US 20140378795A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2014/0378795 A1**

(43) **Pub. Date: Dec. 25, 2014**

McKenna

(54) **DETERMINATION OF A PHYSIOLOGICAL PARAMETER**

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(21) Appl. No.: **14/480,190**

(22) Filed: **Sep. 8, 2014**

Related U.S. Application Data

(63) Continuation of application No. 12/856,801, filed on Aug. 16, 2010, now Pat. No. 8,855,749.

(60) Provisional application No. 61/245,575, filed on Sep. 24, 2009.

Publication Classification

(51) **Int. Cl.**

G06F 19/00	(2006.01)
G06F 19/24	(2006.01)
G06F 17/30	(2006.01)
A61B 5/1455	(2006.01)
A61B 5/00	(2006.01)

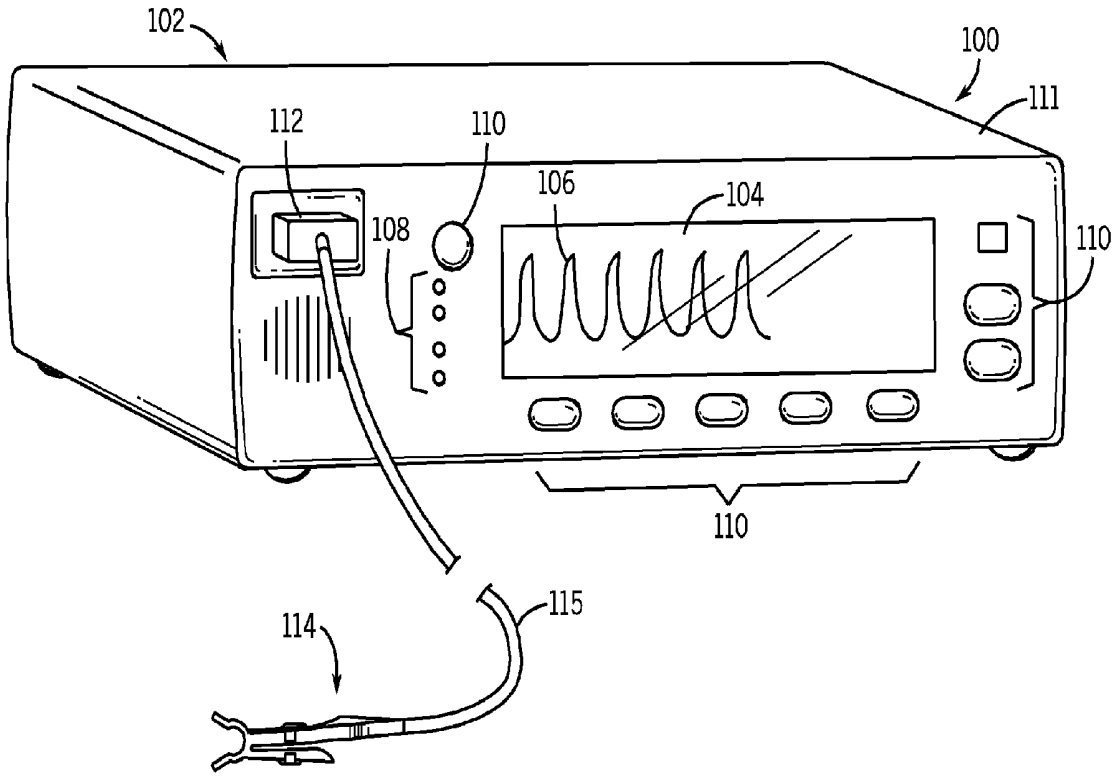
(52) **U.S. Cl.**

CPC ***G06F 19/322*** (2013.01); ***A61B 5/1455*** (2013.01); ***A61B 5/726*** (2013.01); ***A61B 5/0015*** (2013.01); ***G06F 17/30345*** (2013.01); ***G06F 19/3412*** (2013.01); ***G06F 19/24*** (2013.01); ***G06F 17/30477*** (2013.01)

USPC **600/323**; 707/803; 707/740

(57) **ABSTRACT**

Methods and systems are provided for analyzing a physiological signal by applying a continuous wavelet transform on the signal and comparing the wavelet transformation to a library of wavelet signatures corresponding to one or more physiological conditions and/or patient conditions. A pulse oximeter system may relate the wavelet transformation with one or more of the wavelet signatures based on filters and/or thresholds, and may determine that the wavelet transformation indicates that the patient of the physiological signal has a physiological condition indicated by the related wavelet signature. In some embodiments, the pulse oximeter system may use previous analyses in a neural network to update the library. Further, non-physiological components of the wavelet transformation may also be identified and removed.



