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Al-Ali

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(54) **BIDIRECTIONAL PHYSIOLOGICAL INFORMATION DISPLAY**

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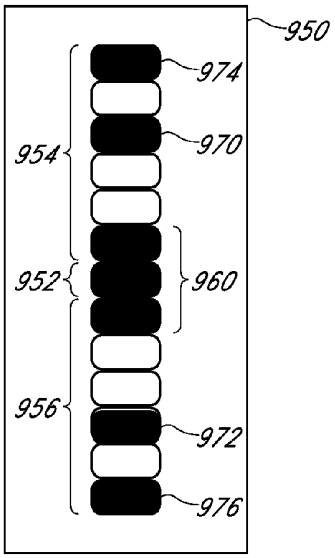
(57) **ABSTRACT**

A patient monitor for displaying a physiological signal can include a visual element having a middle portion indicative of a transition in the physiological signal between physiological states. The visual element can also include first and second extremity portions, the first extremity portion extending from the middle portion in a first direction and the second extremity portion extending from the middle portion in a second direction. The visual element can also include an actionable value indicator to specify a value about the middle portion and the first and second extremity portions. The patient monitor can also include a processor configured to cause the value indicator to actuate in both the first and second directions according to changes in the physiological signal.

20 Claims, 15 Drawing Sheets



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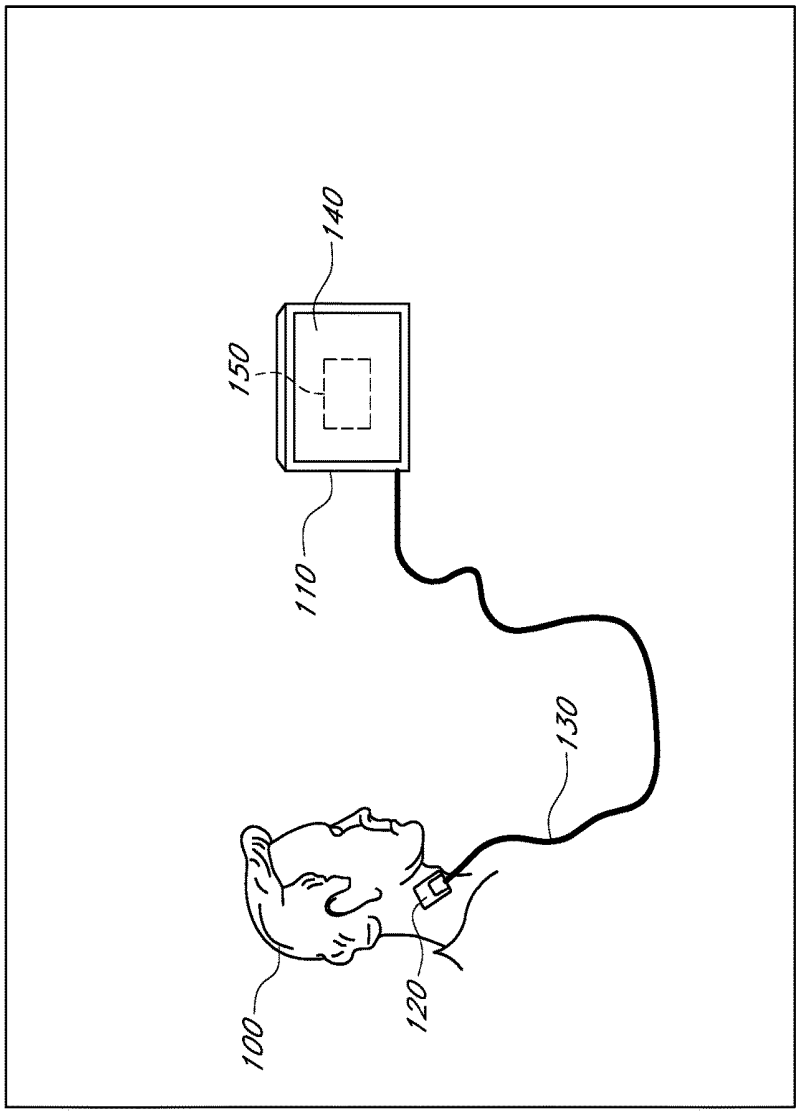

FIG. 1

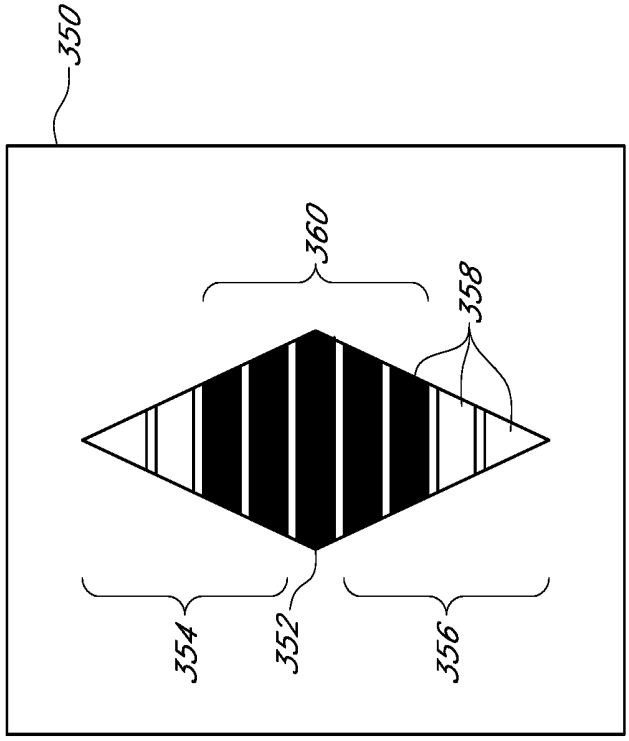

FIG. 3

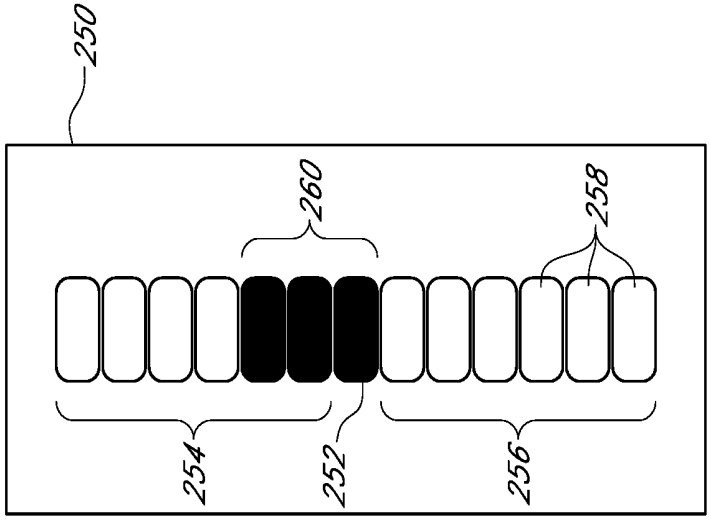

FIG. 2

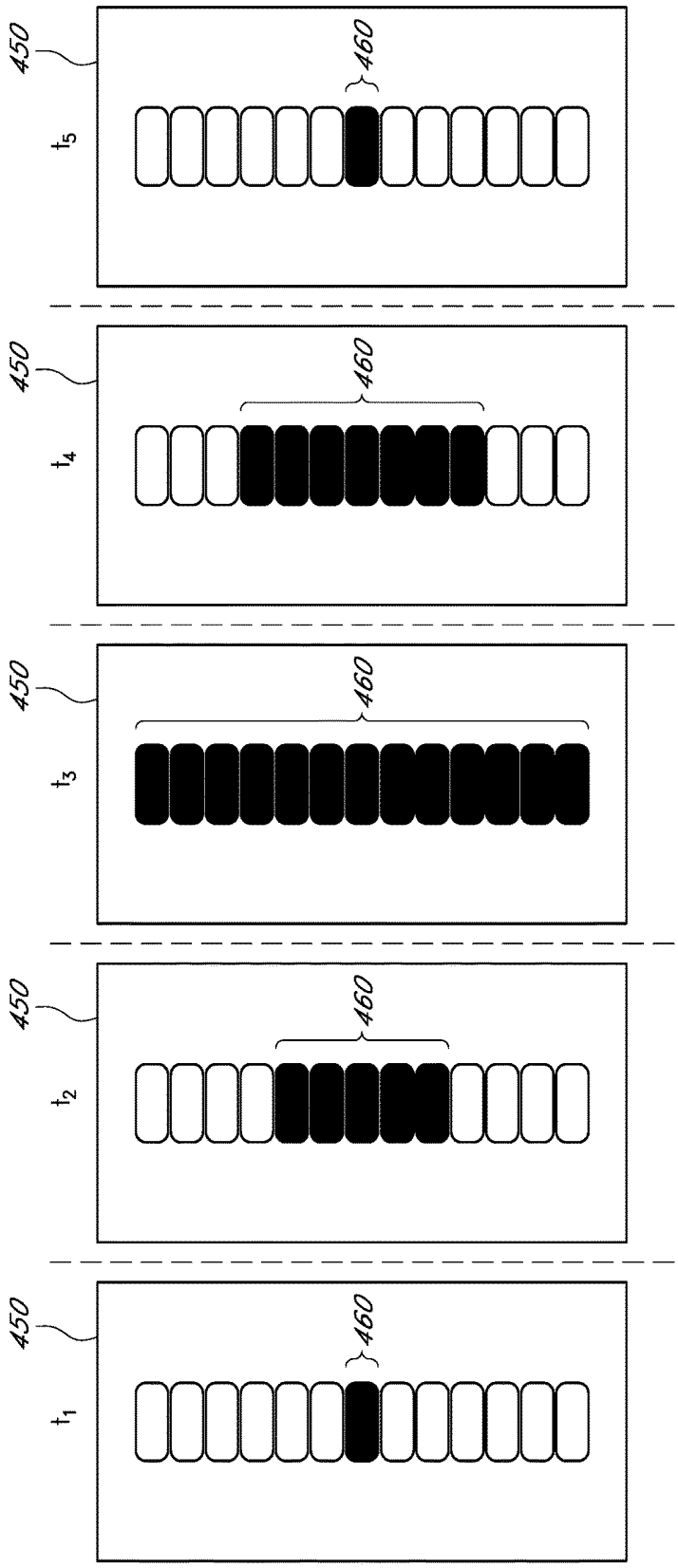

FIG. 4A

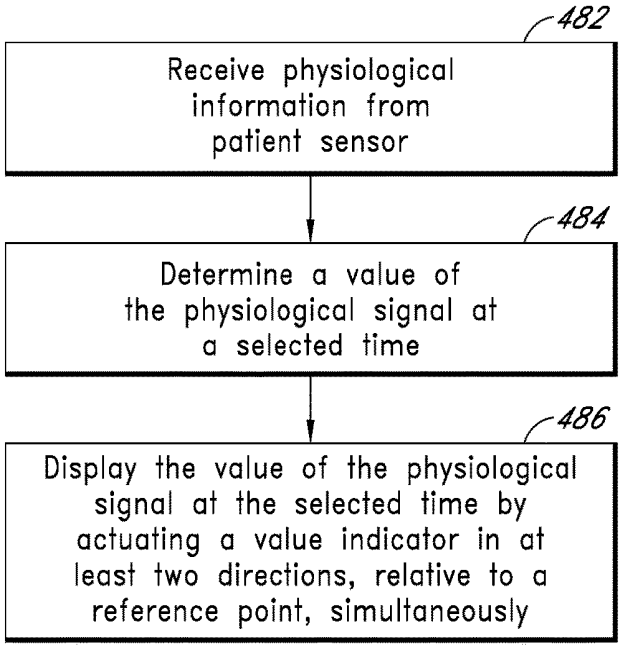
482
Receive physiological information from patient sensor
484
Determine a value of the physiological signal at a selected time
486
Display the value of the physiological signal at the selected time by actuating a value indicator in at least two directions, relative to a reference point, simultaneously

