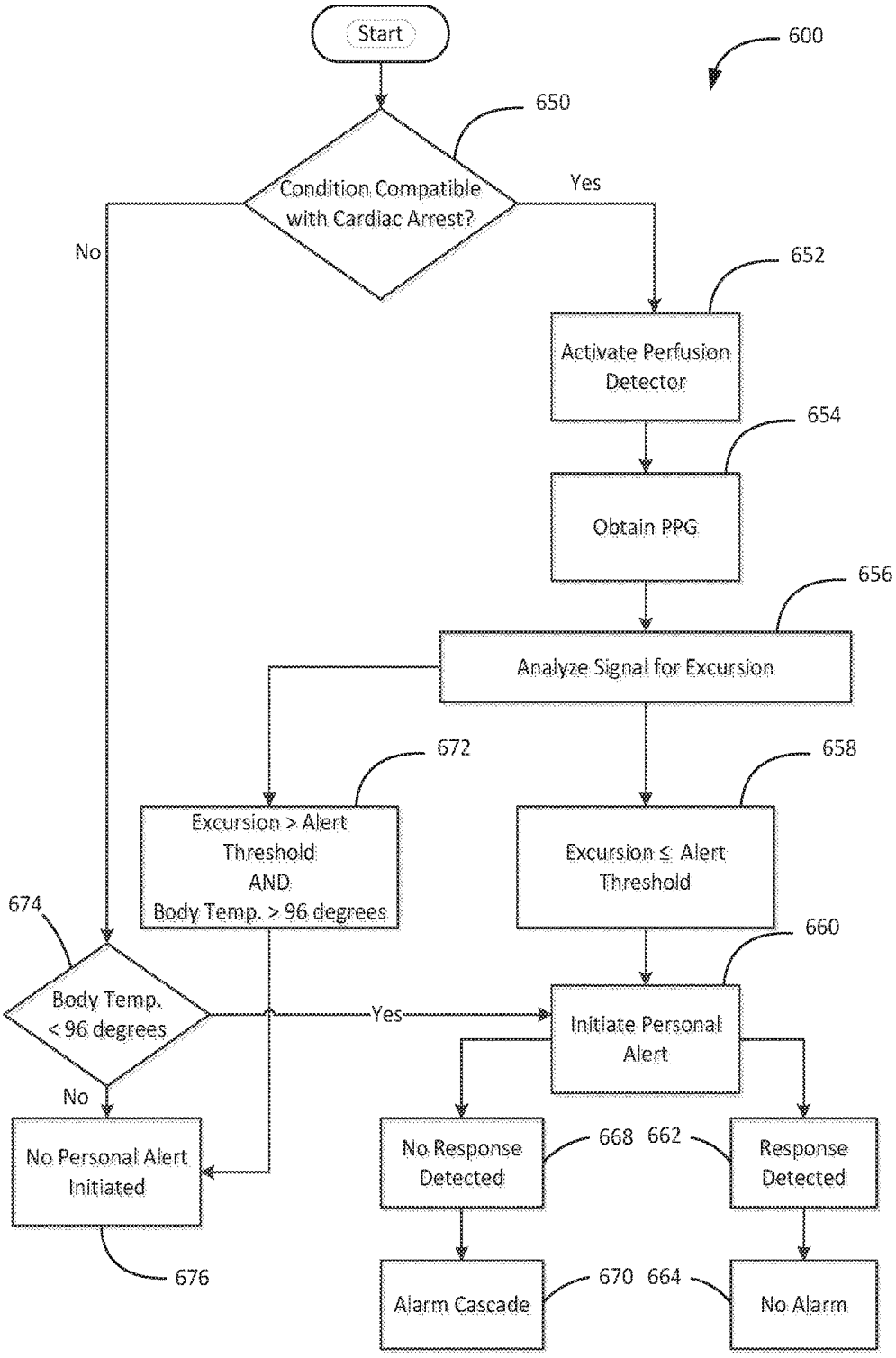

Start
600
650
Condition Compatible with Cardiac Arrest?
Yes
No
652
Activate Perfusion Detector
654
Obtain PPG
656
Analyze Signal for Excursion
672
658
Excursion > Alert Threshold AND Body Temp. > 96 degrees
Excursion ≤ Alert Threshold
674
660
Body Temp. < 96 degrees
Yes
Initiate Personal Alert
No
No Personal Alert Initiated
No Response Detected
668
662
Response Detected
676
Alarm Cascade
670
664
No Alarm

FIG. 6

APPARATUS AND METHODS FOR DETECTING CARDIAC ARREST

TECHNICAL FIELD

[0001] The present disclosure relates to detecting onset of a change in a health condition, and more particularly to apparatus and methods for detecting onset of cardiac arrest.

BACKGROUND

[0002] Cardiac arrest may occur in more than 300,000 Americans each year. If a witness is present when a person falls victim, the chances of survival are greatly increased. Unfortunately, nearly one half of cardiac arrest events occur with no witness present. In such cases as this, the chances of survival are minimal. A common occurrence is a victim who dies in his sleep, or one who collapses at home merely feet from a potential rescuer who is in another room, unaware of the collapse.

[0003] Although the survival rate for witnessed events is also relatively low, there are procedures available and tools that could be used by laypersons that could potentially increase the chances of survival for any individual case. For example, many victims may be promptly resuscitated with placement of an external defibrillator, or by application of proven medical strategies such as therapeutic hypothermia and immediate heart catheterization. In any case, the chances for survival depend heavily on the notification of potential rescuers.

[0004] High-risk groups also have a relatively small chance of falling victim to cardiac arrest, and individuals that do not belong to such groups may have an even smaller probability of falling victim to cardiac arrest than the high-risk groups. To detect the relatively few unfortunate victims, a substantial number of people may be monitored.

[0005] Monitoring many individuals on a continuous basis represents a challenging technological endeavor. Traditional monitoring techniques rely on electrocardiographic (ECG) recordings. These recordings require highly technical recorders and analysis techniques, are prone to noise that mimics life-threatening heart rhythm disturbance, and are inappropriate for continuous daily use. Additionally, even a theoretically perfect continuous ECG recording device would likely be prohibitively expensive for use on populations. Lastly, it would be unable to discern Pulseless Electrical Activity (PEA)—cardiac arrest that occurs with preservation of ECG signals.

[0006] Accordingly, other techniques, apparatus, and methods to monitor for cardiac arrest may be desirable.

SUMMARY

[0007] The present disclosure is directed to apparatus and methods for detecting onset of cardiac arrest. The disclosed embodiments detect perfusion, or a lack thereof, by obtaining photoplethysmogram data and interpreting the data.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Additional aspects and advantages will be apparent from the following detailed description of preferred embodiments, which proceeds with reference to the accompanying drawings, in which:

[0009] FIG. **1** is a block diagram of a perfusion detector for detecting cardiac arrest, according to one embodiment.

[0010] FIG. **2** is a graph illustrating an example of a photoplethysmogram captured by a photoplethysmographic measuring device, according to one embodiment.