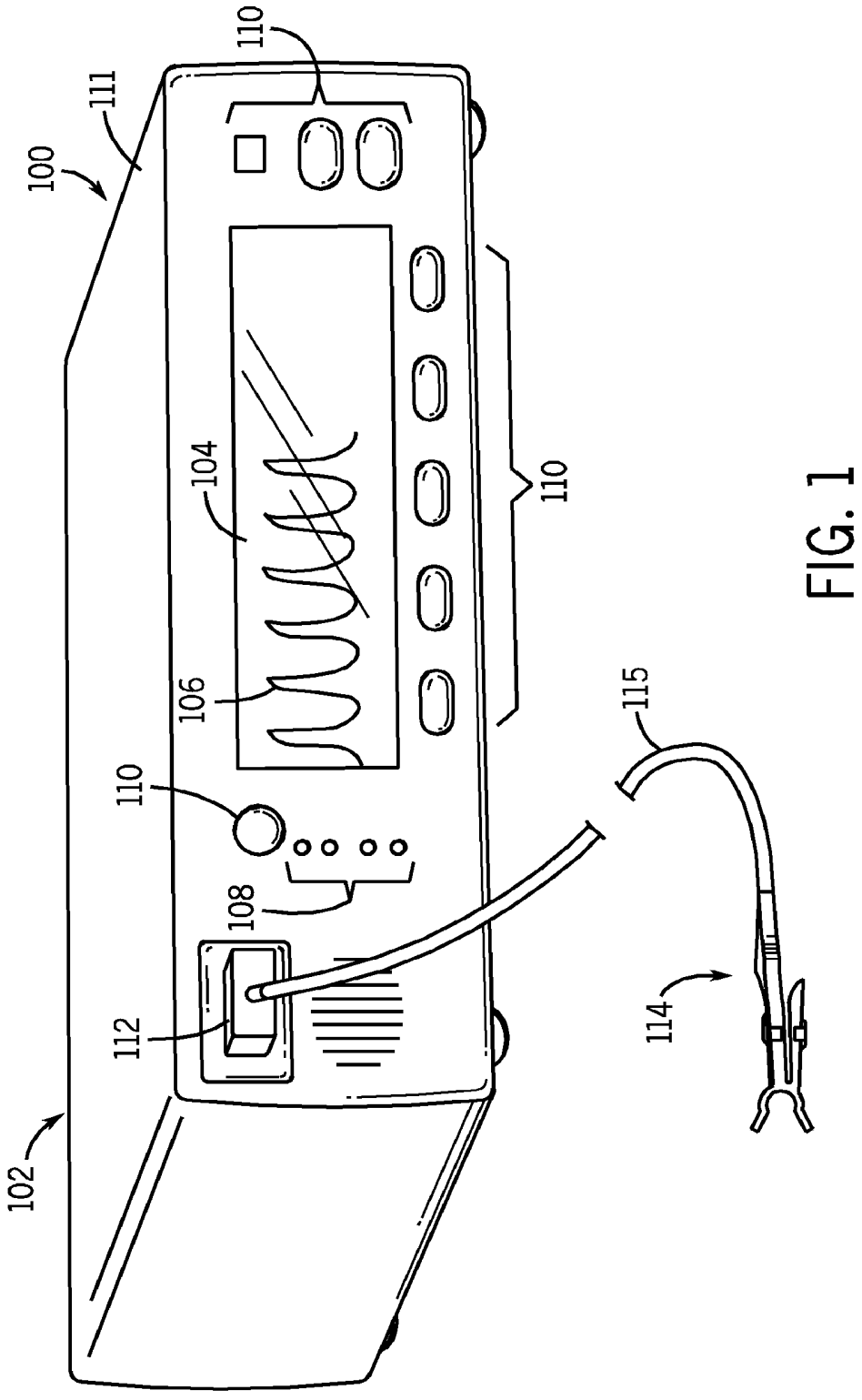


FIG. 1

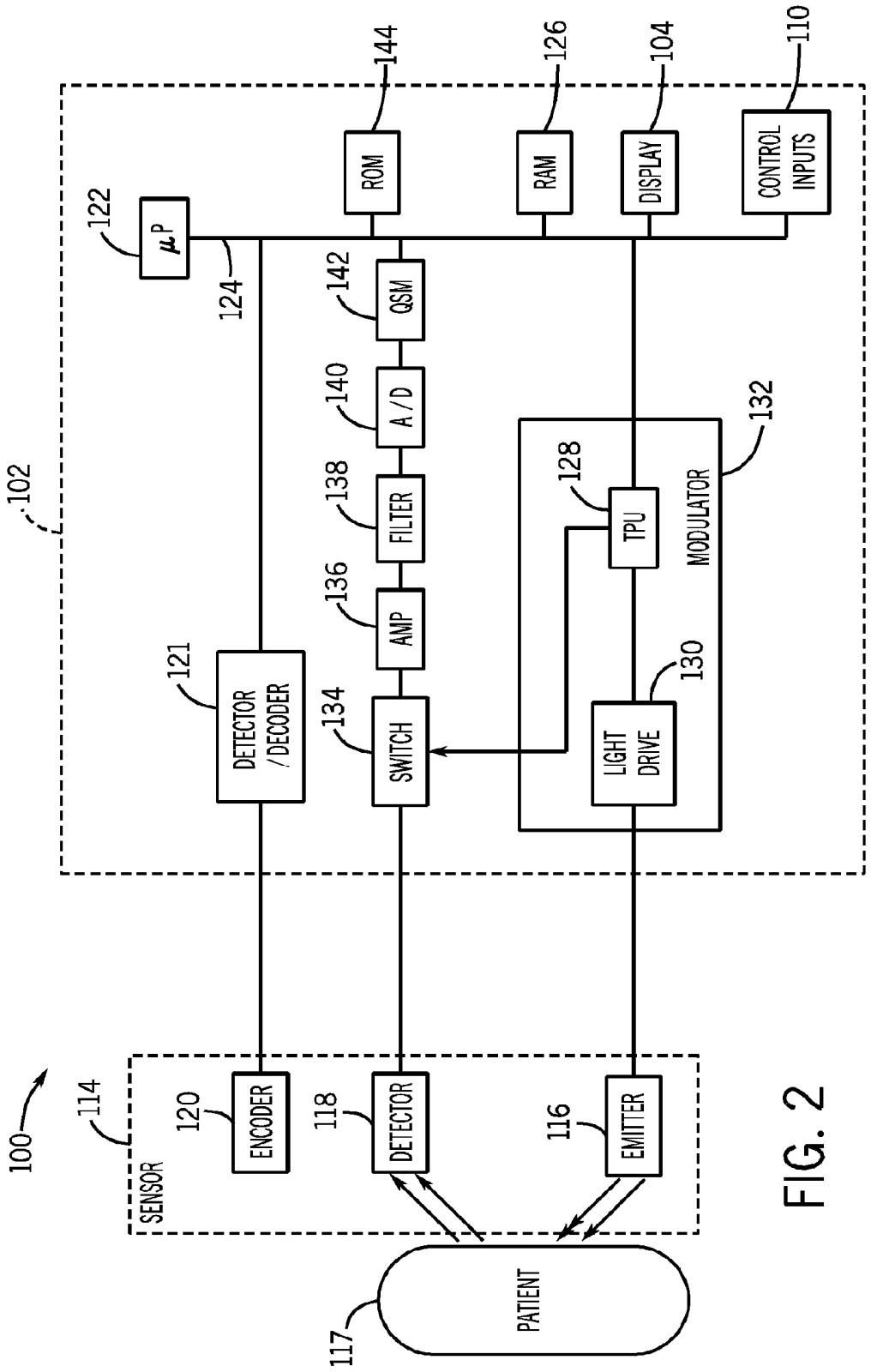

100
102
114
SENSOR
120
ENCODER
118
DETECTOR
116
EMITTER
117
PATIENT
121
DETECTOR /DECODER
134
SWITCH
136
AMP
138
FILTER
140
A/D
142
QSM
122
μP
124
144
ROM
126
RAM
104
DISPLAY
110
CONTROL INPUTS
128
TPU
130
LIGHT DRIVE
132
MODULATOR

FIG. 2

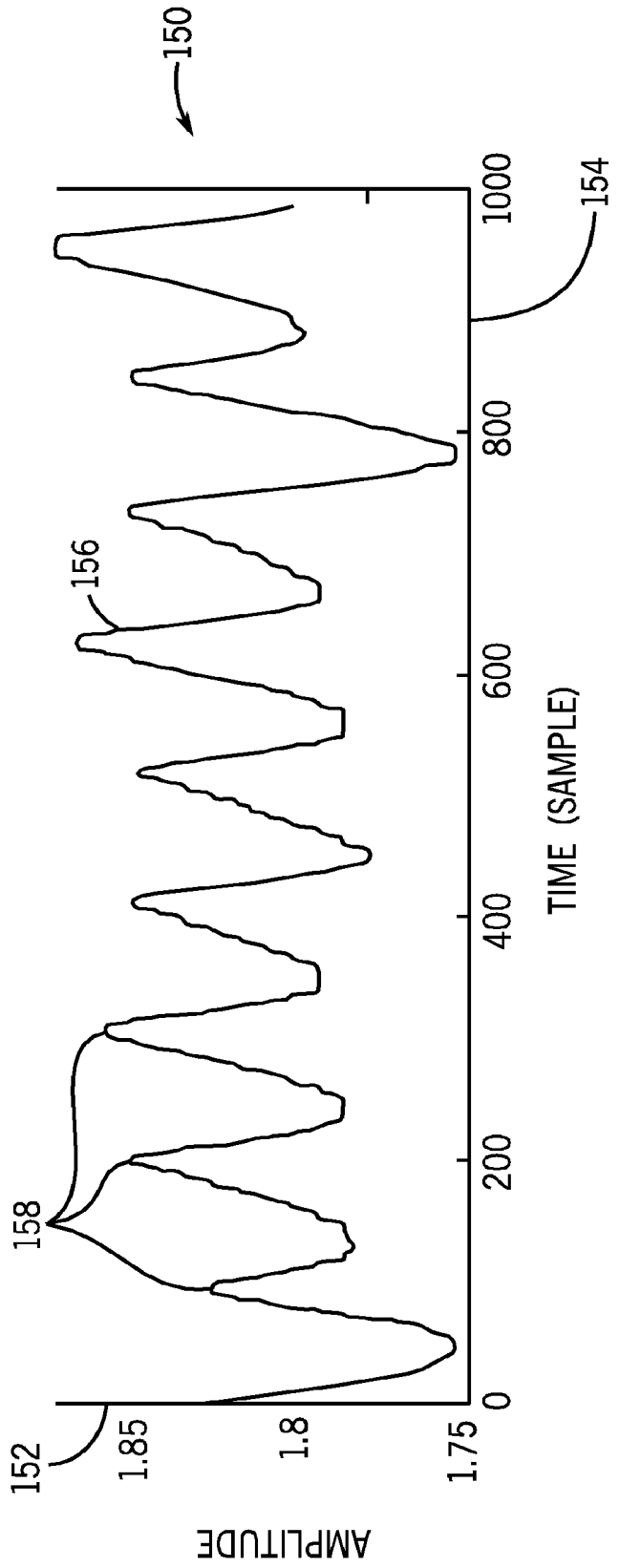

150
152
154
156
158
AMPLITUDE
1.85
1.8
1.75
0
200
400
600
800
1000
TIME (SAMPLE)