FIG. 4B

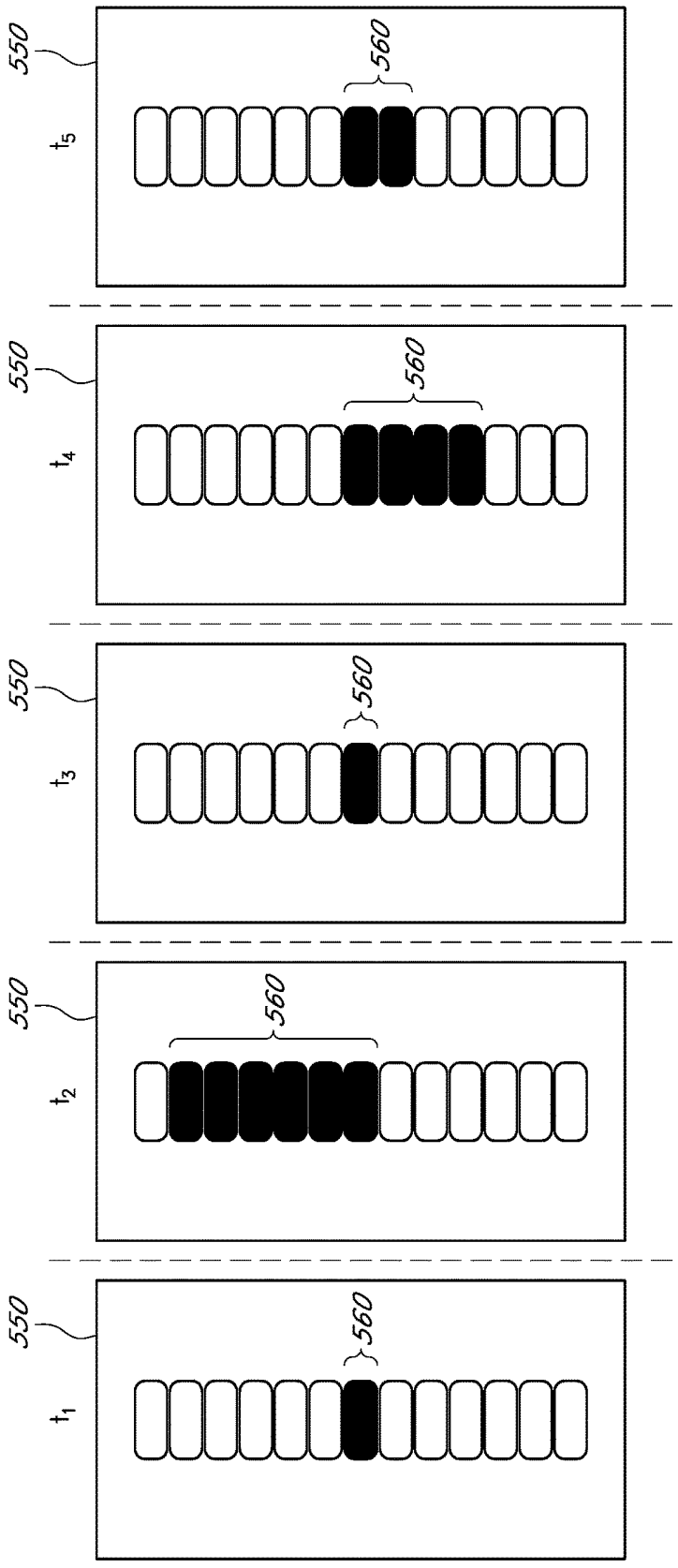

FIG. 5A

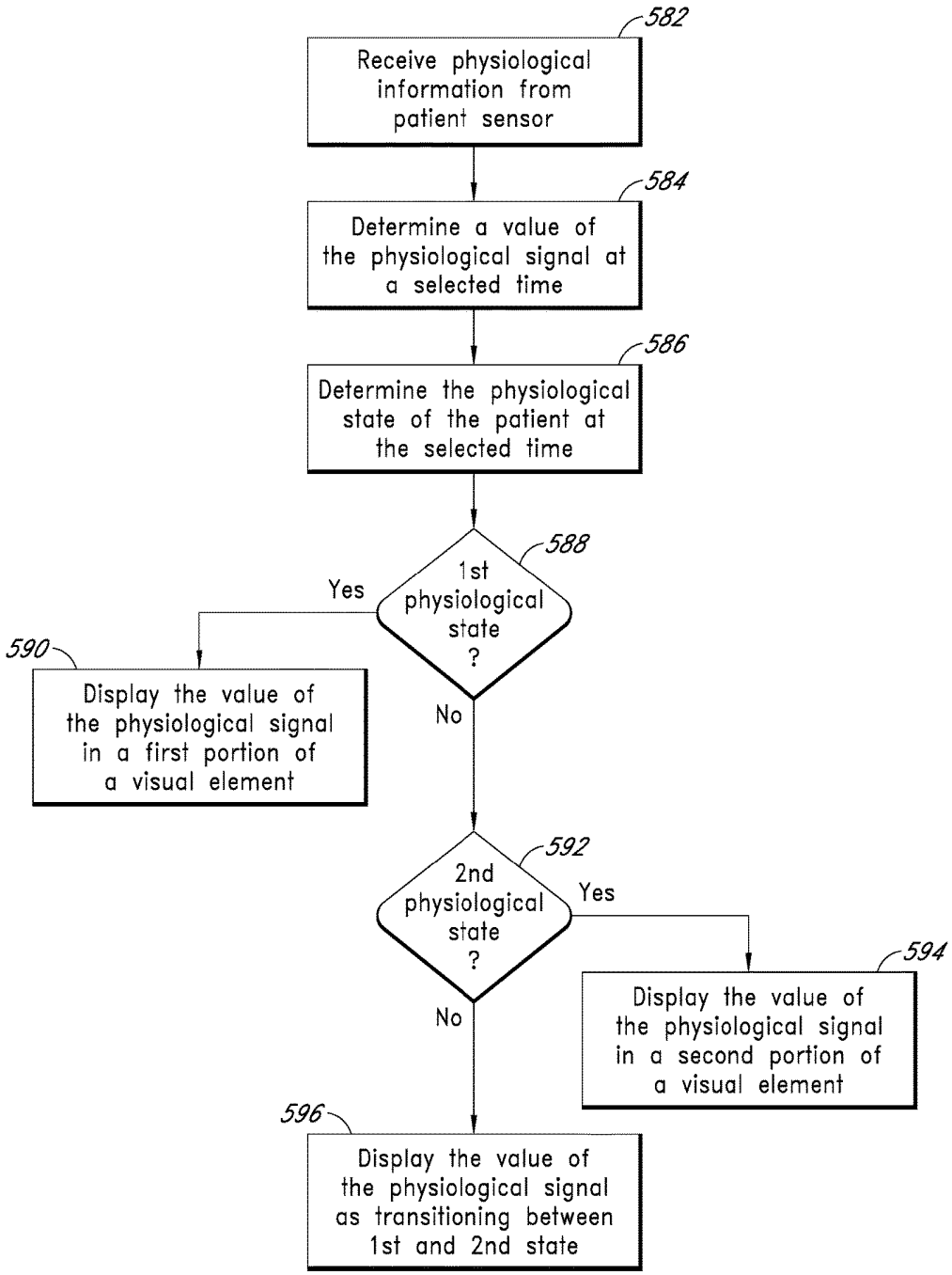
582
Receive physiological information from patient sensor
584
Determine a value of the physiological signal at a selected time
586
Determine the physiological state of the patient at the selected time
588
1st physiological state ?
Yes
590
Display the value of the physiological signal in a first portion of a visual element
No
592
2nd physiological state ?
Yes
594
Display the value of the physiological signal in a second portion of a visual element
No
596
Display the value of the physiological signal as transitioning between 1st and 2nd state

FIG. 5B

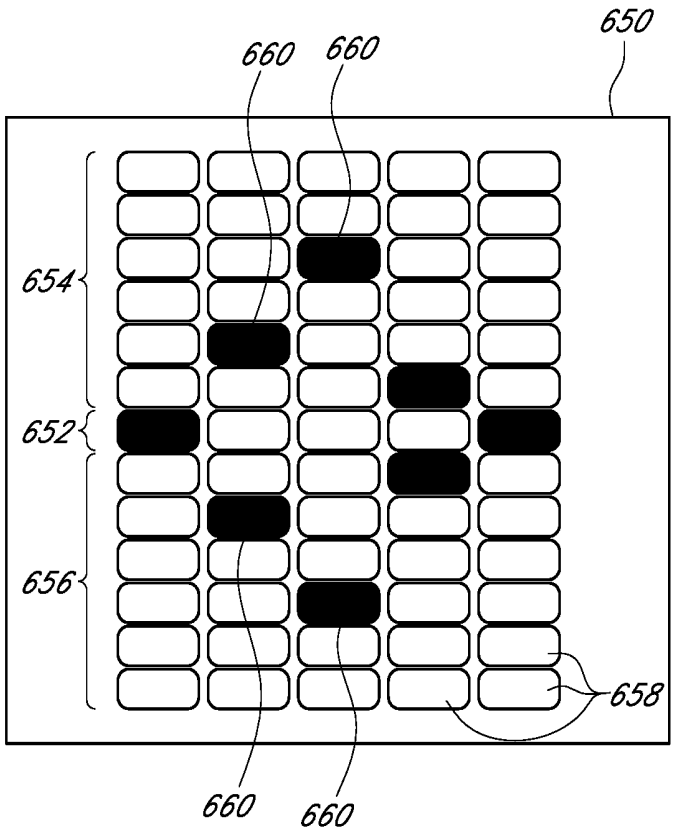

FIG. 6

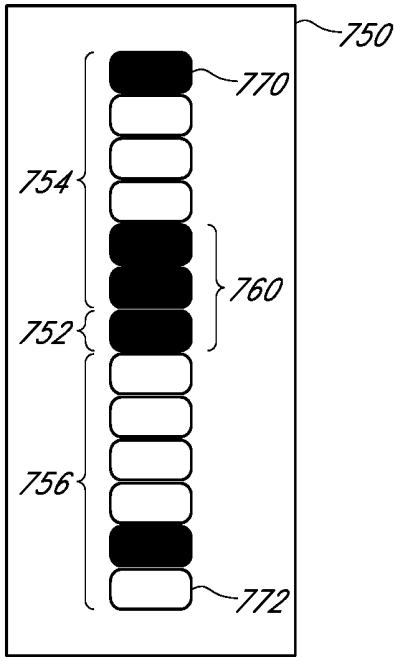

FIG. 7A

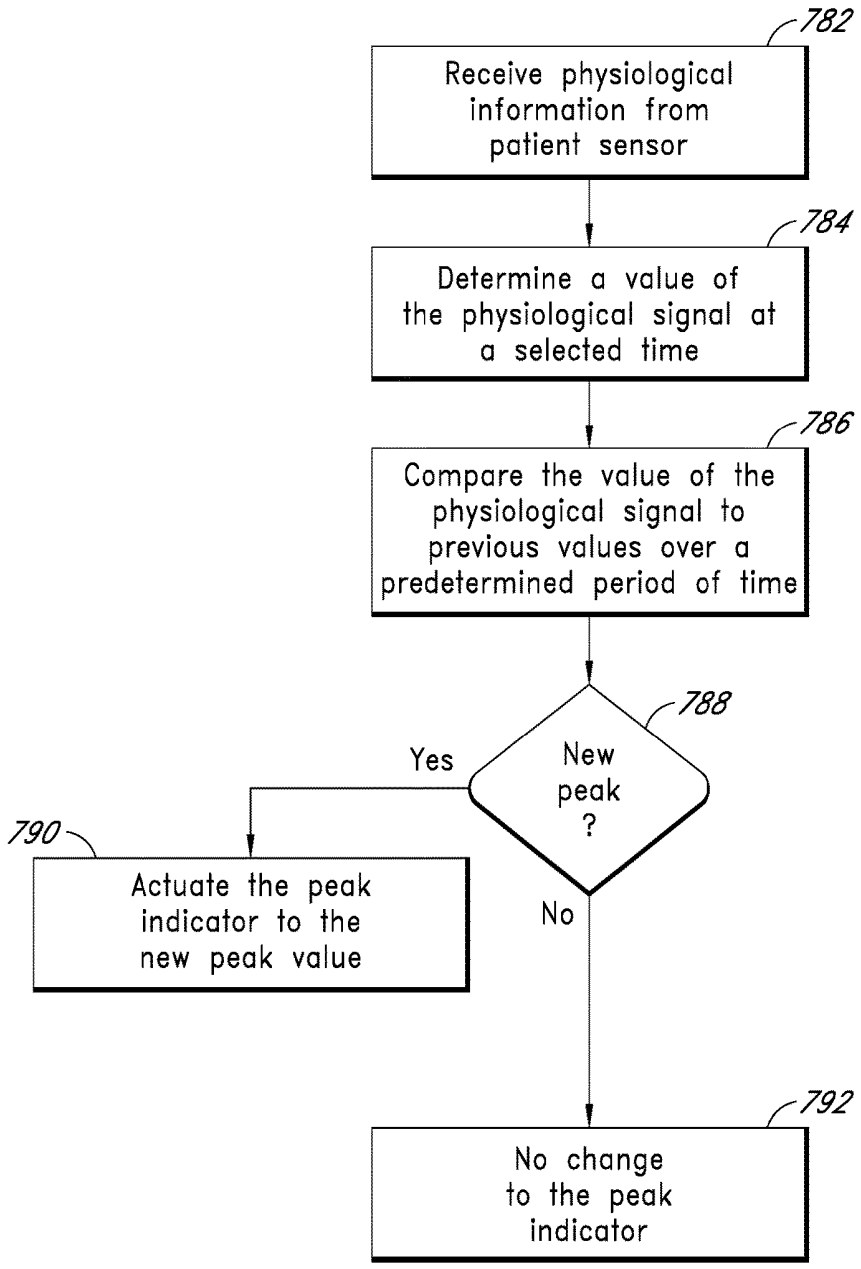
782
Receive physiological information from patient sensor
784
Determine a value of the physiological signal at a selected time
786
Compare the value of the physiological signal to previous values over a predetermined period of time
788
New peak ?
Yes
No
790
Actuate the peak indicator to the new peak value
792
No change to the peak indicator