[0011] FIG. **3** is a graph illustrating an example of a photoplethysmogram that includes a motion artifact as captured by a photoplethysmographic measuring device, according to one embodiment.

[0012] FIG. **4**A is a graph illustrating an example of a photoplethysmogram and a graph of an excursion function, according to one embodiment.

[0013] FIG. **4**B is a graph illustrating the excursion function of FIG. **4**A.

[0014] FIG. **4**C is a graph illustrating the photoplethysmogram of FIG. **4**A.

[0015] FIG. **5** illustrates a method for detecting cardiac arrest, according to one embodiment.

[0016] FIG. **6** illustrates a method for detecting cardiac arrest, according to one embodiment.

DETAILED DESCRIPTION

[0017] Cardiac arrest is a sudden stop in effective blood flow due to a failure of the heart to contract effectively. If not treated within minutes, death of the victim is highly likely. When no witness is present, timely medical treatment is unlikely, and the survival rate is low (e.g., essentially zero). If a witness is present when a person falls victim to cardiac arrest, the chances of survival are greatly increased, because of the possibility of timely medical treatment. Monitoring could potentially be adequate to replace a witness to an event of cardiac arrest and to improve chances of survival of the victim.

[0018] Monitoring many individuals on a continuous basis, however, represents a challenging technological endeavor. Traditional monitoring techniques rely on electrocardiographic (ECG) recordings. These recordings require highly technical recorders and analysis techniques, are prone to noise that mimics life-threatening heart rhythm disturbances, and are inappropriate for continuous daily use. Additionally, even a theoretically perfect continuous ECG recording device would likely be prohibitively expensive for use on populations.

[0019] Newer, commercially available, externally worn heart rate monitors rely on optically derived photoplethysmography. Photoplethysmography is an optical technique that involves obtaining and interpreting photoplethysmogram (PPG) data. The PPG data contains information from which a physiological signal may be derived. In some examples, PPG data can be graphed to show plotted values that correspond to the magnitude of an optical signal. Photoplethysmographic devices utilize signals (and thereby generate PPGs) that are susceptible to motion-artifact and, as such, heart rate measurements reported by these devices are notoriously inaccurate. Nevertheless, accurate detection of cardiac arrest can be accomplished by certain analyses of PPG data. Herein are disclosed apparatus and methods for analyzing PPG data to detect cardiac arrest. Convenient and relatively inexpensive monitoring of large numbers of persons can be accomplished on a continuous basis given that sensors can be configured to be worn in everyday devices such as a wristwatch.

[0020] The present disclosure will be better understood from the detailed description provided below and from the drawings of various embodiments, methods, and examples herein. These specifics, however, are provided for explana-

tory purposes that help the various embodiments of the disclosure to be better understood. The embodiments described herein should therefore not be limited by the described methods and examples.

[0021] FIG. **1** is a block diagram of a perfusion detector for detecting cardiac arrest, according to one embodiment. The perfusion detector **100** may include a photoplethysmographic measuring device **140** and a signal processor **150**. The perfusion detector **100** may optically obtain and/or generate PPG data (e.g., referred to herein as PPG) of a user (e.g., wearer) of the perfusion detector **100** to monitor for a loss of a pulsatile pattern. The PPG may be processed to detect potential cardiac arrest in the user.

[0022] The photoplethysmographic measuring device **140** may include a sensor module **103**, and an analog front-end module (AFE) **102**. The sensor module **103** may comprise a transmitter module **104** and a receiver module **110**. An output signal **118** may be sent from the photoplethysmographic measuring device **140** to the signal processor **150**, where the output signal **118** (e.g., including data of an optically obtained PPG) can be processed to determine whether perfusion (or lack thereof) may indicate potential cardiac arrest.

[0023] In various embodiments, the photoplethysmographic measuring device **140** may transmit an electromagnetic signal **112** from the transmitter module **104** by means of one or more of the individual signal sources **106-1** to **106**-M, with the intent that the electromagnetic signal **112** interacts with a user's skin **116**. As used herein, the individual signal sources **106-1** to **106**-M are referred to as individual signal sources **106**. The electromagnetic signal **112** may have sufficient strength to penetrate the user's skin **116** to a certain depth and interact with the user's blood cells. Some of the electromagnetic signal **112** may reflect at a rate proportional to an amount (e.g., volume) of blood cells flowing through a particular conduit(s) within the path of the electromagnetic signal **112**. The reflected input signal **114** can be received by one or more individual transducers (e.g., individual transducers **109-1** to **109**-N) of the receiver module **110**. The reflected input signal **114** is then converted into an electrical signal. As used herein, the individual transducers **109-1** to **109**-N can be referred to as individual transducers **109** and may denote one or more individual transducers. Stated otherwise, a PPG is at least partially generated from a reflection of the electromagnetic signal **112**.

[0024] In various embodiments, the electromagnetic signal **112** may be red, green, or blue light, or any combination thereof. The signal sources **106** may be light sources. In some embodiments, the electromagnetic signal **112** may have a fundamental frequency that is not within the spectrum of visible light. The fundamental frequency can be infrared or ultraviolet light, but is not limited to such. In other embodiments, the electromagnetic signal **112** may be replaced by or used in conjunction with an audio signal. In some embodiments, the individual signal sources **106** may be light sources. For example, the individual signal sources **106** may be light emitting diodes (LEDs) that emit green light, and the individual transducers **109** may be photodiodes.

[0025] In some embodiments, the transmitter module **104** may utilize multiple of the individual signal sources **106** to vary a resolution of the reading, as well as to vary power consumption. For example, the perfusion detector **100** may by default illuminate one of the individual signal sources **106** and if there appears to be a poor reading and/or low resolution of the reflected input signal **114**, other of the individual signal sources **106** may be illuminated before a presence or loss of perfusion is determined. If a sufficiently strong reading or high resolution of the reflected input signal **114** is achieved, the auxiliary signal sources may be turned off to return to the default power consumption.

[0026] In some embodiments, the transmitter module **104** may be an array of the individual signal sources **106**, where each of the individual signal sources **106** is positioned adjacent to the next. In other embodiments, the individual signal sources **106** in the transmitter module **104** may be angled and/or positioned advantageously to guide the reflected input signal **114** directly toward the receiver module **110**. In some embodiments, the material in which the individual signal sources **106** are embedded may be shaped and/or coated around the individual signal sources **106**. Shaping and/or coating material around the individual signal sources **106** may allow the electromagnetic signal **112** to be transmitted more effectively toward the target area. In some embodiments, the individual signal sources **106** may be light emitting diodes, organic light emitting diodes, light emitting electrochemical cells, and/or the like.

[0027] The receiver module **110** uses the individual transducers **109** to convert the reflected input signal **114** from the user's skin **116** into an electrical signal that can be amplified, filtered, and/or processed. Various embodiments may incorporate more than one of the individual transducer **109** in the receiver module to increase a resolution or reading of the reflected input signal **114** and/or to vary power consumption. For example, the perfusion detector **100** may, by default, provide power to and read from one individual transducer (e.g., the individual transducer **109-1**) in the receiver module **110**, and if there is a poor reading or low resolution of the reflected input signal **114**, other individual transducers (e.g., the individual transducer **109**-N) may be powered and read from before a loss or presence of perfusion is determined. If a sufficiently strong reading or high resolution of the reflected input signal **114** is achieved, the perfusion detector **100** may stop the flow of power to all but one or a few of the individual transducers **109** to return to the default power consumption.