FIG. 3

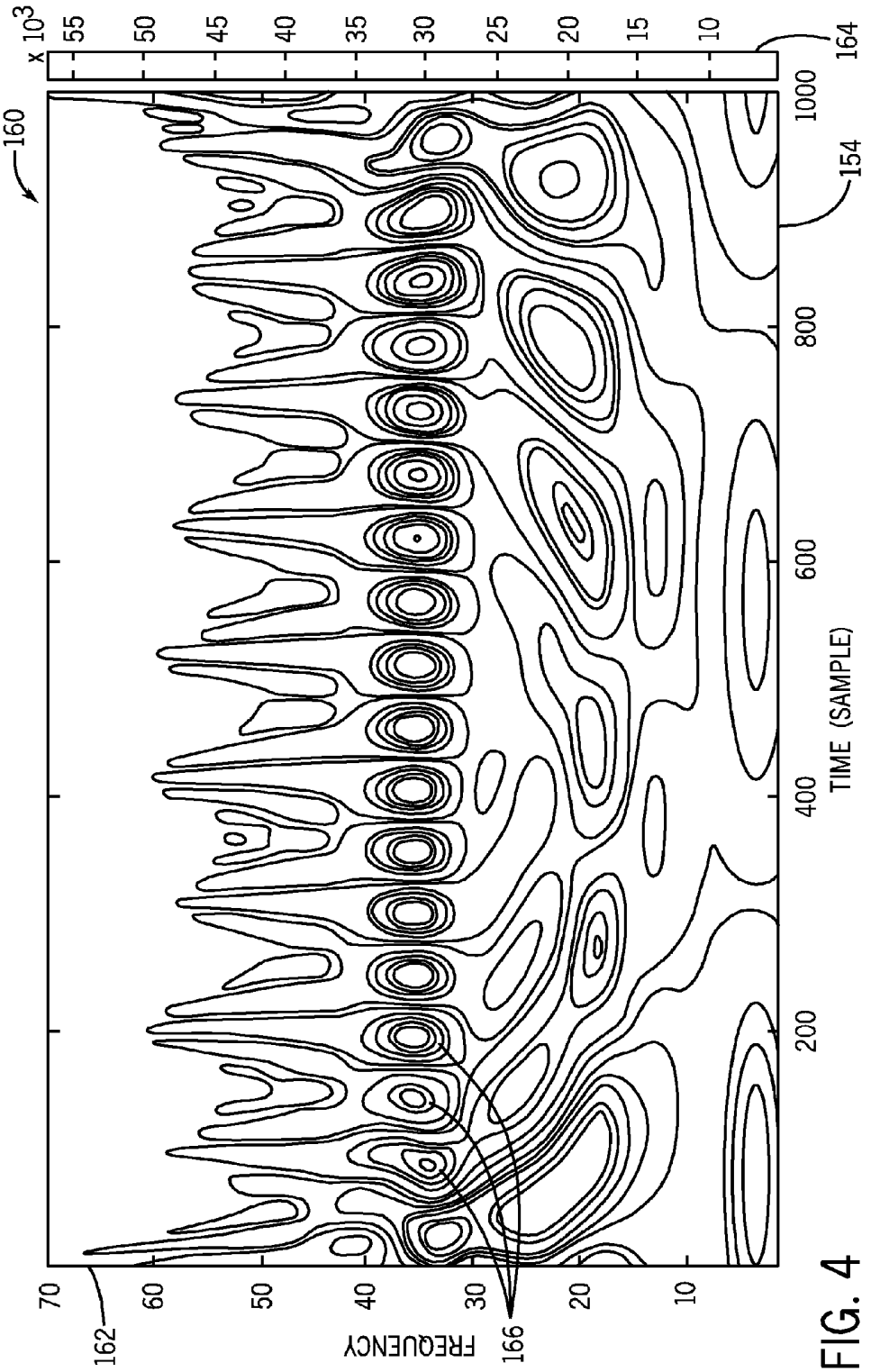

x 10^3
55
50
45
40
35
30
25
20
15
10
164
160
154
1000
800
600
400
200
TIME (SAMPLE)
70
60
50
40
30
20
10
FREQUENCY
162
166