FIG. 7B

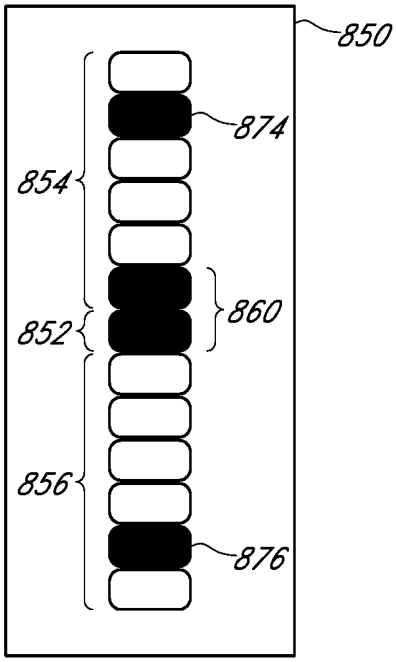

FIG. 8A

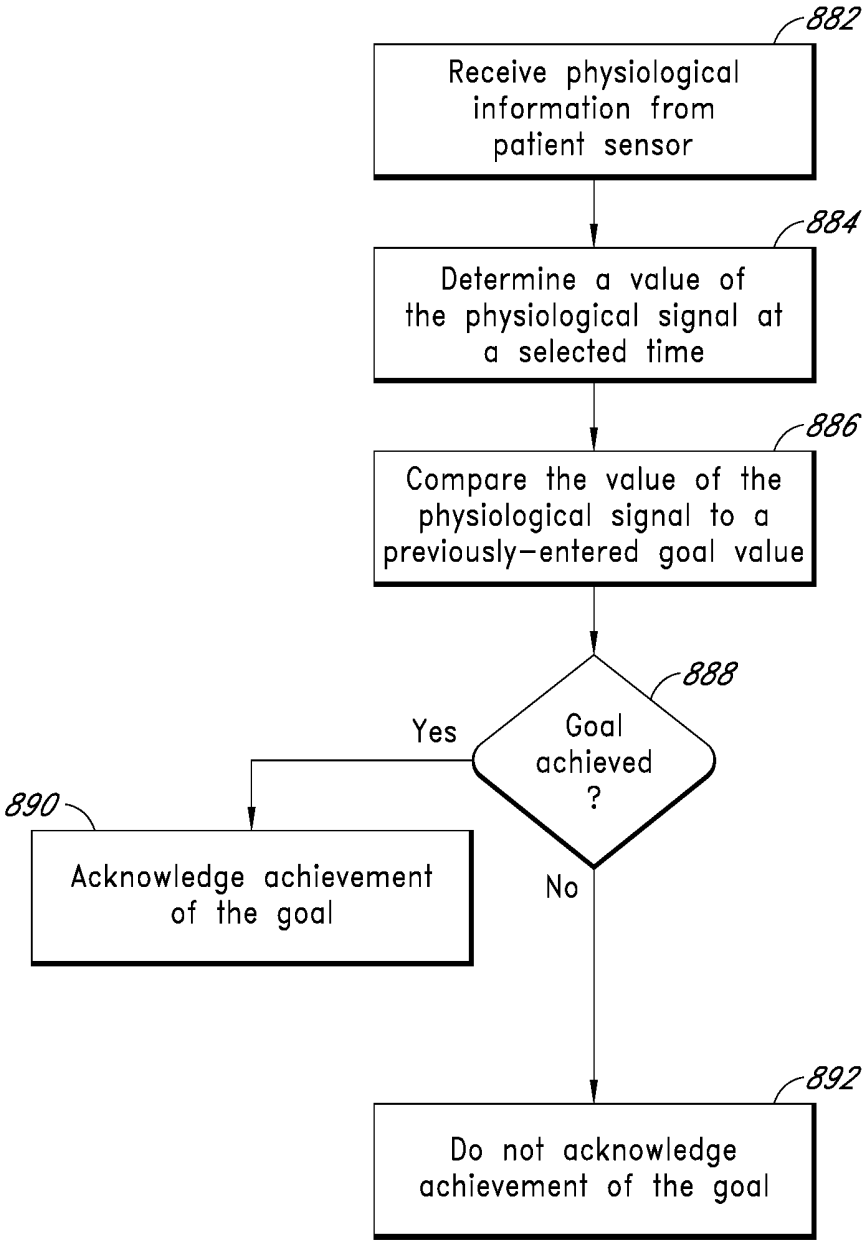
882
Receive physiological information from patient sensor
884
Determine a value of the physiological signal at a selected time
886
Compare the value of the physiological signal to a previously-entered goal value
888
Goal achieved ?
Yes
No
890
Acknowledge achievement of the goal
892
Do not acknowledge achievement of the goal

FIG. 8B

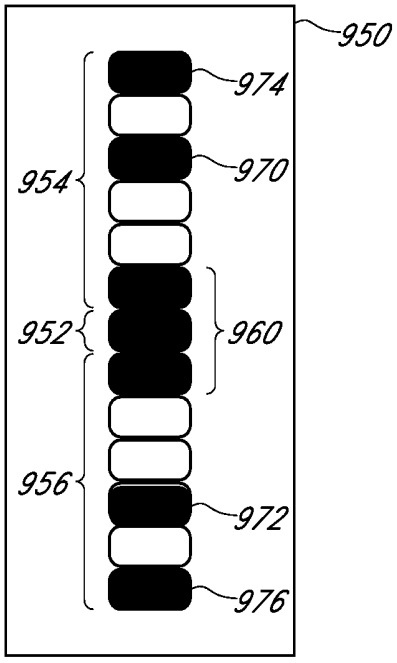

FIG. 9

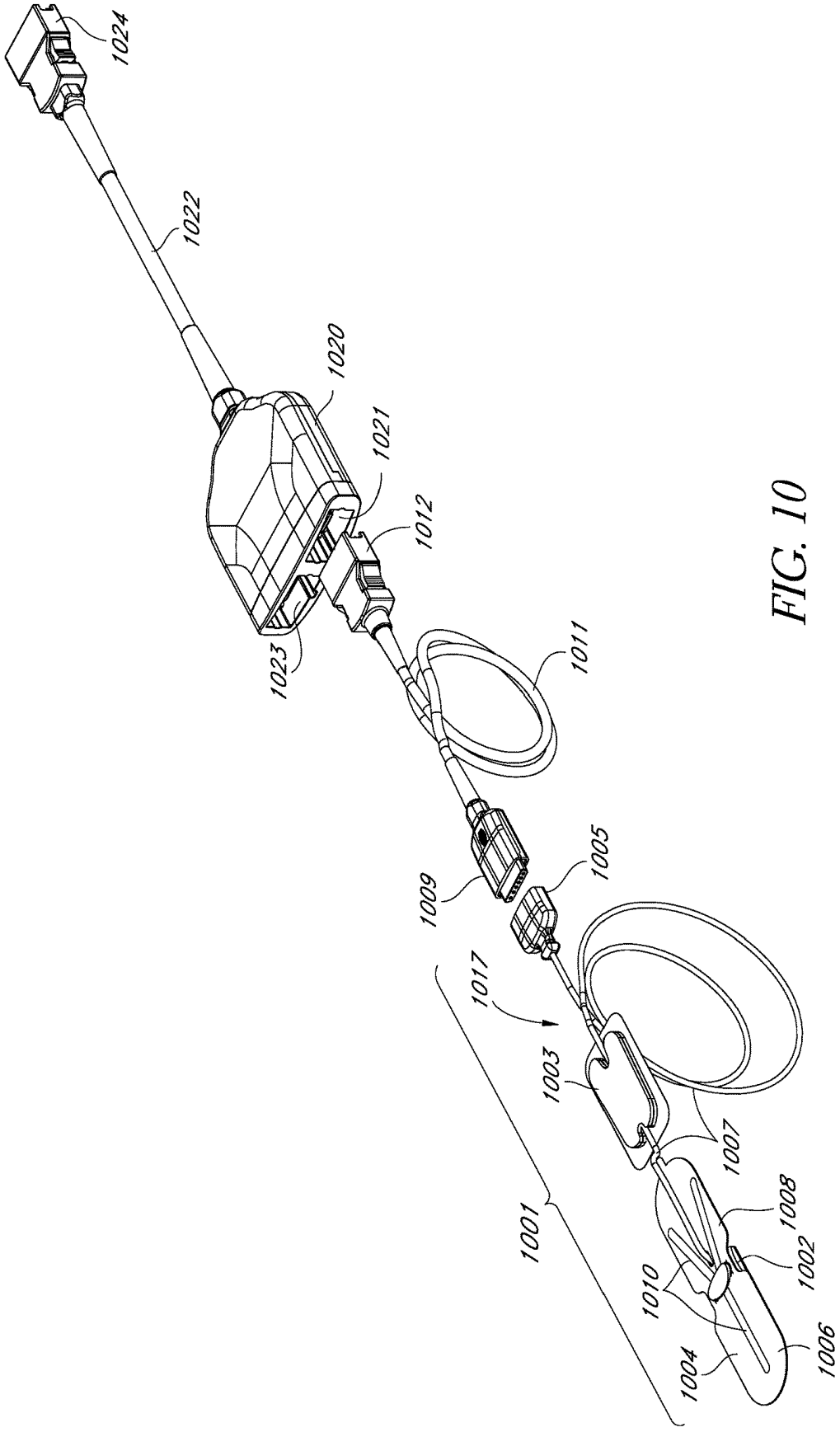
1024
1022
1020
1021
1012
1023
1011
1009
1005
1017
1003
1007
1001
1008
1002
1010
1004
1006

FIG. 10

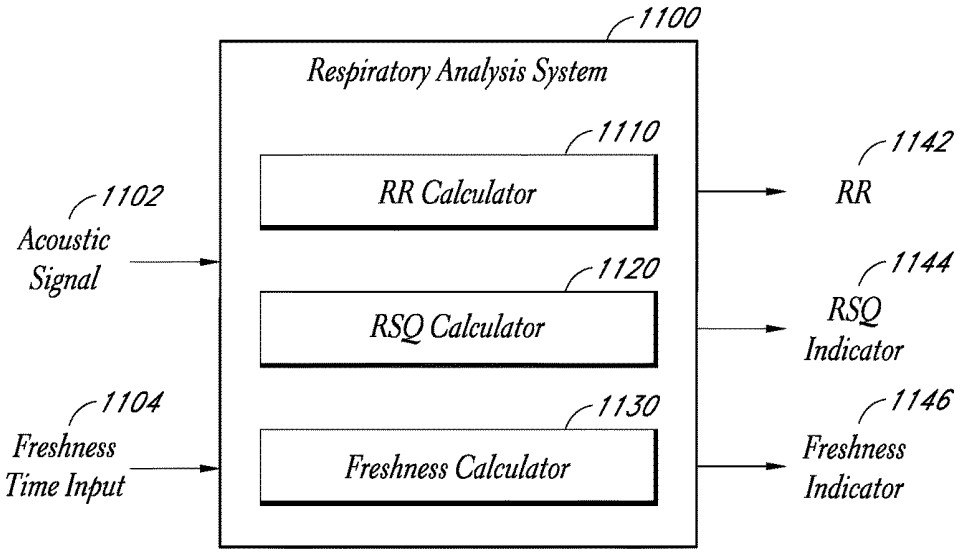
1100
Respiratory Analysis System
1110
RR Calculator
1120
RSQ Calculator
1130
Freshness Calculator
1102
Acoustic Signal
1104
Freshness Time Input
1142
RR
1144
RSQ Indicator
1146
Freshness Indicator