[0028] In some embodiments, the transmitter module **104** includes multiple of the individual signal sources **106** as well as the individual transducers **109**. The perfusion detector **100** may then vary a resolution of the reading of the reflected input signal **114** to be more precise by varying the number of illuminated individual signal sources **106** in the transmitter module **104** and/or powered individual transducers **109** in the receiver module **110**. The best reading of the reflected input signal **114** may be achieved when the maximum number of individual signal sources **106** in the transmitter module **104** are illuminated and the maximum number of individual transducers **109** in the receiver module **110** are powered simultaneously. Power consumption may vary between the transmitter module **104** and receiver module **110**. In some examples, the receiver module **110** may be utilized more heavily than the transmitter module **104**. For example, depending on the devices chosen as the individual transducers **109** in the receiver module **110** and individual signal sources **106** in the transmitter module **104**, it may be more favorable to illuminate one of the individual signal

sources **106** in the transmitter module **104** and power several of the individual transducers **109** in the receiver module **110**.

[0029] In some embodiments, the individual transducers **109** in the receiver module **110** may be positioned such that they are adjacent to each other. In some embodiments, the individual transducers **109** in the receiver module **110** may be angled and/or positioned advantageously such that the reflected input signal **114** is received more directly. The transmitter module **104** and receiver module **110** may be integrated in such a way that the individual signal sources **106** are located on either side of one or more of the individual transducers **109**. In certain embodiments, the individual transducers **109** may be surrounded by the individual signal sources **106**. In some embodiments, the material in which the individual transducers **109** are embedded may be shaped and/or coated in such a way that the reflected input signal **114** may be more effectively directed towards the individual transducers **109**. In some embodiments, the individual transducers **109** may be coated with a substance that filters unwanted frequencies from the reflected input signal **114**. The individual transducers **109** may be photodiodes, phototransistors, photoresistors, and/or the like.

[0030] The AFE **102** may serve as an interface for the transmitter module **104** and the receiver module **110**. The AFE **102** may include the power supplies for the transmitter module **104** and the receiver module **110** respectively. If the perfusion detector **100** requires that the electromagnetic signal **112** be pulsed, the AFE **102** may comprise a clock or counter. The AFE **102** may comprise a control structure such as an LED driver for switching on and off various individual portions of the transmitter and/or receiver modules **104**, **110** respectively (such as the individual signal sources **106** and/or the individual transducers **109**). If the perfusion detector **100** requires that the amplitude of the electromagnetic signal **112** be varied, the AFE **102** may comprise amplifying and/or attenuating circuitry. If the perfusion detector **100** requires that the resolution of the reflected input signal **114** be varied, the AFE **102** may comprise the appropriate amplifying and/or attenuating circuitry.

[0031] The photoplethysmographic measuring device **140** may produce the output signal **118** that may be passed to a signal processor **150**. The signal processor **150** may then analyze the data from the output signal **118** and make a determination of whether perfusion is present, thereby detecting potential cardiac arrest.

[0032] The signal processor **150** may comprise one or more general purpose microcontrollers and/or microprocessors. The signal processor **150** may receive the output signal **118** from the photoplethysmographic measuring device **140**, configure the data from the output signal **118** into a PPG, make a physiological determination, and transmit information regarding the determination (such as a personal alarm or initiation of an alarm cascade) to a variety of external receivers. In some embodiments, the information may be a personal alarm or initiation of an alarm cascade. In other embodiments, the information may be data for a PPG. In some applications, the external receiver may be a cell phone(s) of the user's personally selected emergency contact (s) or caregiver(s). In some applications, the external receiver may be door locks to the user's home, external defibrillators, and/or an audible alarm. In some applications, the external receiver may include a display unit such as a computer monitor or wristwatch display screen whereby a PPG may be viewed.

[0033] In some examples, the personal alarm or the alarm cascade can be implemented utilizing an alarm mechanism (not shown) to alert others that the user is experiencing cardiac arrest. The alarm mechanism can be initiated based on a determination that the user is experiencing cardiac arrest. The alarm mechanism can also, upon detection of cardiac arrest in the user, attempt to arouse a response in the user. The alarm may include location information to indicate to a receiver of the alarm the whereabouts or location of the user.

[0034] FIG. **2** is a graph **200** illustrating an example of a PPG **206** (e.g., PPG data representing a physiological characteristic or measurement) captured by a photoplethysmographic measuring device **140**, according to one embodiment. The PPG **206** of FIG. **2** illustrates where perfusion is present **208** transitioning to loss of perfusion **210**, demonstrating how a loss of perfusion **210** may be detected.

[0035] In the graph **200** of FIG. **2**, the horizontal axis **202** represents units of time and the vertical axis **204** represents an arbitrary signal level. The graph **200** illustrates the values that the PPG **206** may take on when perfusion is present **208** and when there is a loss of perfusion **210**. The PPG **206** is proportional to a reflected input signal from the user's blood cells. When perfusion is present **208** and the cardiac cycle is at a maximum (e.g., during cardiac systole, when the heart is contracting and the capillary-level blood vessels expand), the blood volume within the conduit(s) of focus will increase. Consequently, during this cardiac cycle, a reflected input signal may increase and the PPG **206** may reach a local maximum value **207**. When perfusion is present **208** and the cycle is at a minimum (e.g., during cardiac diastole, when the heart is filling), the blood volume within the conduit(s) of focus will decrease. Consequently, during this cardiac cycle, the reflected input signal may decrease and the PPG **206** may reach a local minimum value **209**.

[0036] When perfusion is present **208**, the difference **212** between the maximum value **207** and the minimum value **209** of a cycle of the PPG **206** may be relatively large. In some examples, the difference **212** may be measured during a time sample encompassing one or more cycles. A time sample may comprise two seconds, 10 seconds, or a different duration of time that includes multiple cycles of heart action. A maximum of one cycle may be compared to a minimum of a different cycle to compute the difference **212** and/or an excursion.

[0037] When there is a loss of perfusion **210**, the difference **214** between a maximum value **207** and a minimum value **209** of a cycle of the PPG **206** may be relatively small as compared to the difference **212**. In some examples, the excursion of the maximum value **207** and the minimum value **209** associated with the difference **212**, and a maximum value and a minimum value associated with the difference **214** of a cycle of the PPG **206**, can be assessed to determine whether perfusion is present **208**.

[0038] Excursion is defined as the difference between the maximum value **207** and the minimum value **209** of the PPG **206**. Equation 1 can be used to calculate the signal excursion:

$$E=A_{max}-A_{min} \quad \text{Equation 1}$$

In equation 1 above, E is the signal excursion, A_{max} is a maximum value (e.g., the maximum value **207**) of the PPG **206**, and A_{min} is a minimum value (e.g., the minimum value

209) of the PPG **206** within a given time period, such as one or more cycles (e.g., two seconds, ten seconds, or a different duration of time).