FIG. 4

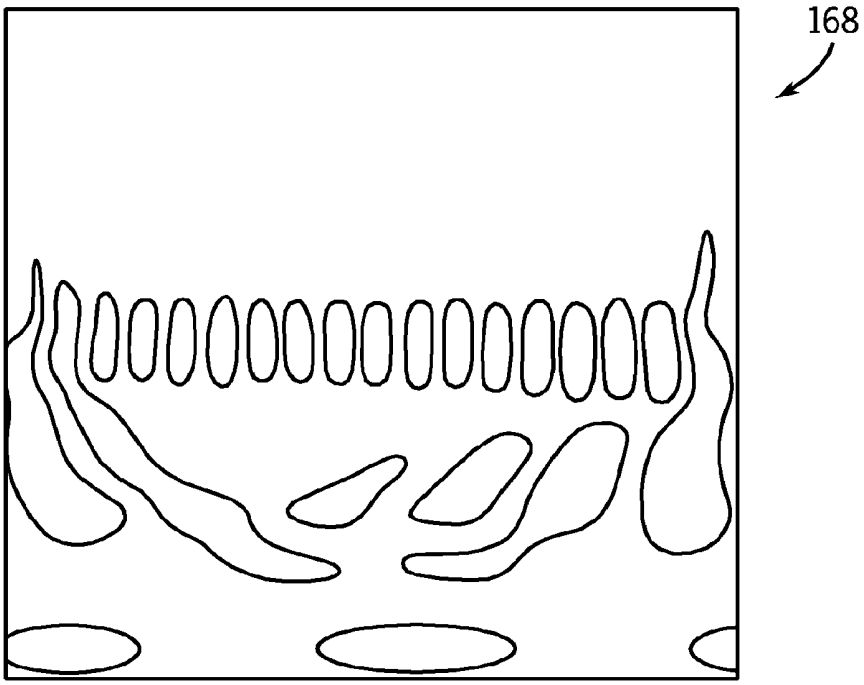


FIG. 5

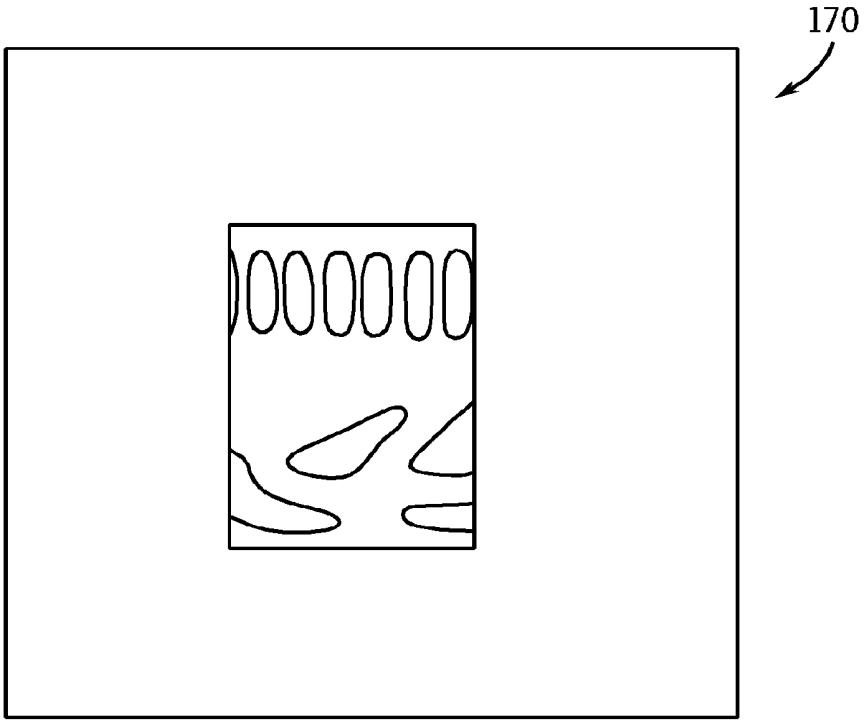


FIG. 6

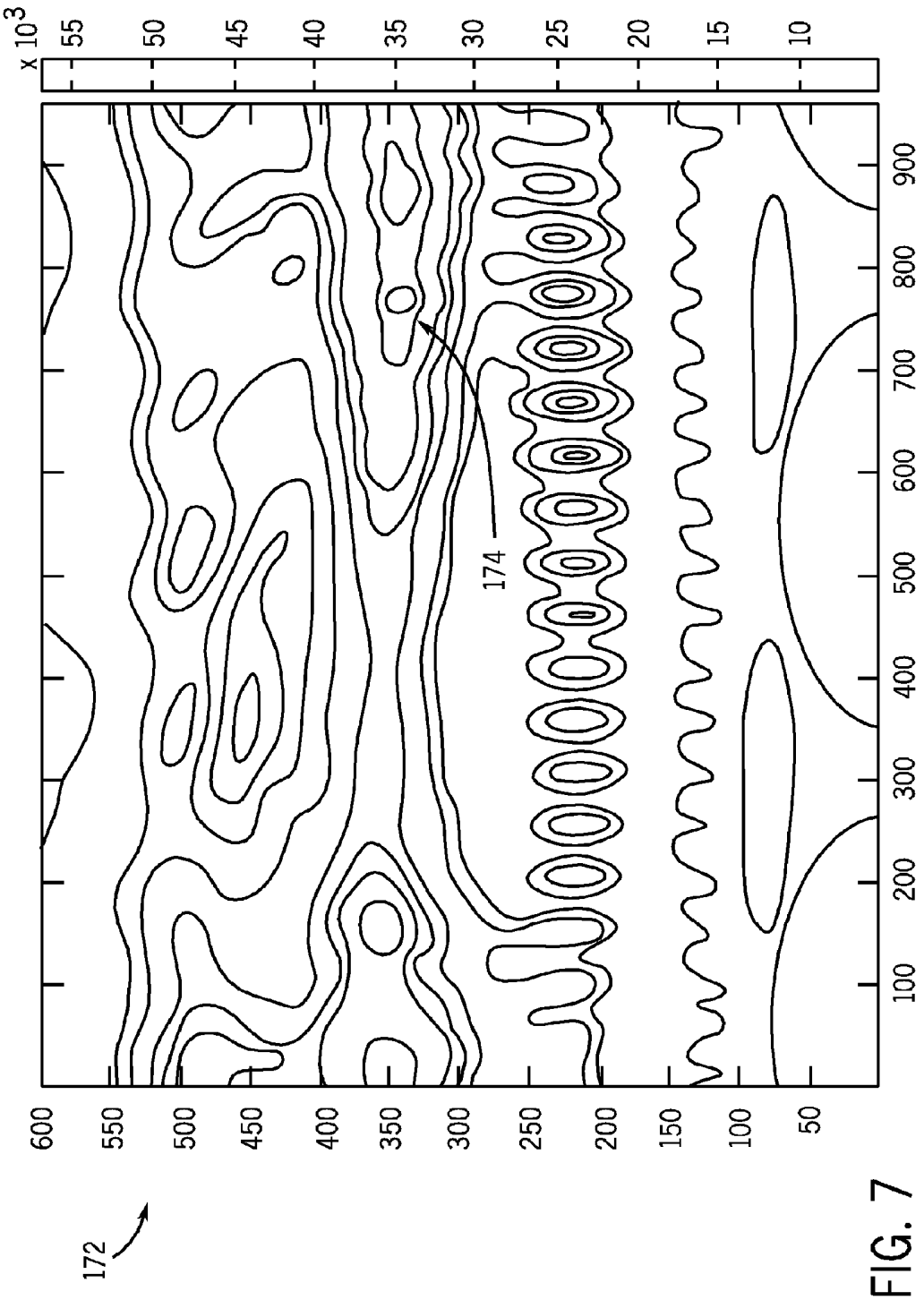

x 10^3
55
50
45
40
35
30
25
20
15
10
100
200
300
400
500
600
700
800
900
600
550
500
450
400
350
300
250
200
150
100
50
174
172

FIG. 7

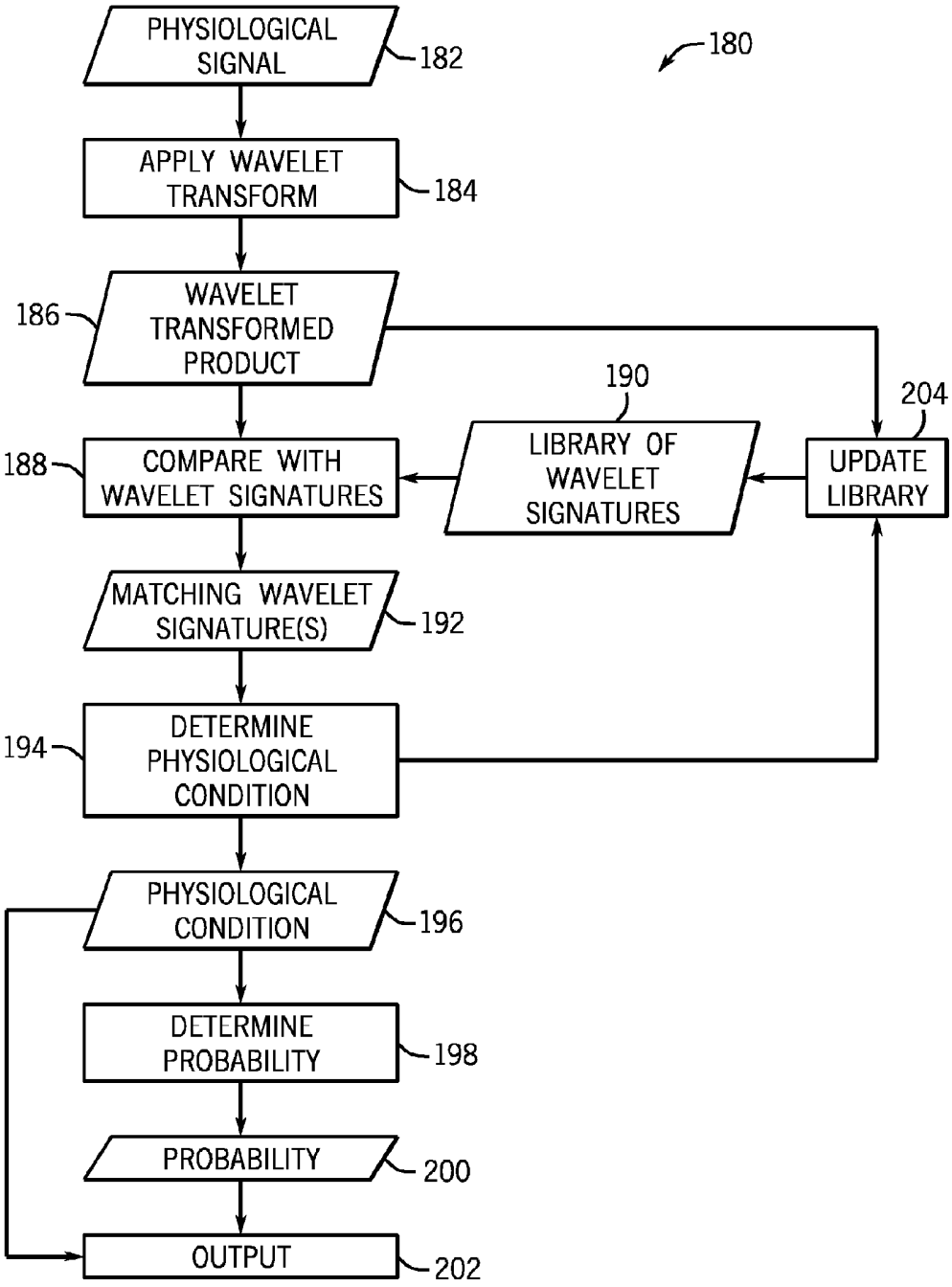

PHYSIOLOGICAL SIGNAL
182
180
APPLY WAVELET TRANSFORM
184
186
WAVELET TRANSFORMED PRODUCT
190
204
188
COMPARE WITH WAVELET SIGNATURES
LIBRARY OF WAVELET SIGNATURES
UPDATE LIBRARY
MATCHING WAVELET SIGNATURE(S)
192
194
DETERMINE PHYSIOLOGICAL CONDITION
PHYSIOLOGICAL CONDITION
196
DETERMINE PROBABILITY
198
PROBABILITY
200
OUTPUT
202

FIG. 8

DETERMINATION OF A PHYSIOLOGICAL PARAMETER

RELATED APPLICATION

[0001] This application is a continuation of U.S. patent application Ser. No. 12/856,801, entitled "Determination of a Physiological Parameter," filed Aug. 16, 2010, which claims the benefit of U.S. Provisional Application No. 61/245,575, entitled "Determination of a Physiological Parameter," filed Sep. 24, 2009, each of which is herein incorporated by reference in their entirety.