FIG. 11

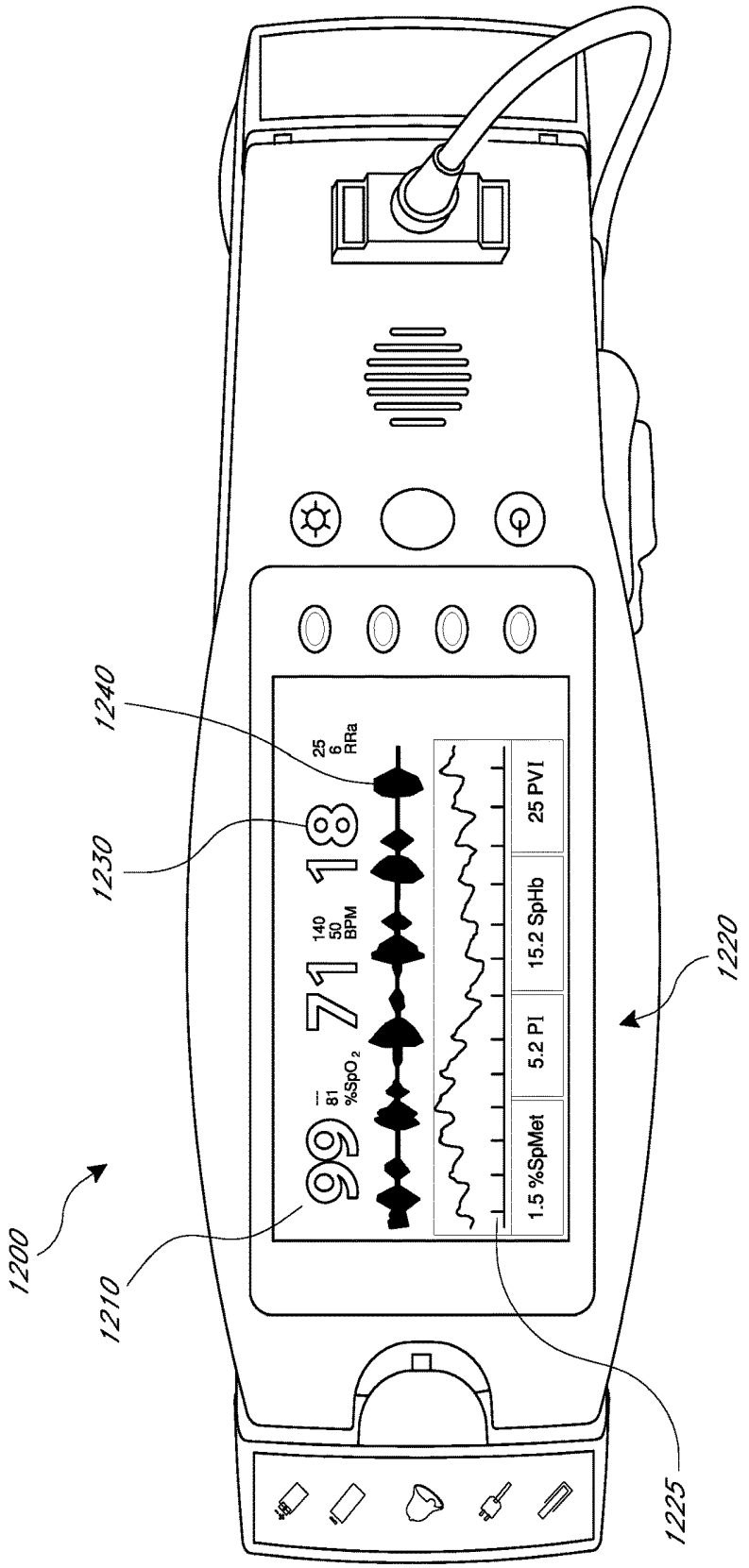
1240
1230
1200
1210
1220
1225
99
71
18
25
6
RRa
140
50
BPM
81
%SpO2
1.5 %SpMet
5.2 PI
15.2 SpHb
25 PVI

FIG. 12

BIDIRECTIONAL PHYSIOLOGICAL INFORMATION DISPLAY

RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 14/444,705, filed Jul. 28, 2014, and entitled "Bidirectional Physiological Information Display," which is a continuation of U.S. patent application Ser. No. 12/904,823, now U.S. Pat. No. 8,790,268, filed Oct. 14, 2010, and entitled "Bidirectional Physiological Information Display," which claims priority from U.S. Provisional Patent Application No. 61/252,083 filed Oct. 15, 2009, and entitled "Displaying Physiological Information," U.S. Provisional Patent Application No. 61/288,843 filed Dec. 21, 2009, and entitled "Acoustic Respiratory Monitor," U.S. Provisional Patent Application No. 61/290,436 filed Dec. 28, 2009, and entitled "Acoustic Respiratory Monitor," and from U.S. Provisional Patent Application No. 61/331,087, filed May 4, 2010, entitled "Acoustic Respiration Display," the disclosures of which are hereby incorporated by reference in their entirety.

This application also relates to the following U.S. patent applications, the disclosures of which are incorporated in their entirety by reference herein:

App. No.	Filing Date	Title
60/893,853	Mar. 8, 2007	MULTI-PARAMETER PHYSIOLOGICAL MONITOR
60/893,850	Mar. 8, 2007	BACKWARD COMPATIBLE PHYSIOLOGICAL SENSOR WITH INFORMATION ELEMENT
60/893,858	Mar. 8, 2007	MULTI-PARAMETER SENSOR FOR PHYSIOLOGICAL MONITORING
60/893,856	Mar. 8, 2007	PHYSIOLOGICAL MONITOR WITH FAST GAIN ADJUST DATA ACQUISITION
12/044,883	Mar. 8, 2008	SYSTEMS AND METHODS FOR DETERMINING A PHYSIOLOGICAL CONDITION USING AN ACOUSTIC MONITOR
61/141,584	Dec. 30, 2008	ACOUSTIC SENSOR ASSEMBLY
61/252,076	Oct. 15, 2009	ACOUSTIC SENSOR ASSEMBLY
12/643,939	Dec. 21, 2009	ACOUSTIC SENSOR ASSEMBLY
14/259,527	Apr. 23, 2014	ACOUSTIC SENSOR ASSEMBLY
14/671,367	Mar. 27, 2015	ACOUSTIC SENSOR ASSEMBLY
14/820,376	Aug. 6, 2015	ACOUSTIC SENSOR ASSEMBLY
61/313,645	Mar. 12, 2010	ACOUSTIC RESPIRATORY MONITORING SENSOR HAVING MULTIPLE SENSING ELEMENTS
12/904,931	Oct. 14, 2010	ACOUSTIC RESPIRATORY MONITORING SENSOR HAVING MULTIPLE SENSING ELEMENTS
14/247,120	Apr. 7, 2014	ACOUSTIC RESPIRATORY MONITORING SENSOR HAVING MULTIPLE SENSING ELEMENTS
15/366,899	Dec. 1, 2016	ACOUSTIC RESPIRATORY MONITORING SENSOR HAVING MULTIPLE SENSING ELEMENTS
12/904,890	Oct. 14, 2010	ACOUSTIC RESPIRATORY MONITORING SENSOR HAVING MULTIPLE SENSING ELEMENTS
12/904,938	Oct. 14, 2010	ACOUSTIC RESPIRATORY MONITORING SENSOR HAVING MULTIPLE SENSING ELEMENTS
12/904,907	Oct. 14, 2010	ACOUSTIC PATIENT SENSOR
61/252,099	Oct. 14, 2009	ACOUSTIC RESPIRATORY MONITORING SYSTEMS AND METHODS
12/904,789	Oct. 14, 2010	ACOUSTIC RESPIRATORY MONITORING SYSTEMS AND METHODS

-continued

App. No.	Filing Date	Title
61/252,062	Oct. 15, 2009	PULSE OXIMETRY SYSTEM WITH LOW NOISE CABLE HUB
61/265,730	Dec. 1, 2009	PULSE OXIMETRY SYSTEM WITH ACOUSTIC SENSOR
12/904,775	Oct. 14, 2010	PULSE OXIMETRY SYSTEM WITH LOW NOISE CABLE HUB
12/905,036	Oct. 14, 2010	PHYSIOLOGICAL ACOUSTIC MONITORING SYSTEM
61/391,098	Oct. 8, 2010	ACOUSTIC MONITOR

Many of the embodiments described herein are compatible with embodiments described in the above related applications. Moreover, some or all of the features described herein can be used or otherwise combined with many of the features described in the applications listed above.

BACKGROUND

Monitoring of respiratory activity in a patient is desirable in clinical situations since death or brain damage can occur within minutes of respiratory failure. As respiratory failure can be difficult to predict, continuous monitoring of respiratory activity is particularly beneficial in high-risk situations. Appropriate monitoring equipment saves lives. Moreover, respiratory monitoring equipment can also be useful for non-critical care, including exercise testing and different types of cardiac investigations.

A patient's respiratory activity can be monitored by an acoustic respiratory monitor. An acoustic respiratory monitor can include one or more acoustic sensors that can be positioned on a patient's body to obtain acoustic respiratory information from a patient for analysis. In some cases, the acoustic sensors may be positioned to detect tracheal sounds, which can be heard at the suprasternal notch or at the lateral neck near the pharynx or at another location on the patient.

SUMMARY

In certain embodiments, a patient monitor for displaying a physiological signal includes a visual element having a middle portion indicative of a transition in the physiological signal between physiological states. The visual element can also include first and second extremity portions, the first extremity portion extending from the middle portion in a first direction and the second extremity portion extending from the middle portion in a second direction. The visual element can also include an actionable value indicator to specify a value about the middle portion and the first and second extremity portions. The patient monitor can also include a processor configured to cause the value indicator to actuate in both the first and second directions according to changes in the physiological signal.

In certain embodiments, a method of displaying physiological information, implemented by a processor, includes providing a value of a physiological parameter to a display of a patient monitor, where the physiological parameter value reflects physiological information obtained from a physiological sensor coupled to a patient. The method can further include calculating a freshness of the physiological parameter value and adjusting an output associated with the parameter value based at least in part on the calculated freshness.

In certain embodiments, a method of displaying physiological information, implemented by a processor, includes outputting a value of a physiological parameter to a display of a patient monitor, where the physiological parameter value reflects physiological information obtained from a physiological sensor coupled to a patient. The method can further include outputting a signal quality indicator reflecting a quality of the physiological information obtained from the physiological sensor, determining whether the value of the physiological parameter is valid, and adjusting the signal quality indicator responsive to said determination.

In certain embodiments, a method of displaying physiological information, implemented by a processor, can include providing a value of a physiological parameter to a display of a patient monitor, where the physiological parameter value reflects physiological information obtained from a physiological sensor coupled to a patient. The method can further include determining whether the value of the physiological parameter is valid, freezing an output associated with the physiological parameter value, calculating a freshness of the physiological parameter value, in response to said freezing, and adjusting the output associated with the parameter value based at least in part on the calculated freshness.

Further, in some embodiments, a method is provided for displaying physiological information on a physiological monitor that can be coupled to a patient sensor that can detect a physiological signal. The method, implemented by a processor, can include outputting a value indicator to a display of the patient monitor, expanding the value indicator in two directions simultaneously in response to increasing values in a parameter measured from the physiological signal, and contracting the value indicator opposite the two directions simultaneously in response to falling values of the measured parameter.

In certain embodiments, a method of displaying physiological information on a physiological monitor, implemented by a processor, can include receiving a physiological signal from a sensor coupled to a patient, where the physiological signal reflects a physiological parameter of the patient. The method can further include activating a visual indicator of a visual element to cause the visual indicator to illuminate from a central region outwards toward both a first end region and a second end region of the visual element and then inwards from the first and second end regions toward the central region, responsive to changes in the physiological parameter.

A physiological monitor can include, in certain embodiments, a processor that can receive physiological information from one or more sensors coupled with a patient and a display having a visual element for representing values of a physiological parameter responsive to the physiological information. The visual element can include a middle portion representing an initial position, first and second extremity portions, the first extremity portion extending from the middle portion in a first direction, and the second extremity portion extending from the middle portion in a second direction, and a value indicator that can illuminate starting from the initial position and expanding both to the first and second extremity portions, followed by contracting at least partway toward the middle portion, responsive to changes in the physiological parameter.