[0039] For each new data point, the new data point (e.g., the physiological signal value) may be compared to the most recently stored maximum value **207** and minimum value **209**, and then the new data point can replace either the maximum value **207** or the minimum value **209** if the new data point exceeds the maximum value **207** or falls below the minimum value **209**. A specified time period may be selected in which the PPG **206** data may be stored. The maximum value **207** or the minimum value **209** that is older than a predetermined time period may be discarded and replaced with a new maximum value and/or a new minimum value.

[0040] The process for determining whether perfusion is present **208** may include establishing an alert threshold. The alert threshold is a minimum excursion value below which perfusion is assumed to be absent. The alert threshold may be calculated using equation 2 below:

$$Th=m_pE_{median} \quad \text{Equation 2}$$

In equation 2, Th is the alert threshold, m_p is a threshold percentage, and E_{median} is the median of excursion values established at a baseline recording.

[0041] The threshold percentage m_p may be selected such that the alert threshold Th is a smaller value than the excursion value when perfusion is present **208**. For example, the threshold percentage m_p may be equal to 10%, such that if the detected excursion is below 10% of the median excursion E_{median} the alert threshold is broken.

[0042] The baseline recording for obtaining the median excursion E_{median} may occur at a time appropriate for establishing a reliable median. For example, the baseline recording may occur one day prior to the current period of analysis.

[0043] A determination can be made that perfusion is absent **210** (e.g., is no longer present) when the current excursion falls below the alert threshold Th, thereby indicating potential cardiac arrest. A personal alarm may be initiated once the alert threshold is broken. If no immediate action to deactivate the personal alarm is detected, an alarm cascade may follow.

[0044] In many commercially available photoplethysmographic measuring devices, detecting perfusion **208** may include extracting or otherwise detecting a heartrate from a PPG. Motion artifacts may significantly compromise the physiological signal integrity, thereby greatly encumbering the process by which a heartrate may be detected. A number of embodiments and/or examples described herein may not measure a heart rate, but rather may determine whether perfusion is present **208** as part of detecting cardiac arrest. It is unlikely that a person would be rendered unresponsive by cardiac arrest when perfusion is present **208**. This is true regardless of heart rate and enables the method of the present disclosure to function unencumbered by a requirement to determine an exact numerical value for heart rate. Whereas in most electronic signal analyses a prominent signal to noise ratio is important, in the presently disclosed embodiments signal and noise may be processed together or separately. A presence of a signal and noise can indicate a lack of an emergency condition or a lack of cardiac arrest.

[0045] FIG. **3** is a graph **300** illustrating an example of a PPG **305** that includes a motion artifact as captured by a photoplethysmographic measuring device, such as the photoplethysmographic measuring device **140** of FIG. **1**, according to one embodiment. In FIG. **3**, the PPG **305** may indicate a case where perfusion is present and the photoplethysmographic measuring device is subject to temporary acceleration. The graph **300** of FIG. **3** illustrates the PPG **305** transitioning from a moment where a motion artifact is present **306** to a moment where little to no motion artifact is present **308**. FIG. **3** demonstrates that a motion artifact does not hinder the effectiveness of the embodiments of the present disclosure in detecting whether cardiac arrest is present.

[0046] In the graph **300** of FIG. **3**, the horizontal axis **302** represents units of time and the vertical axis **304** represents a signal level (e.g., an arbitrary unit). The graph **300** illustrates the values that the PPG **305** may take on when a motion artifact is present **306** or is not present **308**.

[0047] If perfusion is present and a motion artifact is not present **308**, the PPG **305** may reach a local maximum value **314** during cardiac systole. If perfusion is present and a motion artifact is not present **308**, the PPG **305** may also reach a local minimum value **316** during cardiac diastole.

[0048] A motion artifact may be the variations of the PPG **305** that arise from influences other than changes in blood volume within the user's targeted blood vessel(s). Particularly, a motion artifact may be the variations of the PPG **305** that are caused by motion. For example, if the user undergoes any movement, the electromagnetic signal from the photoplethysmographic measuring device (e.g., the electromagnetic signal **112** from the photoplethysmographic measuring device **140** of FIG. **1**) may change the direction of the electromagnetic signal and reflect off a part of the user's skin that has different absorption and/or reflection characteristics. In this example, the amount of reflection may vary and may thereby introduce variations in the PPG **305**. Another example of a motion artifact is if the user moves such that the source of the electromagnetic signal from the photoplethysmographic measuring device changes its distance from the user's skin, thereby changing the relative intensity of the reflected input signal. In this example, the change in relative intensity of the reflected input signal causes a corresponding variation in the PPG **305**. The variations in the PPG **305**, due to a motion artifact, may be much larger than those caused by changes in blood volume within the user's targeted blood vessel(s).

[0049] When a motion artifact is present **306**, the variations of the PPG **305** may be the sum of the variations caused by motion artifacts and the variations caused by perfusion. When the variations caused by motion artifacts and the variations caused by perfusion are summed, the PPG **305** may reach a local maximum value **310** that may or may not occur during cardiac systole. When the variations caused by motion artifact and the variations caused by perfusion are summed, the PPG **305** may also reach a local minimum value **312** that may or may not occur during cardiac diastole.

[0050] The variations of the PPG **305** that are caused by motion artifacts may be difficult to predict or analyze. Consequently, obtaining a periodic pattern from the PPG **305** when motion artifacts are present **306** may be difficult or prone to error. However, determining a periodic pattern from the PPG **305** is not necessary to determine whether perfusion is present. The method of the present disclosure does not attempt to identify a periodic pattern from the PPG **305**, but rather assesses the excursion of the PPG **305**

relative to an alert threshold in order to determine whether perfusion is present. Excursion may be calculated using Equation 1, and the alert threshold may be calculated using Equation 2.

[0051] When a motion artifact is not present **308**, the excursion **320** of the PPG **305** may have a value larger than that set by the alert threshold, and it may be determined that perfusion is present. When a motion artifact is present **306**, the excursion **318** of the PPG **305** may take on a value much larger than that of the excursion **320** of the PPG **305** when a motion artifact is not present **308**. In the case where a motion artifact is not present **308**, the excursion **320** of the PPG **305** takes on a value that is also larger than the alert threshold. Since the alert threshold is not broken when a motion artifact is present **306** in the PPG **305**, no false alarms are triggered on account of motion artifact. As sustained motion artifacts may only occur in persons not suffering cardiac arrest, motion artifacts may be considered to indicate an absence of cardiac arrest.

[0052] If perfusion is lost while the user is temporarily in motion, the user will promptly lose consciousness and motion will cease. Once motion has ceased, the loss of perfusion may be detected and an alarm cascade may follow. When movement indicative of usual personal activities is detected, photoplethysmographic monitoring may be switched off, conserving power output, and enabling convenient, comfortable long-term use by virtue of a practical battery size and/or a smaller device. One example is the condition whereupon another embedded sensor (e.g., an accelerometer, gyroscope, or the like) indicates a lack of personal motion. In such a case, photoplethysmographic monitoring may be switched on.