BACKGROUND

[0002] The present disclosure relates generally to medical devices and, more particularly, to methods of analyzing physiological parameters using wavelet transforms.

[0003] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0004] In the field of medicine, doctors often desire to monitor certain physiological characteristics of their patients. Accordingly, a wide variety of devices have been developed for monitoring many such physiological characteristics. Such devices provide doctors and other healthcare personnel with the information they need to provide the best possible healthcare for their patients. As a result, such monitoring devices have become an indispensable part of modern medicine.

[0005] One technique for monitoring certain physiological characteristics of a patient is commonly referred to as pulse oximetry, and the devices built based upon pulse oximetry techniques are commonly referred to as pulse oximeters. Pulse oximetry may be used to measure various blood flow characteristics, such as the blood-oxygen saturation of hemoglobin in arterial blood, the volume of individual blood pulsations supplying the tissue, and/or the rate of blood pulsations corresponding to each heartbeat of a patient. In fact, the "pulse" in pulse oximetry refers to the time varying amount of arterial blood in the tissue during each cardiac cycle.

[0006] Pulse oximeters typically utilize a non-invasive sensor that transmits light through a patient's tissue and that photoelectrically detects the absorption of the transmitted light in such tissue. A typical pulse oximeter may use light emitting diodes (LEDs) to measure light absorption by the blood. The absorbed and/or scattered light may be detected by the pulse oximeter, which may generate a signal that is proportional to the intensity of the detected light. The received signal may be further processed, and various physiological parameters may be determined based on signal features.

[0007] As certain signal features in the signal may be analyzed to determine physiological parameters, it may be beneficial to analyze the signal in a form from which various signal characteristics may be perceived. For example, some signal processing techniques include transforming the signal such that it may be analyzed in the frequency domain. However, such analyses may not provide information that is discernable in the time domain. Methods of processing the signal to perceive various signal characteristics in different domains, and methods of analyzing the processed signal may better enable the identification of physiological conditions based on a physiological signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Advantages of the disclosed techniques may become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0009] FIG. **1** illustrates a perspective view of a pulse oximeter in accordance with an embodiment;

[0010] FIG. **2** illustrates a simplified block diagram of a pulse oximeter, according to an embodiment;

[0011] FIGS. **3** and **4** depict, respectively, a graph of physiological signal and a corresponding scalogram resulting from a wavelet transformation of the physiological signal, according to an embodiment;

[0012] FIGS. **5-7** illustrate a method of comparing the wavelet transformation of a physiological signal to a wavelet transformation of a signal corresponding to a physiological condition, according an embodiment; and

[0013] FIG. **8** is a flow chart of a method for determining a physiological condition based on a wavelet transformation of a physiological signal, according to an embodiment.

DETAILED DESCRIPTION

[0014] One or more specific embodiments of the present techniques will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0015] Present embodiments relate to determining information from a patient's physiological signal based on a processing and/or comparison of the physiological signal with known signal features. More specifically, a physiological signal is generated by a physiological monitoring system, such as pulse oximeter, in response to light that is detected after being emitted and transmitted through the patient's tissue. The physiological signal may be processed using wavelet transforms to determine various physiological parameters. A wavelet transformation of the physiological signal may enable analyses of certain signal characteristics with respect to both time and frequency. While certain processing techniques or transformations of the physiological signal may result in a globally averaged energy value without information regarding the temporal components of the signal, continuous wavelet transformations may produce information regarding characteristics of the physiological signal (e.g., frequency and/or amplitude) with regard to temporal locations.

[0016] The wavelet transformation of the physiological signal, or the wavelet transformed product, may be analyzed for known signal features by comparing the wavelet transformed product to a library of wavelet signatures. Each of the wavelet signatures in the library may correspond to one or

more physiological conditions and/or patient characteristics. Signal processing techniques may be utilized to determine whether the wavelet transformed product shares substantially similar characteristics with the wavelet signatures, which may indicate that the patient has the physiological condition correlated with the similar wavelet signature. As wavelet transformed products may enable analyses of multiple dimensions of signal characteristics (e.g., frequency and amplitude with respect to time), comparisons between the wavelet transformed products and the wavelet signatures may also include comparisons of multiple dimensions of signal characteristics. Such multi-dimension analyses and/or comparisons may provide more information for estimating physiological data from the physiological signal, and may enable a more accurate estimation than a comparison of signal characteristics in one dimension. In some embodiments, the probability of a physiological condition may also be produced to indicate the accuracy of the physiological data estimates.

[0017] Furthermore, analyses based on wavelet transforms may also involve a supervised learning technique, such as a neural network. For example, previous determinations of physiological conditions may be used to determine physiological conditions in future analyses. In one embodiment, an analysis of a previous wavelet transformed product may have categorized the previous wavelet transformed product as displaying signal characteristics corresponding to a particular physiological condition. Data from the analyses of the previous wavelet transformed product may be used to update the library of wavelet signatures, and/or may be used to form filters for identifying one or more current physiological conditions in analyses of future wavelet transformed products.

[0018] Analyzing the wavelet transformed product may also be useful in identifying components in the physiological signal which may be non-physiological and may affect the accuracy of physiological data determined from the signal. For example, various types of noise and interference that may affect the accuracy physiological data estimations may include non-physiological noise sources such as electrical noise, patient motion, or other interferences. Certain non-physiological signal components may be identifiable when amplitude and/or frequency characteristics are analyzed with regard to temporal locations. In some embodiments, the non-physiological signal components may also be removed after they are identified, such that calculations and/or comparisons may be performed on a "clean" wavelet transformed product, improving the likelihood of estimating accurate physiological data.

[0019] Turning to FIG. **1**, a perspective view of a medical device is illustrated in accordance with an embodiment. The medical device may be a pulse oximeter system **100**. The pulse oximeter system **100** may include a monitor **102**, such as those available from Nellcor Puritan Bennett LLC. The pulse oximeter system **100** may be utilized to observe the blood constituents of a patient's arterial blood to facilitate estimation of the state of oxygen exchange in the patient's body by emitting light into tissue and detecting the light after dispersion and/or reflection by the tissue. The amount of light that passes through the tissue and other characteristics of the light may vary in accordance with the changing amount of certain blood constituents in the tissue and the related light absorption and/or scattering. As with conventional pulse oximeter systems, the pulse oximeter system **100** may emit light from two or more LEDs or lasers into pulsatile tissue and then detect the transmitted light with a light detector (e.g., a photodiode or photo-detector) after the light has passed through the pulsatile tissue. Such measurements may be utilized to estimate a percentage of blood oxygen saturation in the probed volume of blood.

[0020] The monitor **102** may be configured to display calculated parameters on a display **104**. As illustrated in FIG. **1**, the display **104** may be integrated into the monitor **102**. However, the monitor **102** may also be configured to provide data via a port to an external display or secondary monitor. The display **104** may be configured to display computed physiological data including, for example, an oxygen saturation percentage, a pulse rate, and/or a plethysmographic waveform **106**. The oxygen saturation percentage may be a functional arterial hemoglobin oxygen saturation measurement in units of percentage SpO_2, while the pulse rate may indicate a patient's pulse rate in beats per minute. The monitor **102** may also display information related to alarms, monitor settings, and/or signal quality via indicator lights **108**.