For purposes of summarizing the disclosure, certain aspects, advantages and novel features of the inventions have been described herein. It is to be understood that not necessarily all such advantages can be achieved in accordance with any particular embodiment of the inventions disclosed herein. Thus, the inventions disclosed herein can be embodied or carried out in a manner that achieves or optimizes one advantage or group of advantages as taught herein without necessarily achieving other advantages as can be taught or suggested herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Throughout the drawings, reference numbers can be reused to indicate correspondence between referenced elements. The drawings are provided to illustrate embodiments of the inventions described herein and not to limit the scope thereof.

FIG. **1** is a depiction of an embodiment of a patient monitoring system for acquiring, processing, and displaying physiological information (e.g., respiratory-related information);

FIG. **2** is a schematic representation of an embodiment of a visual element for use with the system of FIG. **1** to display a physiological signal (e.g., a respiratory signal);

FIG. **3** is a schematic representation of an embodiment of a visual element for use with the system of FIG. **1** to display a physiological signal (e.g., a respiratory signal);

FIG. **4**A is an embodiment of a series of depictions of the visual element of FIG. **2** shown at different times as a physiological signal (e.g., a respiratory signal) fluctuates;

FIG. **4**B is an embodiment of a flowchart that further describes the illustrations in FIG. **4**A;

FIG. **5**A is an embodiment of a series of depictions of the visual element of FIG. **2** shown at different times as a physiological signal (e.g., a respiratory signal) fluctuates;

FIG. **5**B is an embodiment of a flowchart that further describes the illustrations in FIG. **5**A;

FIG. **6** is an embodiment of a schematic representation of a visual element capable of simultaneously displaying a plurality of values associated with a physiological signal (e.g., a respiratory signal) at a plurality of times;

FIG. **7**A is an embodiment of a schematic representation of a visual element, which includes peak indicators, for displaying a physiological signal (e.g., a respiratory signal);

FIG. **7**B is an embodiment of a flowchart that further describes the illustrations in FIG. **7**A;

FIG. **8**A is an embodiment of a schematic representation of a visual element, which includes goal indicators, for displaying a physiological signal (e.g., a respiratory signal)

FIG. **8**B is an embodiment of a flowchart that further describes the illustrations in FIG. **8**A; and

FIG. **9** is an embodiment of a schematic representation of a visual element, which includes a plurality of types of indicators, for displaying a physiological signal (e.g., a respiratory signal).

FIG. **10** is an embodiment of a top perspective view illustrating an embodiment of a sensor assembly and cable.

FIG. **11** illustrates an embodiment of a respiratory analysis system.

FIG. **12** illustrates an embodiment of a physiological monitor having a respiration display.

DETAILED DESCRIPTION

Systems and methods of visually communicating information about physiological signals (e.g., respiratory signals) to an observer are described herein. In one embodiment, a physiological monitoring system includes one or more sensors to detect a physiological signal from a patient. For example, the physiological signal can be an acoustic representation of a respiratory signal detected by an acoustic

sensor in the vicinity of a patient. The physiological monitoring system can also include a display for communicating information about the physiological signal to an observer, as well as a processor for processing the physiological signal and controlling the display.

In some embodiments, the display includes a visual element with a value indicator for visually communicating a value associated with a physiological signal to an observer. The value indicator can have an initial position and can expand or contract in a first portion of the visual element during a first physiological state. The first physiological state can, for example, correspond to patient inspiration (or inhalation). The value indicator can expand or contract in a second portion of the visual element during a second physiological state, which can correspond, for example, to patient expiration (or exhalation). In other embodiments, the value indicator expands from a reference position in at least two directions simultaneously, the reference position being representative of a transition between first and second physiological states, such as patient inspiration and expiration.

Multidirectional Display

FIG. **1** illustrates a respiratory monitoring system **105** for monitoring the respiratory activity of a patient **100**. The respiratory monitoring system **105** includes a respiratory monitor **110** communicatively coupled to a sensor **120**. The sensor **120** is positioned on the patient's body to detect respiratory sounds. In one embodiment, the sensor **120** includes a piezoelectric crystal transducer to transform sound vibrations in the patient's body into electrical signals. Other types of sensors can also be used. The resulting electrical respiratory signal can be transferred to the respiratory monitor **110** via electrical leads **130**, by wireless transmission, or any other appropriate method. Various sensors and monitors adaptable to be used with any of the embodiments described herein, have been described in the following applications and issued patents: U.S. Provisional No. 60/893,853, filed Mar. 8, 2007; U.S. Provisional No. 60/893,850, filed Mar. 8, 2007; U.S. Provisional No. 60/893,858, filed Mar. 8, 2007; U.S. Provisional No. 60/893,856, filed Mar. 8, 2007; U.S. application Ser. No. 11/547,570, filed Oct. 6, 2006; U.S. application Ser. No. 12/643,939, filed Dec. 21, 2009, and U.S. Pat. No. 6,661,161 (see also FIG. **10**). Each of these references is hereby incorporated by reference in its entirety.

The respiratory monitor **110** can include circuitry to convert the respiratory signal into a digital format, as well as a processor (not shown) to analyze the respiratory signal. For example, the respiratory signal can be processed or analyzed with a Fourier transform or other mathematical transform to determine or analyze the frequency content of the signal. The signal can also be time-averaged, filtered, amplified, or otherwise conditioned or analyzed using the processor. For example, the processor can be configured to determine a patient's inspiratory time, expiratory time, inspiratory to expiratory ratio, inspiratory flow, expiratory flow, tidal volume, minute volume, apnea duration, breath sounds—including rales, rhonchi, or stridor, changes in breath sounds, etc. Regardless of whether the acquired signal is in analog or digital form, has been conditioned, transformed, or otherwise analyzed or altered, it can generally be referred to as a respiratory signal or acoustic signal throughout this disclosure.

Once the respiratory signal has been acquired by the sensor **120** and transferred to the respiratory monitor **110**, the signal, or aspects of it, can be communicated to an observer by a visual element **150** of the respiratory monitor display **140**. FIGS. **2-9** illustrate various embodiments of the visual element **150**. While certain embodiments can be described primarily in the context of displaying respiratory signals, the same principles can be applied to display other types of physiological signals as well, such as heart rate, blood pressure, blood oxygen saturation, etc.

FIG. **2** illustrates a visual element **250**, in this case a bar graph, which can be displayed on a patient monitor to communicate to a user certain aspects of a physiological signal. In some embodiments, the visual element **250** is a color or monochrome segmented LED, LCD, and/or a bit-mapped type display. Other types of displays are also possible and can be used equally well. The bar graph **250** can include a plurality of segments **258**, or any other type of sub-division. In certain embodiments, each segment **258** has an inactive state, such as a dark state, and an active state, such as one or more lit states of varying brightness, or vice versa. In certain embodiments, the lit state includes one or more colors. The segments **258** can be transitioned between dark and lit states, or between colors, in order to convey information about a physiological signal to a user.

One or more segments **258** can make up a middle portion **252** of the bar graph **250**. Other groupings of segments **258** can make up a first extremity portion **254** (e.g., an upper extremity portion) and a second extremity portion **256** (e.g., a lower extremity portion) of the bar graph **250**. In some embodiments, the upper **254** and lower **256** extremity portions of the bar graph **250** are each indicative of relatively larger magnitudes of values of an acquired physiological signal, or some characteristic derived from the acquired physiological signal, than is the middle portion **252**. In other embodiments, however, one of the extremity portions may represent lesser magnitudes than the other, while the middle portion can represent magnitudes between the greater and lesser magnitudes represented by the extremity portions.

In some embodiments, the bar graph **250** is calibrated. For example, the bar graph **250** can be calibrated in units of energy in a physiological signal or, in the case of respiratory signals, in units of respiratory volume. Other calibration units are also possible. In some embodiments, a calibration scale is explicitly indicated on or near the bar graph **250** to communicate quantitative information to an observer about the strength of a physiological signal. In certain embodiments, the calibration scale of the bar graph **250** is reconfigurable, whether manually or automatically, according to the ranges of values present in the physiological signal. For example, in the case of a respiratory signal of a patient with relatively shallow breathing, the dynamic range of the calibration scale can be decreased so that the signal extends over a greater portion of the bar graph **250**. In cases where a patient is breathing very deeply, the dynamic range of the calibration scale can be increased to avoid clipping of the visual depiction of the respiratory signal.

The bar graph **260** can also include a value indicator **260** which actuates in time, e.g. by transitioning bar graph segments **258** between dark and lit states, as the physiological signal changes. In some embodiments, the value indicator **260** is a grouping of one or more segments **258**, the number of which changes as the value indicator **260** actuates, of the visual element **250**. The value indicator **260** can be indicative of any characteristic of an acquired physiological signal and can actuate anywhere along the bar graph **250**. For example, the value indicator **260** can represent the amplitude of a physiological waveform at a point in time, the amplitude of a selected frequency range of the physiological signal over a specified time period, or the intensity of the physiological signal at a point in time.

Other characteristics of a physiological signal can also be represented by the value indicator **260**. For example, in the case of a respiratory signal, the value indicator **260** can represent an indication of the acoustic volume of breathing sounds picked up by an acoustic sensor **120**. In some embodiments, an indication of the acoustic volume of a patient's respiratory sounds is related to the amplitude of a relatively low frequency envelope of a sound waveform detected by the sensor **120**. The value indicator **260** can also represent the respiratory rate of a patient, the depth of breathing, or any other type of information related to a respiratory signal, including a quality of a respiratory signal (see FIG. **11**).

It should be understood that while FIG. **2** illustrates one embodiment of a value indicator, many different types of value indicators can be used in various embodiments. The value indicator **260** illustrated in FIG. **2** is one that is well-suited to embodiments where the visual element **150** includes a bar graph. However, other types of value indicators may be better-suited to other types of visual elements **150**. The term "value indicator," in addition to having its ordinary meaning, is intended to refer to any type of visual indicator capable of graphically communicating to a user a value associated with a physiological signal, including amplitude, frequency, etc. related to a physiological signal.

In certain embodiments, the value indicator **260** expands in length to indicate increases in the value or magnitude of a selected characteristic of the physiological signal. Conversely, the value indicator may contract in length to indicate decreases in the value or magnitude of the signal. While the value indicator **260** is shown in FIG. **1** as only extending from the middle portion **252** into the upper extremity portion **254** of the bar graph **250**, in other embodiments, it may extend into both extremity portions **254**, **256** simultaneously.

The value indicator **260** can change colors and/or flash as it actuates as an additional method of conveying information to a user. For example, the value indicator **260** could be displayed in red for relatively small values or magnitudes of a respiratory signal, which may correspond to shallow breathing by a patient. In other embodiments, the value indicator **260** flashes between dark and lit states to indicate shallow breathing. If the patient's breathing increases to normal levels, however, the value indicator **260** may change to green or cease flashing. Similar methods of changing colors of the value indicator **260** or causing it to flash can be used to indicate other aspects of a respiratory signal, such as if the patient's respiratory rate drops below a predetermined or user-selected threshold.

In certain embodiments, the middle portion **252** of the bar graph indicates a transition between two or more different physiological states. The states can, for example, be any detectable or distinct physiological event, phase, or condition. In some, but not all, embodiments, a transition between physiological states represents the occurrence or presence of a distinct physiological event or condition, rather than simply a greater or lesser degree of a continuing physiological event or condition. In embodiments where the bar graph **260** is used to communicate values of an acquired patient respiratory signal, the middle portion **252** of the bar graph **250** can indicate a transition between inspiration and expiration in the patient's respiratory activity, each of which is a distinct phase of respiratory activity. In other words, when a value in the middle portion **252** of the bar graph is marked, it is an indication of the patient transitioning between inspiration and expiration. In other embodiments, the middle portion **252** marks a transition of a physiological signal between normal and abnormal values. For example, the middle portion **252** could mark where a patient's blood oxygen saturation transitions between healthy and dangerous levels.

In addition to the generally rectangular shaped bar graph shown in FIG. **2**, other bar graph shapes are also possible. For example, FIG. **3** illustrates a diamond-shaped visual element **350**. Much like the bar graph **250**, the diamond-shaped visual element **350**, or diamond graph, can include a plurality of segments **358**, one or more of which can make up a middle portion **352** as well as upper **354** and lower **356** extremity portions. The diamond graph can also include an actionable value indicator **360**. It should be understood that, while the bar graph **250** and the diamond graph **360** are each shown as comprising of a number of discrete segments **258**, **358**, this is not required. Furthermore, those of skill in the art can recognize a wide variety of variations in shapes, sizes, colors, etc. of the visual elements disclosed in this specification which can be used in various embodiments.