[0053] FIGS. **4**A to **4**C are graphs **400**, **400***b*, **400***c* illustrating an example of a PPG **405** and/or an excursion function **450**, according to embodiments of the present disclosure. FIG. **4**A shows a graph **400** comprising an excursion function **450** and a PPG **405**. FIG. **4**B shows the graph **400***b* (e.g., a subset of data of graph **400**) comprising the excursion function **450**. FIG. **4**C shows the graph **400***c* (e.g., another subset of data of graph **400**) comprising the PPG **405**.

[0054] FIGS. **4**A to **4**C include a motion artifact **446** as captured by a photoplethysmographic measuring device, such as the photoplethysmographic measuring device **140** of FIG. **1**. The PPG **405** and the excursion function **450** include a plurality of instances of perfusion **444**, a plurality of instances of motion artifact(s) **446**, and a plurality of instances of an absence of both perfusion and motion artifacts **448**.

[0055] In FIGS. **4**A to **4**C, the horizontal axis **402** represents units of time and the vertical axis **404** represents a signal level (e.g., an arbitrary unit). The graph **400** illustrates the values that the PPG **405** may take during instances when the motion artifacts are present **446**, instances when perfusion is present **444**, and instances when there is an absence of both perfusion and motion artifacts **448**. The units of time can comprise a duration of time. For example, each unit of time in the horizontal axis **402** can represent one second, two seconds, three seconds, four second, or a different unit of time.

[0056] The presence of the motion artifacts **446** is also referenced as noise. The noise can be due to extraneous interference. The excursion function **450** represents a continuous calculation of a difference between a maximum value and minimum value of the PPG **405**. The excursion function **450** can lag as compared to the PPG **405**. A lag **449** comprises a duration of time in which the maximum value and the minimum value are gathered.

[0057] The PPG **405** is recorded from a user experiencing ventricular fibrillation (e.g., cardiac arrest rhythm). During the instances of absence of both perfusion and motion artifacts **448**, the values of the excursion function **450** may fall to less than one-fifth of a baseline recording. Cardiac arrest can be identified when, during instances of the absence of both perfusion and motion artifacts **448**, the values of the excursion function **450** fall to less than one-fifth of a baseline recording.

[0058] FIG. **5** illustrates a method **500** for detecting cardiac arrest, according to one embodiment. The method **500** shows operations that may be performed to determine whether perfusion is present in a user, and thereby determine whether the user may be suffering from cardiac arrest. The method **500** may determine whether perfusion is present in the user while conserving power and circumventing false alarms despite the presence of motion artifacts. If a loss of perfusion is detected, a personal alert and possibly an alarm cascade may be initiated.

[0059] The method **500** of FIG. **5** may be performed using one or more of an embedded sensor such as an accelerometer, a perfusion detector (e.g., the perfusion detector **100** of FIG. **1**), and a variety of external receivers. The embedded sensor (e.g., an accelerometer, a gyroscope, and/or the like) may be used to detect motion, thereby potentially indicating absence of cardiac arrest. If a lack of motion is detected from the embedded sensor, then the perfusion detector may be used to obtain a PPG, and the excursion of the physiological signal shown by the PPG may be analyzed to determine whether perfusion is present. If an absence of perfusion is detected, the variety of external receivers may be used to perform an alarm cascade.

[0060] The method **500** may include checking or determining **502** that the user's condition (e.g., state or status) is compatible with cardiac arrest. For example, if it is determined **502** that the user's condition is not compatible with cardiac arrest (e.g., by virtue of motion being detected by an embedded motion sensor), the method **500** may be halted and restarted at a later time, thereby conserving power that would otherwise be consumed by additional operations.

[0061] If it is determined **502** that the user's condition is compatible with cardiac arrest at **502**, a perfusion detector (e.g., the perfusion detector **100** of FIG. **1**) may be activated at **504**. The perfusion detector may then obtain **506** a PPG. The physiological signal shown by the PPG may be analyzed **508** for excursion. An excursion value is compared against an alert threshold. For example, it can be determined **510** that the excursion is greater than the alert threshold. It can also be determined **512** that excursion is less than or equal to the alert threshold.

[0062] If the excursion value of the physiological signal shown by the PPG is determined **510** to be greater than the alert threshold, then it can be assumed that perfusion is present and the method **500** may be restarted and no personal alert is initiated **514**. If the excursion value of the physiological signal shown by the PPG is determined **512** to be less than or equal to the alert threshold, a personal alert may be initiated **516**. The user may be given a certain amount of time to respond to the personal alert, and if a response is detected **520**, then the method **500** may be restarted and no

alarm cascade is initiated at **524**. If the user is given a certain amount of time to respond to the personal alert and no response is detected **518**, then an alarm cascade may be initiated **522**.

[0063] As a part of the alarm cascade, previously designated individuals such as a spouse, one or more household members, neighbors, or emergency personnel may be alerted by means of cellular telephones, SMS text, an audible siren, or the like, and the user's location information may be provided within the alert communication. Additionally, network-connected devices such as door locks, and automatic external defibrillators may be activated to facilitate rescue.

[0064] FIG. **6** illustrates a method **600** for detecting cardiac arrest, according to one embodiment. The method **600** shows operations that may be performed to determine whether perfusion is present in a user, and thereby determine whether the user may be suffering from cardiac arrest. The method **600** may determine whether perfusion is present in the user while conserving power and circumventing false alarms despite the presence of motion artifact(s). If a loss of perfusion is detected, a personal alert and possibly an alarm cascade may be initiated.

[0065] The method **600** of FIG. **6** may be performed using one or more of an embedded sensor such as an accelerometer, a perfusion detector (e.g., the perfusion detector **100** of FIG. **1**), and a variety of external receivers. The embedded sensor (e.g., an accelerometer, a gyroscope, and/or the like) may be used to detect motion, thereby potentially indicating absence of cardiac arrest. If a lack of motion is detected from the embedded sensor, then the perfusion detector may be used to obtain a PPG, and the excursion of the physiological signal shown by the PPG may be analyzed to determine whether perfusion is present. If an absence of perfusion is detected, the variety of external receivers may be used to perform an alarm cascade.

[0066] The method **600** includes determining **650** whether a condition of the user of the perfusion detector is compatible with cardiac arrest. A condition of the user can include a movement of the user, the presence of perfusion, and/or a movement of the perfusion detector in relation to the user, among other conditions of the user that may contribute to a determination of whether the user is experiencing cardiac arrest. For example, the embedded sensor(s) can be used to determine whether a reading of the perfusion detector is due to perfusion or a motion artifact.