[0021] To facilitate user input, the monitor **102** may include a plurality of control inputs **110**. The control inputs **110** may include fixed function keys, programmable function keys, and soft keys. Specifically, the control inputs **110** may correspond to soft key icons in the display **104**. Pressing control inputs **110** associated with, or adjacent to, an icon in the display may select a corresponding option. The monitor **102** may also include a casing **111**. The casing **111** may aid in the protection of the internal elements of the monitor **102** from damage.

[0022] The monitor **102** may further include a sensor port **112**. The sensor port **112** may allow for connection to an external sensor **114**, via a cable **115** which connects to the sensor port **112**. The sensor **114** may be of a disposable or a non-disposable type. Furthermore, the sensor **114** may obtain readings from a patient, which can be used by the monitor to calculate certain physiological characteristics such as the blood-oxygen saturation of hemoglobin in arterial blood, the volume of individual blood pulsations supplying the tissue, and/or the rate of blood pulsations corresponding to each heartbeat of a patient.

[0023] Turning to FIG. **2**, a simplified block diagram of a pulse oximeter system **100** is illustrated in accordance with an embodiment. Specifically, certain components of the sensor **114** and the monitor **102** are illustrated in FIG. **2**. The sensor **114** may include an emitter **116**, a detector **118**, and an encoder **120**. The emitter **116** may receive modulated drive signals from the monitor **102**, and may activate and deactivate a light emitting device at certain intervals. For example, the monitor **102** may activate and deactivate components that emit light of different wavelengths, such that light of different wavelength is alternately emitted.

[0024] The emitter **116** may be capable of emitting one or more wavelengths of light, e.g., RED and infrared (IR) light, into the tissue of a patient **117**, where the RED wavelength may be between about 600 nm and about 700 nm, and the IR wavelength may be between about 800 nm and about 1000 nm. The emitter **116** may include a single emitting device, for example, with two light emitting diodes (LEDs) or the emitter **116** may include a plurality of emitting devices with, for example, multiple LED's at various locations. Regardless of the number of light emitting devices, the emitter **116** may be used to measure, for example, blood oxygen saturation, water fractions, hematocrit, or other physiologic parameters of the patient **117**, as discussed herein. It should be understood that, as used herein, the term "light" may refer to one or more of

radio, microwave, millimeter wave, infrared, visible, ultraviolet, gamma ray or X-ray electromagnetic radiation, and may also include any wavelength within the radio, microwave, infrared, visible, ultraviolet, or X-ray spectra, and that any suitable wavelength of light may be appropriate for use in accordance with the present disclosure.

[0025] In one embodiment, the detector **118** may be an array of detector elements that may be capable of detecting light at various intensities and wavelengths. In operation, light enters the detector **118** after passing through the tissue of the patient **117**. The detector **118** may convert the light at a given intensity, which may be directly related to the absorbance and/or reflectance of light in the tissue of the patient **117**, into an electrical signal. That is, when more light at a certain wavelength is absorbed or reflected, less light of that wavelength is typically received from the tissue by the detector **118**. For example, the detector **118** may include one or more photodiodes, or any other element capable of converting light into either a current or voltage. After converting the received light to an electrical signal, the detector **118** may send the signal, which may be a pleth signal, to the monitor **102**, where physiological characteristics may be calculated based at least in part on the absorption of light in the tissue of the patient **117**.

[0026] In some embodiments, the sensor **114** may include an encoder **120**, which may contain information about the sensor **114**, such as what type of sensor it is (e.g., whether the sensor is intended for placement on a forehead or digit) and the wavelengths of light emitted by the emitter **116**. This information may allow the monitor **102** to select appropriate algorithms and/or calibration coefficients for calculating the patient's **117** physiological characteristics. The encoder **120** may, for instance, be a memory on which one or more of the following information may be stored for communication to the monitor **102**: the type of the sensor **114**; the wavelengths of light emitted by the emitter **116**; and the proper calibration coefficients and/or algorithms to be used for calculating the patient's **117** physiological characteristics. In one embodiment, the data or signal from the encoder **120** may be decoded by a detector/decoder **121** in the monitor **102**.

[0027] Signals from the detector **118** and the encoder **120** may be transmitted to the monitor **102**. The monitor **102** may include one or more processors **122** coupled to an internal bus **124**. Also connected to the bus **124** may be a RAM memory **126** and a display **104**. The monitor **102** may also include a modulator **132**, which may include a time processing unit (TPU) **128** and light drive circuitry **130**. The modulator **132** may modulate the drive signals that activate the LEDs or other emitting structures of the emitter **116**. The modulator **132** may be hardware-based, software-based, or some combination thereof. For example, a software aspect of the modulator **132** may be stored on the memory **126** and may be controlled by the processor **122**. The TPU **128** may include a sine wave generator, and may provide timing control signals to light drive circuitry **130**, which controls when the emitter **116** is activated, and if multiple light sources are used, the multiplexed timing for the different light sources. TPU **128** may also control the gating-in of signals from detector **118** through a switching circuit **134**. These signals are sampled at the proper time, depending at least in part upon which of multiple light sources is activated, if multiple light sources are used.

[0028] The received signal from the detector **118** may be processed to provide certain physiological data. In one embodiment, the received signal may be passed through an amplifier **136**, a low pass filter **138**, and an analog-to-digital converter (ADC) **140** for amplifying, filtering, and digitizing the electrical signals the from the sensor **114**. The digital data may then be stored in a queued serial module (QSM) **142**, for later downloading to RAM **126** as QSM **142** fills up. There may also be multiple parallel paths for separate amplifiers, filters, and A/D converters for multiple light wavelengths or spectra received. Further, the processor **122** may calculate the oxygen saturation based on the received signals corresponding to the light received by the detector **118**. For example, the processor **122** may perform instructions or algorithms stored on the memory **144**, and may be configured to perform calculations to estimate physiological parameters based on the received signals.

[0029] The processor **122** may also be configured to perform various signal processing operations (e.g., filtering, warping, Fourier transforms, and/or wavelet transforms, etc.) in the estimation of physiological parameters. For example, the processor **122** may apply a wavelet transform to the physiological signal, and the wavelet transformed product may be analyzed to identify a physiological condition and/or identify non-physiological signal components. In some embodiments, the wavelet transformed product may be compared with other wavelet transformations which correspond to various physiological conditions. A table of wavelet transformations may be stored in the RAM **126** or memory **144**. Furthermore, the processor **122** may utilize a supervised learning technique, such as a neural network, to identify physiological conditions in a physiological signal.

[0030] The graph **150** of FIG. **3**, depicts the amplitude **152** over time **154** of a physiological signal **156** which may be generated by a monitor **102** in response to light received at the detector **118** (as in FIG. **2**). The physiological signal **156** may be any signal from which may be processed according to the present techniques, and may include information obtainable by emitting various types of waves towards the patient **117**, including photon density waves. For example, the physiological signal **156** may include a plethysmographic (pleth) signal or phase change signal (e.g., from a photon density wave).

[0031] The physiological signal **156** may be processed to enable the identification of certain physiological parameters of the patient **117**. In one embodiment, wavelet transforms may be applied at the monitor **102** to produce an energy map having both time and frequency information. In one embodiment, algorithms or instructions may be implemented or performed by the monitor **102** (e.g., by the processor **122**) to transform the physiological signal **156**, such that the signals may be analyzed with respect to time, frequency, and/or amplitude. For example, the wavelet transform of a signal x(t) may be defined in the equation below:

$$T(a,b)=\frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty}x(t)\psi^{*}\left(\frac{t-b}{a}\right)dt \qquad \text{eq. (1)}$$

[0032] In eq. (1), $\psi'(t)$ is the complex conjugate of the wavelet function $\psi(t)$. The variable a is the dilation parameter of the wavelet, and b is the location parameter of the wavelet. In one or more embodiments, any suitable wavelet function, including a Morlet wavelet, may be used to obtain a time-frequency representation of the physiological signal **156**. The transform of eq. (1) may be regarded as a time-frequency

representation where the characteristic frequency associated with the wavelet is inversely proportional to the scale a, and can be used to construct a representation of a signal on a transform surface. The energy density function of the wavelet transform, also referred to as the scalogram, may be defined by the equation below:

$$S_R(a, b) = \frac{|T(a, b)|^2}{a} \quad \text{eq. (2)}$$

where "| |" is the modulus operator. Thus, by applying the wavelet transform on a time-based signal for the time-frequency representation of the signal, and then applying the energy density function of the wavelet transform, a scalogram may be produced. The scalogram, which may also be interpreted as a spectral density of frequency over time, may be a three dimensional model (having time, frequency, and magnitude) from which certain physiological information may be obtained.