While the visual element **150** of FIG. **1** may be a bar graph, as described herein, many other shapes and embodiments are also possible. For example, the visual element **150** can be any graphical shape or symbol with a reference point about which the graphical shape or symbol extends, expands, or otherwise modulates in at least two directions. In one embodiment, the visual element **150** is a circle (not shown), though other shapes can also be used, whose size increases and decreases in response to changes in a physiological signal, such as a respiratory signal. For example, the circle may have an initial diameter that is indicative of a transition between two or more physiological states. In one embodiment, the diameter of the circle increases during a first physiological state, such as patient inspiration, while the diameter decreases during a second physiological state, such as patient expiration. Therefore, when the diameter of the circle is larger than the initial diameter, an observer can see that the patient is in a first physiological state. When the diameter of the circle is smaller than the initial diameter, an observer can see that the patient is in a second physiological state. Many other types of visual elements **150** are also possible.

FIG. **4**A is a series of depictions of the visual element of FIG. **2** shown at different times as a physiological signal (e.g., a respiratory signal) fluctuates. FIG. **4**A includes still frames of a bar graph **450** at times t**1**, t**2**, t**3**, t**4**, and t**5** as the value indicator **460** actuates in response to changes in a patient's respiratory signal. In this example, the value indicator **460** represents the acoustic volume of the respiratory sounds picked up by the acoustic sensor **120**.

FIG. **4**B is a flowchart that further describes the illustrations in FIG. **4**A. At block **482**, a processor (not shown) in a physiological monitoring system (e.g., **105**) receives physiological information from a patient sensor (e.g., **120**). At block **484**, the processor determines the value of the physiological signal at a selected time. At block **486**, the processor causes the value of the physiological signal at the selected time to be displayed on a patient monitor (e.g., **110**) by actuating a value indicator in at least two directions, relative to a reference point, simultaneously. This process can be performed repeatedly for each of a plurality of selected times, as seen in FIG. **4**A.

Returning now to FIG. **4**A, at time t**1**, the value indicator **460** shows that the acoustic volume of the patient's breathing is relatively small. This can occur in a respiratory signal during an instant between inspiration and expiration (or between expiration and inspiration) by a patient where substantially no breathing sound is detected. At time t**2**, the value indicator **460** has expanded to indicate the detection of

a greater acoustic volume. In this embodiment, both the upper and lower extremity portions of the bar graph **450** are representative of relatively greater magnitudes of the acoustic volume of the respiratory signal than is the middle portion of the bar graph **450**. Thus, the value indicator expands both in the direction of the upper extremity portion of the bar graph **450** as well as the lower extremity portion, in this case, by a substantially equal amount. At time t**3**, the value indicator **460** expands even further in both directions and indicates a relatively loud acoustic respiratory sound. Relatively large acoustic respiratory sounds, such as this, are typically detected during the middle portion of a patient inspiratory or expiratory phase. At time t**4**, the value indicator **460** has contracted somewhat, representing a decrease in the acoustic volume of the patient's respiratory signal. Finally, at time t**5**, the value indicator **460** contracts to the middle portion of the bar graph **450**, indicating that the patient has completed one inspiratory phase and is transitioning to an expiratory phase, or vice versa.

In the embodiment illustrated in FIG. **4**A, the middle portion of the bar graph **450** is indicative of a transition between inspiratory and expiratory phases in the patient's respiratory activity. As the patient inhales, the acoustic volume of the patient's breathing sounds increases, causing the value indicator to expand in the direction of both extremity portions of the bar graph **450** until such time as the acoustic volume reaches its peak and begins to taper off, causing the value indicator to contract back toward the middle portion of the bar graph **450**. The patient can then begin to exhale, at which point the acoustic volume of the patient's breathing sounds can increase once again and the cycle shown in FIG. **4** can generally repeat itself, though the maximum value detected during inspiratory and expiratory phases, as well as the time to complete each phase, may not be equal. The series of bar graphs **450** shown in FIG. **4** can, therefore, be representative of patient inspiration or expiration. In certain cases it may be desirable to distinguish patient inspiration from expiration. For example, the value indicator **460** could be displayed in green during inspiration and in blue during expiration. In other embodiments, the value indicator **460** could blink during one respiratory phase while remaining solid during the other. Other mechanisms for distinguishing between patient inspiration and expiration in this embodiment are also possible.

A multi-directional visual element such as illustrated and described with respect to FIGS. **2**-**8**A provides several clinical advantages in certain embodiments. For example, clinical monitors typically display a multitude of data related to many different physiological parameters of a patient. Some monitors display several numerical values related to a patient's overall health, such as blood pressure, pulse rate, blood oxygen concentration or saturation, etc. Monitors also often display several graphical images, or waveforms, as well. Although such information can be clinically useful to a medical provider, in some cases the quantity of information provided on a physiological monitor's display can cause confusion. For example, a clinician may be overwhelmed with the quantity of information provided and may not find the particular information desired when quickly glancing at the monitor's display. In such cases it is particularly useful to provide certain types of physiological information with a unique visual element that can be quickly discerned by a clinician. By doing so, the medical practitioner can become accustomed to visualizing particular physiological information (e.g., respiratory information) with a particular visual element (e.g., those described with respect to FIGS. **2**-**8**A). This can allow the medical practitioner to quickly find the information of interest from an information-rich visual display.

FIG. **5**A is another example of a series of depictions of the visual element of FIG. **2** shown at different times as a physiological signal (e.g., a respiratory signal) fluctuates. The value indicator **560** indicates the acoustic volume of the respiratory sounds detected by the acoustic sensor **120**. Both extremity portions of the bar graph **550** are representative of relatively larger magnitude values of the acoustic volume of the respiratory signal than is the middle portion of the bar graph. However, the value indicator **560** in this embodiment actuates in the region of one of the extremity portions of the bar graph **550** at a time. For example, the upper extremity portion of the bar graph **550** can correspond to a first phase of a physiological event (e.g., the respiratory signal which correspond to a patient inspiratory phase), while the lower extremity portion of the bar graph can correspond to a second phase of a physiological event (e.g., an expiratory phase). Therefore, the value indicator **560** represents different physiological states, phases, conditions, activities, etc. along different directions, or in different regions.

FIG. **5**B is a flowchart that further describes the illustrations in FIG. **5**A. At block **582**, a processor (not shown) in a physiological monitoring system (e.g., physiological monitoring system **105** or any other system described herein) receives physiological information from a patient sensor (e.g., patient sensor **120** or any other sensor described herein). At block **584**, the processor determines the value of the physiological signal at a selected time. At block **586**, the processor determines a physiological state of the patient at the selected time, as represented by the value of the physiological signal at that time. If the patient is in a first physiological state (e.g., inspiration) at decision block **588**, then the processor causes the value of the physiological signal to be displayed in a first portion of a visual element. If the patient is in a second physiological state (e.g., expiration) at decision block **592**, then the processor causes the value of the physiological signal to be displayed in the second portion of the visual element. If the patient is not in either of the first or second physiological states, then, in some embodiments, it can be assumed that the patient is transitioning between the first and second physiological states, and the value of the physiological signal is displayed accordingly at block **596**. This process can be performed repeatedly for each of a plurality of selected times, as seen in FIG. **5**A.

Returning now to FIG. **5**A, at time t**1**, the value indicator **560** shows that a relatively small acoustic volume has been detected. Again, during normal respiratory activity this corresponds to a transition between patient inspiration and expiration. At time t**2**, the value indicator **560** expands in the region of the upper extremity portion of the bar graph **550** to indicate the detection of relatively loud patient inspiration sounds. At time t**3**, the value indicator **560** contracts back to the middle portion of the bar graph **550**, indicating the end of the inspiratory phase. The position of the value indicator **560** at time t**4** corresponds to the detection of a moderately loud expiratory signal. Later, at time t**5**, the acoustic volume of the patient's expiratory action is shown to have decreased somewhat before it can eventually return back to the middle portion of the bar graph **550**, indicating the completion of the patient's expiratory phase. As illustrated in FIG. **5**A, the acoustic volume of a patient's breathing sounds during inspiratory and expiratory phases does not necessarily reach the same maximum value. Nor are the two respiratory phases necessarily of equal duration.

FIGS. **4**A, **4**B, **5**A, and **5**B merely represent two examples of ways in which a value indicator can actuate in response to changes in a patient's respiratory, or other physiological, signal according to different embodiments. In this way, a patient's respiratory activity can be easily monitored by a caregiver observing the respiratory monitor **110**. As discussed previously, a patient's respiratory activity can be continuously monitored by an acoustic sensor **120** and transmitted to the patient respiratory monitor **110**. The respiratory monitor **110** can include circuitry to sample the acquired continuous time respiratory signal and convert it into a digital representation. This operation results in a discrete series of time samples which approximate the continuous-time respiratory signal. The respiratory monitor **110** can also include a processor to analyze the respiratory signal and to cause a value indicator to actuate in accordance with changes in the respiratory signal over time, as illustrated in FIGS. **4**A, **4**B, **5**A, and **5**B.

In some embodiments, one respiratory data point is displayed by a visual element (e.g., visual element **150** or other visual elements described herein) for every time sample of the continuous-time signal. In other words, the value indicator actuation refreshes once for each time sample of the respiratory signal, e.g., if the continuous-time respiratory signal is sampled 60 times per second, the value indicator refreshes 60 times per second as well. However, the series of respiratory data points displayed by a visual element can also be different than the number of time samples that are taken from the continuous-time signal. For example, if the continuous-time respiratory signal is sampled 60 times per second, the value indicator may be configured to only refresh for every third time sample. In other embodiments, a plurality of time samples are combined to form a single value in the series of data points displayed by the visual element. For example, the value indicator can be configured to display a series of data points where each data point represents the average (e.g., a moving average) or median of a group of time samples in order to smooth the actuation of the value indicator. It is also possible for the value indicator to be configured to actuate at a higher rate than the sampling rate of the continuous-time respiratory signal by interpolating between time samples.

Some embodiments can be configured to display more than one data point (e.g., a value) at a time. For example, FIG. **6** is a schematic representation of a visual element capable of simultaneously displaying a plurality of values associated with a physiological signal (e.g., a respiratory signal). The visual element **650** includes an array of segments **658**. The visual element **650** also includes a middle portion **652**, as well as upper **654** and lower **656** extremity portions which are indicative of differing values of a respiratory, or other physiological, signal. Each of the five columns of segments represents a separate value in a series of data points displayed on the visual element **650**. For example, the first column of segments can represent the value of a physiological signal at time t**1**, the second column can represent the value at time t**2**, etc.

In addition, each column of segments **658** includes a value indicator **660**, which actuates in response to changes in a physiological signal as described above. The value indicators **660** in FIG. **6** only have their end points illuminated, rather than all intervening segments **658** as well. In other embodiments, end points and intervening segments **658** are both illuminated. Other types of value indicators are also possible. Each value indicator **660** can be configured to refresh in turn one after another until an end column, e.g., the right-most column, in the visual element **650** has been reached. At this point the pattern may repeat and the value indicator in the opposite end column, e.g., the left-most column, can be refreshed. Other patterns for refreshing the value indicators **660** are also possible. For example, the value indicators **660** can be configured to all refresh simultaneously and hold their respective values until the next refresh time. Since the value indicator **650** shows a plurality of values, it can be configured to show an entire inspiratory or expiratory phase. In other embodiments, the visual element **650** can be configured to display entire respiratory periods, i.e., one inspiratory phase and one expiratory phase, or even several respiratory periods, at once.

In some embodiments, a visual element (e.g., **150**) also includes separate indicators to communicate additional information to an observer. For example, FIG. **7**A is a schematic representation of a visual element, which includes peak indicators, for displaying a physiological signal (e.g., a respiratory signal). The bar graph **750** includes a middle portion **752**, an upper extremity portion **754**, and a lower extremity portion **756**. The bar graph **750** also includes a value indicator **760** which can be configured to actuate in response to changes in a detected respiratory signal. The bar graph **750** also includes an inspiration peak indicator **770** as well as an expiration peak indicator **772**. The peak indicators **770**, **772** can be configured to communicate to an observer the maximum magnitude that a patient's respiratory signal has reached during inspiratory and expiratory phases over a pre-determined time period. The peak indicators **770**, **772** may be useful to a caregiver as an indication of the history of the patient's breathing activity and may aid in diagnoses or in decision making related to the patient's care.

In one embodiment, the peak indicators **770**, **772** of FIG. **7**A are portions of the bar graph **750** which have been configured to remain activated (e.g., in a lit up state) to show the maximum values or magnitudes attained by the patient's respiratory signal over a period of time. For example, the peak indicators **770**, **772** remain activated even when the current value shown by the value indicator **760** is other than the peak value, or values, represented by the peak indicators **770**, **772**. For example, in FIG. **7**A, the value indicator **760** shows a current inspiratory signal value of a moderate level. The inspiration peak indicator **770**, however, shows that the patient's inspiratory signal reached a maximum value represented by the upper most segment of the bar graph **750** within some pre-determined period of time in its history. Likewise, the expiration peak indicator **772** shows the maximum value reached by the patient's expiratory signal over a period of time. In other embodiments, the peak indicator **772** illuminates to a different color than the physiological signal portion displayed on the bar graph **750**.