[0067] The embedded sensor(s) can indicate that the perfusion detector is in motion. The embedded sensor(s) can sense, for example, acceleration to determine motion. The acceleration can indicate that the reading generated by the perfusion detector is attributed to a motion artifact. In some examples, a user may travel in a vehicle, such as an airplane, a bus, and/or a train, among other possible vehicles that can transport users. The embedded sensor(s) can indicate motion. For example, the embedded sensor(s) can report a change in global positioning system (GPS) coordinates. A change in GPS coordinates can be indicative of user movement which may be attributed to travel. Such movement indicates that the condition of the user is not compatible with cardiac arrest.

[0068] In response to determining **650** that a condition of the user is not compatible with cardiac arrest, the method **600** determines **674** whether the body temperature of the user is less than 96 degrees. The perfusion detector can include a temperature sensor. The temperature sensor can be, for example, a thermistor sensor. The temperature sensor indicates to the perfusion detector a temperature of the user and/or the perfusion detector. The perfusion detector can determine **674**, via the signal processor **150** (see FIG. **1**), whether the user's temperature is less than 96 degrees.

[0069] A user temperature that is less than 96 degrees is indicative of possible cardiac arrest or other issue. Although 96 degrees is used in the example shown in FIG. **6**, other temperature thresholds can be selected. For example, a temperature threshold can be equal to 97 degrees or 95 degrees, among other temperature thresholds. As a user experiences cardiac arrest, the temperature of the user drops.

[0070] Determining **674** that the temperature of the user is less than 96 degrees in conjunction with the determination **650** that the user condition is not compatible with cardiac arrest is indicative that a user is experiencing cardiac arrest while the perfusion detector and/or the user is moving. For example, the user can experience cardiac arrest while traveling in a vehicle.

[0071] The method **600** can proceed to initiate **660** a personal alert based on a determination **674** that the user temperature is less than 96 degrees. The method **600** can proceed to abstain **676** from initiating a personal alert based on the determination **674** that the user temperature is greater than 96 degrees.

[0072] In response to determining **650** that a condition of the user is compatible with cardiac arrest (e.g., no movement detected), the method **600** can proceed to activate **652** the perfusion detector. Based on activating **652** the perfusion detector, the method **600** obtains **654** the PPG. The method **600** then analyzes **656** the signal, obtained by the perfusion detector, to determine whether excursion is present. Based on a determination **672** that excursion (e.g., the signal indicative of excursion) is greater than an alert threshold and that the body temperature is greater than or equal to 96 degrees, the method can proceed to abstain **676** from initiating a personal alert. Although not shown, the method **600** can proceed to initiate **660** a personal alert if excursion is less than or equal to an alert threshold and the body temperature of the user is greater than or equal to 96 degrees.

[0073] Based on a determination **658** that excursion is less than or equal to the alert threshold, the method **600** can proceed to initiate **660** a personal alert. In response to initiating **660** the personal alert, the method **600** can determine **668** that no response is detected or determine **662** that a response is detected. The response can include a response by the user. The response can be an interaction with the perfusion detector or a change in the user such that excursion is greater than an alert threshold.

[0074] If no response is detected, then an alarm cascade can be initiated **670** to take further action to illicit a response from the user. If a response is detected, the method **600** abstains **664** from initiating an alarm cascade.

[0075] The disclosed systems and apparatuses may include one or more processors to execute operations to detect cardiac arrest. For example, the signal processor **150** of FIG. **1** may comprise one or more processors. The one or more processors may include one or more general purpose devices, such as an Intel®, AMD®, or other standard microprocessor and/or microcontroller. The one or more processors may include a special purpose processing device, such as an ASIC, SoC, SiP, FPGA, PAL, PLA, FPLA, PLD, or other customized or programmable device. The one or more processors may perform distributed (e.g., parallel)

processing to execute or otherwise implement functionalities of the present embodiments. The one or more processors may run a standard operating system and perform standard operating system functions. It is recognized that any standard operating system may be used, such as, for example, Microsoft® Windows®, Apple® MacOS®, Disk Operating System (DOS), UNIX, IRJX, Solaris, SunOS, FreeBSD, Linux®, or ffiM® OS/2® operating system, and so forth. In some examples, the one or more processors may run application software to execute operations to detect cardiac arrest without the use of an operating system. For example, the application software may run bare metal on the one or more processors.

[0076] The one or more processors may be in electronic communication with an electronic memory, which may include static RAM, dynamic RAM, flash memory, one or more flip-flops, ROM, CD-ROM, DVD, disk, tape, or magnetic, optical, or other computer storage medium. The electronic memory may include a plurality of program modules and program data.

[0077] The program modules may include all or portions of other elements of the system. The program modules may run multiple operations concurrently or in parallel by or on the one or more processors. In some embodiments, portions of the disclosed modules, components, and/or facilities are embodied as executable instructions embodied in hardware or in firmware, or stored on a non-transitory, machine-readable storage medium. The instructions may comprise computer program code that, when executed by a processor and/or computing device, cause a computing system to implement certain processing steps, procedures, and/or operations, as disclosed herein. The modules, components, and/or facilities disclosed herein may be implemented and/or embodied as a driver, a library, an interface, an API, FPGA configuration data, firmware (e.g., stored on an EEPROM), and/or the like. In some embodiments, portions of the modules, components, and/or facilities disclosed herein are embodied as machine components, such as general and/or application-specific devices, including, but not limited to: circuits, integrated circuits, processing components, interface components, hardware controller(s), storage controller(s), programmable hardware, FPGAs, ASICs, and/or the like.

[0078] The program data stored on the electronic memory may include data generated by the system, such as by the program modules or other modules. The stored program data may be organized as one or more databases.

[0079] A perfusion detector may include an I/O interface, which may facilitate interfacing with one or more input devices and/or one or more output devices. The input device(s) may include a keyboard, mouse, touch screen, light pen, tablet, microphone, sensor, or other hardware with accompanying firmware and/or software. The output device(s) may include a monitor or other display, printer, speech or text synthesizer, switch, signal line, or other hardware with accompanying firmware and/or software. In some examples, output device(s) may also include wireless output devices such as WiFi devices, Bluetooth devices, and/or other wireless technologies. The wireless output device may be used to facilitate communications via a cell phone, for example. The output devices may also be wired output devices such as universal serial bus (USB) devices.

[0080] As can be appreciated, other methods and processes are available and included in the descriptions above describing operation of the system embodiments and are within the scope of the present disclosure.

EXAMPLE EMBODIMENTS

[0081] Some examples of embodiments of systems and methods of anonymized transparent exchange of information are provided below.

[0082] Example 1. An apparatus for detecting cardiac arrest, comprising a photoplethysmographic measuring device, including a transmitter module to transmit a signal toward a user to interact with the skin of the user and a receiver module to receive a reflection of the signal and generate a photoplethysmogram; and a signal processor to process the photoplethysmogram to detect whether the user is experiencing cardiac arrest.

[0083] Example 2. The apparatus of Example 1, wherein the signal processor to process the photoplethysmogram is further configured to detect perfusion in the user to determine whether the user is experiencing cardiac arrest.

[0084] Example 3. The apparatus of Example 1, further comprising an alarm mechanism to alert others that the user is experiencing cardiac arrest based on a determination that the user is experiencing cardiac arrest.