[0033] A wavelet transformation of the physiological signal **156** in FIG. **3** is represented as the scalogram **160** in FIG. **4**. As discussed, the scalogram **160** may be an example of a wavelet transformed product, and may be a time-frequency representation of the physiological signal **156**. The physiological signal **156** and the time-frequency representation of the signal **156** may be represented over the same time **154** in the graph **150** and the scalogram **160**. The scalogram **160** may provide a relationship between frequency **162** and amplitude, which may be depicted as a spectral density **164** in the scalogram **160**. For example, a spectral range **164** may be used to determine the signal amplitude at any temporal location **154**.

[0034] Different features may be seen at different frequencies of the scalogram **160**, and may match temporally with the original physiological signal **156**. For example, changes in amplitude or frequency in the physiological signal **156**, such as the amplitude peaks **158**, may correspond to certain spectral variations, such as the features **166**, in the spectral density **164** of the scalogram **160**. The amplitude peaks **158** and/or features **166** in the scalogram **160** may correspond to some physiological parameter (e.g., oxygen saturation, pulse rate, breathing rate, etc.) within a frequency band of the wavelet-transformed signal **156**.

[0035] Certain features **166** in the scalogram **160**, such as patterns, ridges, or spots, may be the locus of points of local maxima in the plane, and may provide information such as amplitude or instantaneous frequency of the signal **156** at that temporal location **154**. Thus, both the amplitude (i.e., represented by the spectral density **164**), as well as the instantaneous frequency **162** of the physiological signal **156**, may be available for any temporal location **154** of the scalogram **160**. As some transformations (e.g., a typical Fourier transformation) may return a globally averaged energy value without information regarding the temporal location of signal components, the temporal location of certain signal characteristics may not be available. Thus, applying wavelet transforms may be particularly useful in identifying certain signal features within the physiological signal **156**. The identification of certain signal features of the physiological signal **156** through its corresponding scalogram **160** may enable the monitor **102** to better determine various physiological conditions.

[0036] Due to the repetitive nature of physiological conditions, a wavelet analysis of a physiological signal enabling analyses with respect for temporal location may used to detect repetition or patterns in a scalogram. Thus, various physiological conditions may be determined by analyzing certain repeated features (e.g., patterns of ridges, spots, etc.). In contrast, noise, motion artifacts, and other non-repetitive phenomena which are not typically characterized by a recurring pattern or signature may be identified as a non-physiological signal component. Thus, various non-physiological components, such as spectral peaks or spikes, may also be identified and resolved (e.g., disregarded, removed, etc.) to produce more accurate data estimates from the physiological signal.

[0037] FIGS. **5-7** depict one example of how a pattern indicative of a physiological condition may be detected in a scalogram. In one embodiment, a physiological signal may be processed, such as by applying wavelet transforms, to produce a wavelet transformed product, represented by the scalogram **168** in FIG. **5**. The scalogram **168** may be analyzed in view of a wavelet signature **170** (FIG. **6**), which may be a wavelet transform or some portion thereof, to determine the presence of some pattern of interest exemplified by the wavelet signature **170**. For example, in some embodiments, the scalogram **168** may be cross-correlated with the wavelet signature **170** to determine whether the pattern of interest is present in the scalogram **168**. The resulting image **172** (FIG. **7**) may represent a cross-correlation of the scalogram **168** with the wavelet signature **170**. The identification of some pattern of interest in the scalogram **168** may include setting a threshold spectral intensity for the resulting image **172**. Instances in the image **172** that exceed a threshold intensity may indicate that the pattern from the wavelet signature **170** is present in the spectrogram **168**. For example, the presence of the depicted darker spot **174** in the image **172** may be used to determine that a pattern from the signature **170** exists in the scalogram **168**. Detecting pattern in the scalogram **168** may indicate that the patient of the scalogram **168** has one or more physiological conditions.

[0038] The present techniques include analyzing a wavelet transformed physiological signal (e.g., a scalogram) with multiple wavelet signatures, such as the wavelet signature **170** of FIG. **6**. Each wavelet signature may be a wavelet transformation of a signal corresponding to a physiological condition. For example, in some embodiments, multiple wavelet signatures may be organized in a library of wavelet signatures and stored in the RAM **126** or the ROM **144** of the monitor **102** (as in FIG. **2**). The monitor **102** may utilize various matching or filtering techniques to determine whether a wavelet transformed product shares substantially similar characteristics to any of the wavelet signatures in the library. For example, cross-correlation techniques and/or threshold techniques similar to those described with respect to FIGS. **5-7** may be used for each wavelet signature analysis. When a monitor **102** determines that a wavelet transformed product has a high correlation with a particular wavelet signature, the monitor may categorize the patient **117** from which the signal was generated as having a particular physiological condition.

[0039] Furthermore, the monitor **102** may execute a supervised learning technique, such as an artificial neural network, to determine physiological data from a wavelet transformed product. An artificial neural network may be used to represent or process nonlinear functions, such as a wavelet transformed product, and apply and/or analyze the wavelet transformed product with a large data set, such as a library of wavelet signatures. The artificial neural network engine may be data

processing architecture which may be implemented in software, hardware, or a combination of both. Further, the artificial neural network may be executed by the processor **122**, an external computer system coupled to the monitor **102**, or by hardware of the monitor **102** (not illustrated). In some embodiments, a supervised learning technique may involve utilizing a previously analyzed wavelet transformed physiological signal to update a library of wavelet signatures.

[0040] Determining a physiological condition based on a wavelet transformation of a physiological signal and a comparison of the wavelet transformed signal with multiple wavelet signatures may be depicted in the flow chart **180** of FIG. **8**. As discussed, a physiological signal **182** may be generated in response to an intensity of light received at a detector **118** of a pulse oximeter sensor **114** (as in FIGS. **1** and **2**). The monitor **102** may process the physiological signal **182** by applying wavelet transforms (block **184**) to produce a wavelet transformed product **186** that is a representation of the physiological signal **182** in time and frequency domains. For example, the wavelet transformed product **186** may be represented in a scalogram (as in FIGS. **4** and **5**). The monitor **102** may then analyze the wavelet transformed product **186** to determine physiological data.

[0041] The monitor **102** may analyze the wavelet transformed product **186** by comparing the product **186** with a library **190** of wavelet signatures **170** (block **188**). Each of the wavelet signatures **170** may be a wavelet transformation having features and/or patterns which correspond to a particular physiological condition. Furthermore, the wavelet signatures **170** may be categorized in the library **190** based on patient characteristics such as gender, age, weight, or diagnosis, or characteristics of the pulse oximeter **100**, including sensor type, sensor placement, etc. The categorization of wavelet signatures may enable the monitor **102** to compare the wavelet transformed product **186** with the most relevant wavelet signatures in the library **190**. For example, the monitor may determine which of the wavelet signatures **170** in the library **190** have similar patient characteristics as the patient and similar sensor specifications as the sensor measuring the physiological signal **182**. The monitor **102** may then determine whether the any of these wavelet signatures **170** share substantially similar characteristics (e.g., patterns of scalogram features such as ridges or spots) with the wavelet transformed product **186**. While in some embodiments, the monitor **102** may perform a comparison of the wavelet transformed product **186** with all the wavelet signatures **170** in the library **190**, in other embodiments, limiting the comparisons to categories of similar wavelet signatures **170** may reduce processing power.