The peak indicators **770**, **772** can be configured to actuate to higher levels when new peak values in the patient's respiratory signal are attained. Similarly, the peak indicators **770**, **772** may actuate to show smaller values if the patient's breathing activity has trended downward and previously reached peak values have not been met within the most recent pre-determined period of time.

The peak indicators **770**, **772** can be configured to show the maximum values or magnitudes attained by a patient's respiratory signal over any period of time in the history of the signal. In one embodiment, for example, the peak indicators **770**, **772** show the maximum acoustic volumes reached by a patient's respiratory signal over the course of the past five minutes. In some embodiments, the time period is configured to be adjustable by a caregiver.

FIG. **7**B is a flowchart that further describes the illustrations in FIG. **7**A. At block **782**, a processor (not shown) in

a physiological monitoring system (e.g., **105**) receives physiological information from a patient sensor (e.g., **120**). At block **784**, the processor determines the value of the physiological signal at a selected time. At block **786**, the processor compares the value of the physiological signal at the selected time to previous values over a predetermined period of time. If the value of the physiological signal at the selected time reflects a new peak value, then the processor proceeds from decision block **788** to block **790** where it actuates a corresponding peak indicator **770**, **772** to reflect the new peak value. Otherwise, at block **792**, the processor does not change the peak indicator **770**, **772**. This process can be performed over for each new value of the physiological signal.

As illustrated in FIG. **7**A, the peak indicators **770**, **772** may be a segment, or other portion, of the bar graph **750**. In these embodiments, the peak indicators **770**, **772** can be displayed in different colors from the value indicator **760** for clarity in identifying the peak values or magnitudes. In other embodiments, the peak indicators **770**, **772** may be configured to blink on and off. In still other embodiments, the peak indicators **770**, **772** may be located adjacent the bar graph rather than being a part of the bar graph and may include an icon, arrow, or other graphical element. Other arrangements are also possible and can be recognized by those of skill in the art.

Some embodiments include additional types of indicators. For example, FIG. **8**A is a schematic representation of a visual element, which includes goal indicators, for displaying a physiological signal (e.g., a respiratory signal). The bar graph **850** includes goal indicators **874**, **876** which represent a value of a respiratory, or other physiological, signal for which a patient is to strive to reach. In the case of respiratory signals, this type of goal indicator can be beneficial to patients in need of exercising their lungs while recovering from surgery or as therapy for some other medical condition. Certain embodiments include an inspiratory goal indicator **874** and an expiratory goal indicator **876**. Each of these goal indicators **874**, **876** is a visual cue that indicates to a patient a target value to try to reach in his or her breathing.

In FIG. **8**A, for example, if the value indicator **860** is understood to show the instant where the patient's inspiratory phase has reached its peak value or magnitude, which in this case is relatively low, the patient can see from the bar graph that he or she must breathe more deeply in order to reach the target value represented by the inspiratory goal indicator **874**. Thus, the goal indicators **874**, **876** help a patient strive to reach a desired level of breathing activity, whether for the purposes of recovery, testing, or some other reason. In some embodiments, the goal indicators **874**, **876** are set and reconfigured by a caregiver, such as a doctor or nurse, or by the patient himself.

The goal indicators **874**, **876** can be a segment, or other portion, of the bar graph **850**, such as an LED, LCD, and/or an icon, color, sound, or combination thereof. In such cases it may be desirable to display the goal indicators in a color other than that used for the value indicator **860**. In some embodiments, the goal indicators **874**, **876** are configured to blink, for example, when the patient achieves the targeted value of the physiological signal. In still other embodiments, the goal indicators **874**, **876** are accompanied by an audible indicator which sounds when the patient reaches the targeted goal. Many other configurations for displaying the goal indicators and signaling when the goal has been met are possible as well.

FIG. **8**B is a flowchart that further describes the illustrations in FIG. **8**A. At block **882**, a processor (not shown) in a physiological monitoring system receives physiological information from a patient sensor. At block **884**, the processor determines the value of the physiological signal at a selected time. At block **886**, the processor compares the value of the physiological signal at the selected time to a goal value that has been previously inputted by a caregiver or by the patient. If the value of the physiological signal at the selected time meets or exceeds the goal value, then the processor proceeds from decision block **888** to block **890** where it causes an acknowledgement that the goal has been reached to be given. This acknowledgement can be, for example, an audible sound. Otherwise, at block **892**, the processor causes no such acknowledgement to be given. This process can be performed over for each new value of the physiological signal.

Some embodiments include more than one type of additional indicator beyond a value indicator. This is represented in FIG. **9**, which is a schematic representation of a visual element that includes a plurality of types of indicators for displaying a physiological signal (e.g., a respiratory signal). The bar graph **950** includes peak indicators **970**, **972**, as well as goal indicators **974**, **976**. The bar graph **950** also includes a middle portion **952**, an upper extremity portion **954**, a lower extremity portion **956**, and a value indicator **960** which is configured to actuate in response to changes in a detected physiological signal. In FIG. **9**, it can be seen that the patient's respiratory signal has reached a peak value or magnitude marked by the peak indicators **970**, **972** that still falls short of the patient's targeted goal, as marked by the goal indicators **974**, **976**. Thus the patient, or a caregiver, can recognize that the patient should continue to strive to breathe more deeply.

Additional types of indicators can also be included in various embodiments. As is described herein, these indicators can be configured as portions of a bar graph, for example. They may also be numbers, letters, or symbols located adjacent a visual element such as a bar graph. In some embodiments, indicators described herein are actionable in response to changes in a physiological signal. For example, in addition to the peak and goal indicators described above, a bar graph **950**, or other type of visual element (e.g., visual element **150** or any other visual element described herein), can include indicators to show average values of a patient's respiratory signal during inspiratory or expiratory phases. The bar graph **950** could also include short-term peak indicators which are configured to represent value or magnitude peaks attained during a relatively short-term history of the patient's respiratory activity as well as long-term peak indicators which are configured to represent value or magnitude peaks attained over the course of a longer period of time. It should be apparent to those of skill in the art that the bar graph **950**, or other type of visual element, can also include many other types of indicators to communicate to an observer any type of information related to a physiological signal.

Some embodiments include visual elements with additional information in the form of text, numbers, images, icons, or symbols, for example. In one embodiment, a visual element includes numbers which indicate the respiratory rate (e.g., breaths per minute) and/or respiratory period (e.g., seconds per breath) of a patient. A visual element can also include a numerical depiction of a value related to a physiological signal or an indication of signal quality (see FIG. **11**). Other types of information that would be recognized by those in the skill as having a relationship to a physiological signal or of being of some benefit to a caregiver can also be included with the visual element.

In some embodiments, the patient monitor **110** also includes a speaker or other device capable of producing audible sounds. The patient monitor **110** can be configured to output a sound that varies in response to changes in a physiological signal. For example, the patient monitor **110** can output a sound that increases and decreases in volume in response to changes in a physiological signal. In one embodiment, the sound increases as the value or magnitude of the signal increases, and decreases as the value or magnitude of the signal decreases. In some embodiments, the pitch of the sound varies in response to changes in the physiological signal. For example, the pitch of the sound may increase as the value or magnitude of the signal increases, and may decrease as the value or magnitude of the signal decreases. Some embodiments produce "beeps" or other sounds that occur closer together or further apart in time in response to changes in the physiological signal. Some embodiments of the physiological monitor **110** output one sound during inspiration and a different sound during expiration of a respiratory signal as a non-visual indication of the different phases of the respiratory signal.

In some embodiments, the speaker is also configured to emit alarms when a patient enters into a dangerous or undesirable condition. For example, if the physiological monitor **110** detects a temporary cessation in the patient's breathing, such as might occur in a patient with apnea, the speaker can emit an alarm. The speaker may also be configured to emit an alarm if the patient's respiratory rate or depth of respiration decreases beyond a certain threshold.

FIG. **10** illustrates an embodiment of a sensor system **1000** including a sensor assembly **1001** and a monitor cable **1011** suitable for use with any of the physiological monitors and cables described herein. The sensor assembly **1001** includes a sensor **1015**, a cable assembly **1017**, and a connector **1005**. The sensor **1015**, in one embodiment, includes a sensor subassembly **1002** and an attachment subassembly **1004**. The cable assembly **1017** of one embodiment includes a sensor **1007** and a patient anchor **1003**. A sensor connector subassembly **1005** is connected to the sensor cable **1007**.

The sensor connector subassembly **1005** can be removably attached to an instrument cable **1011** via an instrument cable connector **1009**. The instrument cable **1011** can be attached to a cable hub **1020**, which includes a port **1021** for receiving a connector **1012** of the instrument cable **1011** and a second port **1023** for receiving another cable. The hub **1020** is an example of the splitter cable described above, and as such, can include decoupling circuitry. In certain embodiments, the second port **1023** can receive a cable connected to an optical sensor (e.g., a pulse oximetry sensor) or other sensor. In addition, the cable hub **1020** could include additional ports in other embodiments for receiving additional cables. The hub includes a cable **1022** which terminates in a connector **1024** adapted to connect to a physiological monitor (not shown).

The sensor connector subassembly **1005** and connector **1009** can be configured to allow the sensor connector **1005** to be straightforwardly and efficiently joined with and detached from the connector **1009**. Embodiments of connectors having connection mechanisms that can be used for the connectors **1005**, **1009** are described in U.S. patent application Ser. No. 12/248,856 (hereinafter referred to as "the '856 application"), filed on Oct. 9, 2008, which is incorporated in its entirety by reference herein. For example, the sensor connector **1005** could include a mating feature (not shown) which mates with a corresponding feature (not shown) on the connector **1009**. The mating feature can include a protrusion which engages in a snap fit with a recess on the connector **1009**. In certain embodiments, the sensor connector **1005** can be detached via one hand operation, for example. Examples of connection mechanisms can be found specifically in paragraphs [0042], [0050], [0051], [0061]-[0068] and [0079], and with respect to FIGS. 8A-F, 13A-E, 19A-F, 23A-D and 24A-C of the '856 application, for example.

The sensor connector subassembly **1005** and connector **1009** can reduce the amount of unshielded area in and generally provide enhanced shielding of the electrical connection between the sensor and monitor in certain embodiments. Examples of such shielding mechanisms are disclosed in the '856 application in paragraphs [0043]-[0053], [0060] and with respect to FIGS. 9A-C, 11A-E, 13A-E, 14A-B, 15A-C, and 16A-E, for example.

In an embodiment, the acoustic sensor assembly **1001** includes a sensing element, such as, for example, a piezoelectric device or other acoustic sensing device. The sensing element can generate a voltage that is responsive to vibrations generated by the patient, and the sensor can include circuitry to transmit the voltage generated by the sensing element to a processor for processing. In an embodiment, the acoustic sensor assembly **1001** includes circuitry for detecting and transmitting information related to biological sounds to a physiological monitor. These biological sounds can include heart, breathing, and/or digestive system sounds, in addition to many other physiological phenomena. The acoustic sensor **1015** in certain embodiments is a biological sound sensor, such as the sensors described herein. In some embodiments, the biological sound sensor is one of the sensors such as those described in the '883 application. In other embodiments, the acoustic sensor **1015** is a biological sound sensor such as those described in U.S. Pat. No. 6,661,161, which is incorporated by reference herein in its entirety. Other embodiments include other suitable acoustic sensors.

The attachment sub-assembly **1004** includes first and second elongate portions **1006**, **1008**. The first and second elongate portions **1006**, **1008** can include patient adhesive (e.g., in some embodiments, tape, glue, a suction device, etc.). The adhesive on the elongate portions **1006**, **1008** can be used to secure the sensor subassembly **1002** to a patient's skin. One or more elongate members **1010** included in the first and/or second elongate portions **1006**, **1008** can beneficially bias the sensor subassembly **1002** in tension against the patient's skin and reduce stress on the connection between the patient adhesive and the skin. A removable backing can be provided with the patient adhesive to protect the adhesive surface prior to affixing to a patient's skin.

The sensor cable **1007** can be electrically coupled to the sensor subassembly **1002** via a printed circuit board ("PCB") (not shown) in the sensor subassembly **1002**. Through this contact, electrical signals are communicated from the multi-parameter sensor subassembly to the physiological monitor through the sensor cable **1007** and the cable **1011**.