[0085] Example 4. The apparatus of Example 1, further comprising a personal alarm to, upon detection of cardiac arrest in the user, attempt to arouse a response in the user.

[0086] Example 5. The apparatus of Example 1, further comprising a sensor to detect whether a condition of the user is compatible with cardiac arrest.

[0087] Example 6. The apparatus of Example 5, wherein the sensor comprises one or more of a gyroscope and an accelerometer to detect movement of the user.

[0088] Example 7. The apparatus of Example 1, wherein the signal transmitted toward the user to interact with the skin comprises an electromagnetic signal.

[0089] Example 8. The apparatus of claim 7, wherein the electromagnetic signal comprises green visible light.

[0090] Example 9. A perfusion detector for detecting cardiac arrest, comprising a photoplethysmographic measuring device, including: a transmitter module to transmit a signal toward a user to interact with the skin of the user, and a receiver module to receive a reflection of the signal; a signal processor to: process a photoplethysmogram obtained by the photoplethysmographic measuring device to detect whether perfusion is present in the user, wherein the photoplethysmogram is generated from the reflection of the signal; and determine whether the user is experiencing cardiac arrest based on whether perfusion is present in the user; and an alarm mechanism to alert others that the user is experiencing cardiac arrest based on a determination that the user is experiencing cardiac arrest.

[0091] Example 10. The perfusion detector of Example 9, further comprising a personal alarm to evoke a response in the user, upon detection of cardiac arrest in the user.

[0092] Example 11. The perfusion detector of Example 9, wherein the receiver module comprises one or more individual transducers to receive the reflection of the signal.

[0093] Example 12. The perfusion detector of Example 11, wherein the photoplethysmographic measuring device is further configured to measure a resolution of the reflection of the signal.

[0094] Example 13. The perfusion detector of Example 12, wherein the photoplethysmographic measuring device is further configured to: determine whether the resolution of

the reflection of the signal is less than or equal to a threshold; and based on a determination that the resolution is less than or equal to the threshold, activate an additional number of individual transducers to receive the reflection of the signal to increase the resolution of the signal.

[0095] Example 14. A method for monitoring for cardiac arrest in an individual, the method comprising: transmitting a signal toward a user to interact with the skin of the user; receiving a reflection of the signal; generating a photoplethysmogram based on the reflected signal; determining from the photoplethysmogram whether perfusion is present in the skin of the user; and determining, based on a presence of perfusion, whether the user is experiencing cardiac arrest.

[0096] Example 15. The method of Example 14, wherein receiving the reflection of the signal further comprises receiving the reflection of the signal through one or more individual transducers.

[0097] Example 16. The method of Example 15, further comprising deactivating a portion of the one or more individual transducers to decrease power consumption.

[0098] Example 17. A computer readable storage medium having stored thereon instructions that, when implemented by a computing device, cause the computing device to activate a perfusion detector based on sensor input received from a sensor; transmit, via the perfusion detector, a signal toward a user to interact with the skin of the user; receive, via the perfusion detector, a reflection of the signal; generate a photoplethysmogram based on the reflection of the signal; process the photoplethysmogram to detect perfusion in the user; determine whether the user is experiencing cardiac arrest based on a detected perfusion in the user; and initiate an alarm if the user is experiencing cardiac arrest.

[0099] Example 18. The computer readable storage medium of Example 17, wherein the sensor captures personal motion, wherein the sensor input provides an indication whether personal motion is occurring as captured by the sensor.

[0100] Example 19. The computer readable storage medium of Example 18, wherein the instructions are further configured to activate the perfusion detector based on a determination that the sensor input does not indicate personal motion is occurring.

[0101] Example 20. The computer readable storage medium of Example 17, wherein the instructions to process the photoplethysmogram to detect perfusion further comprises instructions to detect perfusion without regard to motion artifacts.

[0102] Example 21 is a photoplethysmographic measuring device for detecting cardiac arrest. The photoplethysmographic measuring device includes electronic memory to store a photoplethysmogram. The photoplethysmographic measuring device also includes one or more processors designed to transmit a signal toward a user to interact with the skin of the user, receive a reflection of the signal, generate the photoplethysmogram based on the reflection of the signal, and process the photoplethysmogram to detect whether the user is experiencing cardiac arrest.

[0103] Example 22 is the photoplethysmographic measuring device of Example 21, where the one or more processors are further designed to process the photoplethysmogram to detect perfusion in the user to determine whether the user is experiencing cardiac arrest.

[0104] Example 23 is the photoplethysmographic measuring device of Example 21, also including an alarm mechanism to alert others that the user is experiencing cardiac arrest based on a determination that the user is experiencing cardiac arrest.

[0105] Example 24 is the photoplethysmographic measuring device of Example 21, also including a personal alarm designed to, upon detection of cardiac arrest in the user, arouse a response in the user.

[0106] Example 25 is the photoplethysmographic measuring device of Example 21, also including a sensor to detect whether a condition of the user is compatible with cardiac arrest.

[0107] Example 26 is the photoplethysmographic measuring device of Example 21, where the sensor includes one or more of a gyroscope and an accelerometer to detect movement of the user.

[0108] Example 27 is the photoplethysmographic measuring device of Example 21, where the signal transmitted toward the user to interact with the skin includes an electromagnetic signal.

[0109] Example 28 is the photoplethysmographic measuring device of Example 27, where the electromagnetic signal includes green visible light.

[0110] Example 29 is an apparatus for detecting cardiac arrest. The apparatus includes electronic memory to store a photoplethysmogram. The apparatus also includes one or more processors configured to transmit a signal toward a user to interact with the skin of the user, receive a reflection of the signal, generate a photoplethysmogram from the reflection of the signal, process the photoplethysmogram to detect whether perfusion is present in the user and determine whether the user is experiencing cardiac arrest; and an alarm mechanism to alert others that the user is experiencing cardiac arrest.

[0111] Example 30 is the apparatus of Example 29, further including a personal alarm to attempt to evoke a response in the user, upon detection of cardiac arrest in the user.

[0112] Example 31 is a method for monitoring for cardiac arrest in an individual. The method includes transmitting a signal toward a user to interact with the skin of the user, receiving a reflection of the signal, generating a photoplethysmogram based on the reflection of the signal, determining from the photoplethysmogram whether perfusion is present in the skin of the user, and determining based on the presence of perfusion whether the user is experiencing cardiac arrest.

[0113] Example 32 is a computer-readable storage medium having stored thereon instructions that, when implemented by an apparatus for detecting cardiac arrest, cause the apparatus to transmit, via a transmitter module, a signal toward a user to interact with the skin of the user; receive, via a receiver module, a reflection of the signal; generate, via the receiver module, a photoplethysmogram; process, via a signal processor, the photoplethysmogram to detect perfusion in the user; receive, via a processing module, sensor input from a sensor to determine whether a condition of the user is compatible with cardiac arrest and activate a perfusion detector if the condition is compatible with cardiac arrest; receive, via the processing module, perfusion input from the signal processor indicating perfusion in the user; determine, via the processing module, based on the sensor input and the perfusion input whether the user is experiencing cardiac arrest; and initiate, via the processing module, an alarm if the user is experiencing cardiac arrest to notify rescuers of the cardiac arrest.