[0042] The comparison of the wavelet transformed product **186** and the wavelet signatures **170** (block **188**) may be performed through cross-correlating the wavelet transformed product **186** with one or more wavelet signatures **170**, as previously discussed with respect to FIGS. **5-7**. The resulting cross-correlated images may be filtered to determine whether a matching wavelet signature **192** is present. A matching wavelet signature **192** may have similar characteristics as the wavelet transformed product **186**, or may meet a threshold level of correlation. The monitor **102** may then use the matching wavelet signature **192** to determine the physiological condition of the patient (block **194**). The monitor **102** may determine that the patient has one or more physiological conditions **196** corresponding to the matching wavelet signatures **192**.

[0043] In some embodiments, the monitor **102** may also determine the probability (block **198**) that the physiological condition **196** determined for the patient is accurate. Probability may be determined, for example, based on a level of correlation or a degree of similarity between the wavelet transformed product **186** and the matching signature **192**. In one embodiment, determining the probability (block **198**) may also include evaluating and ranking multiple physiological conditions **196**, such that the patient may have more information on possible and/or likely physiological conditions **196**. The probability **200** and/or the physiological condition(s) **196** may be output (block **202**) by the monitor **102**, for example, via the display **104**.

[0044] The display of the physiological condition(s) **196** may include physiological data, such as a patient's heart rate, oxygen saturation, or any other monitored statistic or data. The display of physiological condition(s) **196** may also include recommendations regarding a condition of the patient or the measurement of data. For example, the recommendations may include alerts to a caregiver, such as if the patient's diagnoses requires immediate attention. Recommendations may also be displayed to improve the quality of physiological data. For example, if the position of the sensor or the movement of the patient is causing an inaccurate measurement of the physiological signal **182**, thus resulting in a low probability **200**, the monitor **102** may display recommendations on how to improve the probability **200** and the accuracy of estimating physiological conditions **196**. Such diagnoses and/or recommendations may be organized on the display **104** based on the likelihood that the diagnoses or recommendations are accurate. Furthermore, in some embodiments, the display of physiological condition(s) may also include a diagnosis, such as a specific condition or disease (e.g., arrhythmia), as well as a probability **200** of the accuracy of the diagnosis.

[0045] As discussed, supervised learning techniques may also be implemented in accordance with the present techniques. In one embodiment, the monitor **102** may update the library **190** (block **204**) after determining the physiological condition **196** of the patient. Updating the library (block **204**) may include storing data of the analysis of a current wavelet transformed product **186** in the library **190**, such that future analyses of the wavelet transformed product **186** may be based on an updated library **190**. For example, the monitor may categorize the current wavelet transformed product **186** based on the patient characteristics (e.g., age, gender, diagnosis, etc.) and the determined physiological condition **196**. Thus, in future analyses, the monitor may access wavelet signatures **170** specific to the current patient, or specific to a patient having similar characteristics. Such techniques may result in a higher probability **200** that the monitor **102** may estimate an accurate physiological condition **196**, as the updated wavelet transformed product may have a higher correlation with future wavelet transformed products. This may result in higher confidence diagnoses of a patient based on the patient's wavelet transformed physiological signal.

[0046] While the disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the embodiments provided herein are not intended to be limited to the particular forms disclosed. Rather, the various embodiments may cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims.

What is claimed is:

1. A method for generating a data library, comprising:

acquiring a plurality of physiological signals associated with a physiological condition of a patient;

performing a continuous wavelet transform on each physiological signal to generate a respective wavelet transform product for each physiological signal; and

organizing the wavelet transform products so that the wavelet transform products may be searched using a current wavelet transform product derived from a current physiological signal.

2. The method, as set forth in claim **1**, wherein acquiring the plurality of physiological signals comprises acquiring the wavelet transform products.

3. The method, as set forth in claim **1**, comprising saving the wavelet transform products to the data library.

4. The method, as set forth in claim **1**, wherein the physiological condition of the patient comprises one or more of patient physiological data, recommendations, diagnoses, and patient characteristics.

5. The method, as set forth in claim **1**, comprising organizing the wavelet transform products based on one or more of patient physiological data, recommendations, diagnoses, and patient characteristics.

6. The method, as set forth in claim **1**, comprising acquiring the plurality of physiological signals from a pulse oximeter sensor of a pulse oximeter system.

7. The method, as set forth in claim **6**, comprising organizing the wavelet transform products based on characteristics of the pulse oximeter system.

8. The method, as set forth in claim **6**, wherein the pulse oximeter sensor comprises an encoder configured to transmit information indicative of a type of the pulse oximeter sensor to a processor that is configured to organize the wavelet transform products based on the type of the pulse oximeter sensor.

9. The method, as set forth in claim **1**, comprising utilizing a supervised learning technique to update the wavelet transform products in the data library with the current wavelet transform product.

10. The method, as set forth in claim **9**, wherein updating the wavelet transform products in the data library comprises categorizing the current wavelet transform product obtained from a patient based on one or both of the patient's age and the patient's gender so that the updated wavelet transform products may be searched using a future wavelet transform product derived from a future physiological signal.

11. A system for generating a data library, comprising:

a processor configured to:

acquire a plurality of physiological signals associated with a physiological condition of a patient;

perform a continuous wavelet transform on each physiological signal to generate a respective wavelet transform product for each physiological signal; and

organize the wavelet transform products so that the wavelet transform products may be searched using a current wavelet transform product derived from a current physiological signal; and

a memory configured to store the wavelet transform products.

12. The system, as set forth in claim **11**, wherein the processor is configured to organize the wavelet transform products based on one or more of patient physiological data, recommendations, diagnoses, and patient characteristics.

13. The system, as set forth in claim **11**, comprising a pulse oximetry sensor configured to acquire the plurality of physiological signals.

14. The system, as set forth in claim **13**, wherein the processor is configured to organize the wavelet transform products based on characteristics of the pulse oximeter system.

15. The system, as set forth in claim **13**, wherein the pulse oximeter sensor comprises an encoder configured to transmit information indicative of a type of the pulse oximeter sensor to the processor, and the processor is configured to organize the wavelet transform products based on the type of the pulse oximeter sensor.

16. The system, as set forth in claim **11**, wherein the processor is configured to utilize a supervised learning technique to update the wavelet transform products in the data library with the current wavelet transform product.

17. A method, comprising:

receiving a plurality of physiological signals associated with a plurality of physiological conditions from a medical monitoring system at a processor;

performing, via the processor, a continuous wavelet transform on each physiological signal to generate a respective wavelet transform product for each physiological signal; and

categorizing, via the processor, the wavelet transform products in a data library based on characteristics of the medical monitoring system.

18. The method of claim **17**, wherein the wavelet transform products in the data library are categorized based on a type of the medical monitoring system.

19. The method of claim **17**, comprising:

obtaining a current physiological signal using a current medical monitoring system;

deriving a current wavelet transform product from the current physiological signal; and

identifying the wavelet transform products obtained via the medical monitoring system having similar characteristics to the current medical monitoring system, and comparing the identified wavelet transform products to the current wavelet transform product to identify the identified wavelet transform products having similar characteristics to the current wavelet transform product.

20. The method of claim **17**, wherein the medical monitoring system is a pulse oximetry system.

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专利名称(译)	确定生理参数		
公开(公告)号	US20140378795A1	公开(公告)日	2014-12-25
申请号	US14/480190	申请日	2014-09-08
[标]申请(专利权)人(译)	柯惠有限合伙公司		
申请(专利权)人(译)	COVIDIEN LP		
当前申请(专利权)人(译)	COVIDIEN LP		
[标]发明人	MCKENNA EDWARD M		
发明人	MCKENNA, EDWARD M.		
IPC分类号	G06F19/00 G06F19/24 G06F17/30 A61B5/1455 A61B5/00		
CPC分类号	G06F19/322 A61B5/1455 A61B5/726 G06F17/30477 G06F17/30345 G06F19/3412 G06F19/24 A61B5/0015 G16H10/60 G06F16/23 G06F16/2455 G06K9/00557 G16B40/00 G16H40/40 G16H50/20		
优先权	61/245575 2009-09-24 US		
外部链接	Espacenet USPTO		

摘要(译)

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