[0114] The foregoing specification has been described with reference to various embodiments. However, those skilled in the art appreciate that various modifications and changes can be made without departing from the scope of the present disclosure and the underlying principles of the invention. Accordingly, this disclosure is to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope thereof. Likewise, benefits, other advantages, and solutions to problems have been described above with regard to various embodiments. However, benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential feature or element.

[0115] While the principles of this disclosure have been shown in various embodiments, many modifications of structure, arrangements, proportions, the elements, materials and components, used in practice, which are particularly adapted for a specific environment and operating requirements, may be used without departing from the principles and scope of this disclosure. These and other changes or modifications are intended to be included within the scope of the present disclosure.

1. An apparatus for detecting cardiac arrest, comprising:
a photoplethysmographic measuring device including:
a transmitter module to transmit a signal toward a user to interact with skin of the user, and
a receiver module to:
receive a reflection of the signal; and
generate a photoplethysmogram; and
a signal processor to process the photoplethysmogram to detect whether the user is experiencing cardiac arrest.

2. The apparatus of claim **1**, wherein the signal processor to process the photoplethysmogram is further configured to detect perfusion in the user to determine whether the user is experiencing cardiac arrest.

3. The apparatus of claim **2**, wherein the signal processor detects perfusion in the user by calculating an excursion value based on a maximum value and a minimum value of the photoplethysmogram during a time period.

4. The apparatus of claim **1**, further comprising an alarm mechanism to alert others that the user is experiencing cardiac arrest based on a determination that the user is experiencing cardiac arrest.

5. The apparatus of claim **1**, further comprising a personal alarm to, upon detection of cardiac arrest in the user, attempt to arouse a response in the user.

6. The apparatus of claim **1**, further comprising a sensor to detect whether a condition of the user is compatible with cardiac arrest.

7. The apparatus of claim **5**, wherein the sensor comprises one or more of a gyroscope and an accelerometer to detect movement of the user.

8. The apparatus of claim **1**, wherein the signal transmitted toward the user to interact with the skin comprises an electromagnetic signal.

9. A perfusion detector for detecting cardiac arrest, comprising:
a photoplethysmographic measuring device including:
a transmitter module to transmit a signal toward a user to interact with skin of the user, and
a receiver module to receive a reflection of the signal;
a signal processor to:
process a photoplethysmogram obtained by the photoplethysmographic measuring device to detect whether perfusion is present in the user, wherein the photoplethysmogram is generated from the reflection of the signal; and
determine whether the user is experiencing cardiac arrest based on whether perfusion is present in the user; and
an alarm mechanism to alert others that the user is experiencing cardiac arrest based on a determination that the user is experiencing cardiac arrest.

10. The perfusion detector of claim **9**, further comprising a personal alarm to evoke a response in the user, upon detection of cardiac arrest in the user.

11. The perfusion detector of claim **9**, wherein the receiver module comprises one or more individual transducers to receive the reflection of the signal.

12. The perfusion detector of claim **11**, wherein the photoplethysmographic measuring device is further configured to measure a resolution of the reflection of the signal.

13. The perfusion detector of claim **12**, wherein the photoplethysmographic measuring device is further configured to:
determine whether the resolution of the reflection of the signal is less than or equal to a threshold; and
based on a determination that the resolution is less than or equal to the threshold, activate an additional number of individual transducers to receive the reflection of the signal to increase the resolution of the signal.

14. A method for monitoring for cardiac arrest in an individual, the method comprising:
transmitting a signal toward a user to interact with skin of the user;
receiving a reflection of the signal;
generating a photoplethysmogram based on the reflected signal;
determining from the photoplethysmogram whether perfusion is present in the skin of the user; and
determining, based on a presence of perfusion, whether the user is experiencing cardiac arrest, wherein presence of perfusion is determined by calculating an excursion value based on a maximum value and a minimum value of the photoplethysmogram during a time period.

15. The method of claim **14**, wherein receiving the reflection of the signal further comprises receiving the reflection of the signal through one or more individual transducers.

16. The method of claim **15**, further comprising deactivating a portion of the one or more individual transducers to decrease power consumption.

17. A computer readable storage medium having stored thereon instructions that, when implemented by a computing device, cause the computing device to:
activate a perfusion detector based on sensor input received from a sensor;
transmit, via the perfusion detector, a signal toward a user to interact with skin of the user;
receive, via the perfusion detector, a reflection of the signal;
generate a photoplethysmogram based on the reflection of the signal;
process the photoplethysmogram to detect perfusion in the user,

wherein perfusion is detected by calculating an excursion value based on a maximum value and a minimum value of the photoplethysmogram during a time period;

determine whether the user is experiencing cardiac arrest based on a detected perfusion in the user; and

initiate an alarm if the user is experiencing cardiac arrest.

18. The computer readable storage medium of claim **17**, wherein the sensor captures personal motion,

wherein the sensor input provides an indication whether personal motion is occurring as captured by the sensor.

19. The computer readable storage medium of claim **18**, wherein the instructions are further configured to activate the perfusion detector based on a determination that the sensor input indicated personal motion is not occurring.

20. The computer readable storage medium of claim **17**, wherein the instructions to process the photoplethysmogram to detect perfusion further comprises instructions to detect perfusion without regard to motion artifacts.

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专利名称(译)	用于检测心脏停搏的装置和方法		
公开(公告)号	US20190125276A1	公开(公告)日	2019-05-02
申请号	US15/801186	申请日	2017-11-01
当前申请(专利权)人(译)	健康警报，LLC		
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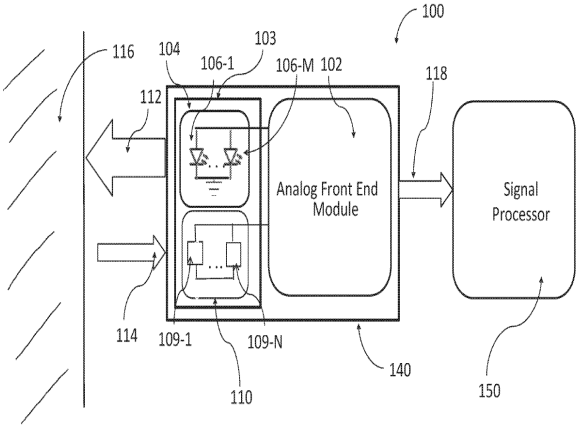
IPC分类号	A61B5/00 A61B5/024		
CPC分类号	A61B5/7282 A61B5/746 A61B5/02416 A61B2562/0219 A61B2560/0209 A61B5/01 A61B5/11		
外部链接	Espacenet USPTO		

摘要(译)

用灌注监测器检测心脏骤停发作的装置和方法。检测心脏骤停包括向用户发送信号以与用户的皮肤交互，接收信号的反射，生成光电容积描记图，以及处理光电容积描记图以检测用户是否正在经历心脏骤停。