In various embodiments, not all of the components illustrated in FIG. **10** are included in the sensor system **1000**. For example, in various embodiments, one or more of the patient anchor **1003** and the attachment subassembly **1004** are not included. In one embodiment, for example, a bandage or tape is used instead of the attachment subassembly **1004** to attach the sensor subassembly **1002** to the measurement site. Moreover, such bandages or tapes can be a variety of different shapes including generally elongate, circular and oval, for example. In addition, the cable hub **1020** need not

be included in certain embodiments. For example, multiple cables from different sensors could connect to a monitor directly without using the cable hub **1020**.

Additional information relating to acoustic sensors compatible with embodiments described herein, including other embodiments of interfaces with the physiological monitor, are included in U.S. patent application Ser. No. 12/044,883, filed Mar. 7, 2008, entitled "Systems and Methods for Determining a Physiological Condition Using an Acoustic Monitor," (hereinafter referred to as "the '883 application"), the disclosure of which is hereby incorporated by reference in its entirety. An example of an acoustic sensor that can be used with the embodiments described herein is disclosed in U.S. patent application Ser. No. 12/643,939, incorporated above.

Freshness Indicator

Referring to FIG. **11**, a respiratory analysis system **1100** is shown. The respiratory analysis system **1100** can calculate one or more parameters related to an acoustic signal obtained from a patient. The respiratory analysis system **1100** can calculate, among other parameters, respiratory rate (sometimes referred to as RR), respiratory signal quality (RSQ), and freshness of the respiratory rate calculation. Advantageously, in certain embodiments, the respiratory analysis system **1100** can output data and/or indicators reflecting one or more of these parameters, thereby assisting clinicians with assessing a health status of a patient.

The respiratory analysis system **1100** includes three example modules in the depicted embodiment. These modules include a respiratory rate calculator **1110**, an RSQ calculator **1120**, and a freshness calculator **1130**. Each of these modules can include hardware and/or software for performing certain tasks. An acoustic signal **1102** is received by the respiratory analysis system **1100** and is used by one or more of the modules to perform these tasks. The acoustic signal **1102** can be obtained from an acoustic sensor, such as any of the sensors described above, coupled to a living patient.

The respiratory rate calculator **1100** can analyze the acoustic signal **1102** to determine a respiratory rate measurement for the patient. The respiratory rate measurement can vary with time. The respiratory rate calculator **1100** can output the respiratory rate measurements **1142** for presentation to a clinician. For example, the respiratory rate calculator **1100** can output the respiratory rate measurements **1142** to a display or to another clinician device over a network (such as a nurse's station computer in a hospital).

The RSQ calculator **1120** can calculate an objective measure of the quality of the acoustic signal **1102**. The RSQ calculator **1120** can, for instance, quantitatively determine how corrupted the acoustic signal **1102** is by noise, how similar the acoustic signal **1102** is to known waveform characteristics of respiratory signals, and the like. Based at least in part on this analysis, the RSQ calculator **1120** can output an RSQ indicator **1144** that reflects the calculated quality of the acoustic signal **1102**. The RSQ calculator **1120** can output the RSQ indicator **1144** to a display or to another clinician device over a network. Advantageously, in certain embodiments, the RSQ indicator **1144** can be implemented as any of the visual indicators or elements described above. For instance, the RSQ indicator **1144** can be a bidirectional bar graph. As signal quality changes, the bidirectional bar graph could change accordingly.

The RSQ indicator **1144** could be a unidirectional bar graph instead of a bidirectional bar graph. The RSQ indicator **1144** can also be a binary indicator, indicating low or high RSQ. The RSQ indicator **1144** could also be a numerical value, such as a percentage or the like. In another embodiment, the RSQ indicator **1144** can be an occurrence indicator, such as the occurrence indicator described in U.S. Pat. No. 6,996,427, titled "Pulse Oximetry Data Confidence Indicator," filed Dec. 18, 2003, the disclosure of which is hereby incorporated by reference in its entirety. Any combination of the indicators described herein and/or other types of indicators could be used.

The freshness calculator **1130** calculates a freshness or relevance of the respiratory rate measurement **1142**. In some situations, the respiratory rate calculator **1110** and/or the RSQ calculator **1120** might determine that a calculated respiratory rate measurement **1142** is invalid, of low quality, or cannot be measured. An invalid respiratory rate measurement **1142** can be, for example, a measurement that is not physiological possible (such as a measurement that is too high). An invalid measurement can also be a measurement that changes rapidly over a short period of time. One option when invalid or other low quality measurements occur is to discard the invalid or low quality respiratory rate value and not display a new measurement until a valid or higher quality value is obtained. However, not displaying a respiratory rate value (or showing zero) can confuse a clinician if the patient is still breathing.

Thus, instead of displaying no (or zero) value in low quality signal conditions, the respiratory rate calculator **1110** can continue to output the previous respiratory rate measurement **1142** for a certain amount of time. This amount of time can be determined by the freshness calculator **1130**. The freshness calculator **1130** can include a counter, timer, or the like that increments (or decrements) as soon as a low or invalid signal condition is detected by the respiratory rate calculator **1110** or the RSQ calculator **1120**. When the freshness calculator **1130** determines that a certain amount of time has elapsed, for example, by comparison with a predetermined threshold time value, the freshness calculator **1130** can cause the respiratory rate calculator **1110** to output a zero or no respiratory rate value. Conversely, if while the freshness calculator **1130** is incrementing (or decrementing) the counter the respiratory rate calculator **1110** produces a valid or higher quality respiratory rate measurement **1142**, the freshness calculator **1130** can reset the counter.

The amount of time elapsed before the freshness calculator **1130** outputs a zero or no respiratory rate value can be user-configurable. The respiratory analysis system **1100** can, for instance, output a user interface control on a display of a patient monitor that enables a clinician to adjust the freshness period. This input by a clinician can then be updated in the freshness calculator **1130**. The respiratory analysis system **1100** can provide a user interface element on a display or the like for the clinician to input the freshness timer input **1104**.

The freshness calculator **1130** can output a freshness indicator **1146** that reflects a freshness of the respiratory rate measurement **1142**. The freshness calculator **1130** can output the freshness indicator **1146** to a display or to another clinician device over a network. The freshness indicator **1146** can be a light, for instance, that turns on when the freshness calculator **1130** is incrementing (or decrementing) the counter. The light could also change color as the counter is incremented (or decremented). The freshness indicator **1146** could also be a bar, a number, or any other visual element. The freshness indicator **1146** could also be an audible indicator, such as an audible alarm. The audible indicator can increase in intensity as the counter is incremented (or decremented).

In another embodiment, the freshness indicator **1146** can be implemented as a flashing version of a parameter value or other value indicator. For example, any numeric value of a parameter can flash to reflect lack of, or a decrease in, freshness. The bidirectional display bar described above can also flash to reflect the lack of freshness. The flashing of the parameter or other value indicator can increase (or decrease) in rate until a defined time period has expired. After this time period has expired, a zero value can be displayed for the parameter. Moreover, when the freshness period has expired, an alarm can be triggered.

In yet another embodiment, the freshness indicator **1146** and the RSQ indicator **1144** are implemented together, for example, as follows. The RSQ indicator **1144** can generally indicate changes in signal quality of a respiration or acoustic signal. The freshness of a respiratory rate measurement **1142** can be calculated as described above. Instead of outputting a separate indicator, the calculated freshness can be used to adjust the output of the RSQ indicator **1144**. If a respiratory rate measurement **1142** is less fresh, for instance, the RSQ indicator **1144** can reflect this as a lower value, a lower bar (or bars), or the like. In one embodiment, the RSQ indicator **1144** is lowered by some percentage, such as 5%, 10%, 20%, or some other percentage. In other embodiments, the RSQ indicator **1144** gradually drops toward some minimum value (such as zero) as the freshness decreases.

Any combination of these features can be used for the freshness indicator **1146**, as well as others.

FIG. **12** illustrates an embodiment of a patient monitor **1200** having a respiration display. The patient monitor **1200** can include any of the features described above. Further, the patient monitor **1200** can implement any of the displays or other features described above. In the depicted embodiment, the patient monitor **1200** displays an example respiration waveform.

The patient monitor **1200** displays parameter indicators for several physiological parameters in the depicted embodiment. Some of these parameter indicators include an oxygen saturation indicator **1210**, hemoglobin, perfusion index, plethysmograph variability index, and other indicators **1220**, and an occurrence graph **1225** reflecting signal quality for an optical signal.

Further, the patient monitor **1200** displays an example respiratory rate indicator **1230** that reflects values of a patient's respiratory rate. This value can be obtained using any of the respiratory rate measurement methods described above. Advantageously, in the depicted embodiment, the patient monitor **1200** also includes a respiration waveform **1240**. This respiration waveform **1240** can represent a patient's time-domain respiration signal or an envelope of the respiration signal over a period of time. The respiration waveform **1240** can be bidirectional or unidirectional in some embodiments. The depicted patient monitor **1200** illustrates a bidirectional respiration waveform **1240**. A unidirectional respiration waveform **1240** might include excursions in a single direction (e.g., positive or negative) from an axis.

The respiration waveform **1240** can reflect an actual respiration signal, providing a clinician with more information about a patient's breathing pattern than just the respiratory rate indicator **1230** alone. The respiration waveform **1240** can enable a clinician to diagnose patient problems by observing, for instance, heights and widths of peaks in the respiratory waveform **1240**, irregularities in the respiratory waveform **1240**, spikes of activity in the respiratory waveform **1240**, general low activity in the respiratory waveform **1240**, some combination of the same, or the like.

It should be noted that although several embodiments herein have described a bidirectional display, a unidirectional display can be used instead to represent respiratory parameters.

Conditional language used herein, such as, among others, "can," "could," "might," "may," "e.g.," and the like, unless specifically stated otherwise, or otherwise understood within the context as used, is generally intended to convey that certain embodiments include, while other embodiments do not include, certain features, elements and/or states. Thus, such conditional language is not generally intended to imply that features, elements and/or states are in any way required for one or more embodiments or that one or more embodiments necessarily include logic for deciding, with or without author input or prompting, whether these features, elements and/or states are included or are to be performed in any particular embodiment.

Depending on the embodiment, certain acts, events, or functions of any of the methods described herein can be performed in a different sequence, can be added, merged, or left out all together (e.g., not all described acts or events are necessary for the practice of the method). Moreover, in certain embodiments, acts or events can be performed concurrently, e.g., through multi-threaded processing, interrupt processing, or multiple processors or processor cores, rather than sequentially.

The various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein can be implemented as electronic hardware, computer software, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. The described functionality can be implemented in varying ways for each particular application, but such implementation decisions should not be interpreted as causing a departure from the scope of the disclosure.

The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein can be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor can be a microprocessor, but in the alternative, the processor can be any conventional processor, controller, microcontroller, or state machine. A processor can also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

The blocks of the methods and algorithms described in connection with the embodiments disclosed herein can be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module can reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of computer-readable storage medium known in the art. An exemplary storage medium is coupled to a processor such that the processor can read information from, and write information to, the storage medium. In the alter-

native, the storage medium can be integral to the processor. The processor and the storage medium can reside in an ASIC. The ASIC can reside in a user terminal. In the alternative, the processor and the storage medium can reside as discrete components in a user terminal.

While the above detailed description has shown, described, and pointed out novel features as applied to various embodiments, it can be understood that various omissions, substitutions, and changes in the form and details of the devices or algorithms illustrated can be made without departing from the spirit of the disclosure. As can be recognized, certain embodiments of the inventions described herein can be embodied within a form that does not provide all of the features and benefits set forth herein, as some features can be used or practiced separately from others. The scope of certain inventions disclosed herein is indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

What is claimed is:

1. A system comprising:

one or more respiratory sensors configured to be coupled with a patient and to generate a respiration waveform representing inspiration and expiration cycles of the patient;

a processor configured to receive the respiration waveform from the one or more respiratory sensors; and

a display configured to display a visual element for representing values of an amplitude of the respiration waveform, the visual element comprising:

a middle portion corresponding to a reference position representative of a transition between the inspiration and the expiration,

a first extremity portion extending from the middle portion in a first direction,

a second extremity portion extending from the middle portion in a second direction,

a value indicator configured to visually depict values of the amplitude of the respiration waveform during the inspiration and the expiration cycles, wherein the amplitude of the respiration waveform comprises an acoustic volume of the patient's respiratory sounds, and

first and second goal indicators positioned between the reference position and the first and second extremity portions, respectively, the first and second goal indicators visually indicating a goal value of the amplitude of the respiration waveform that the patient is to strive to reach during inspiration, wherein the goal value of the amplitude of the respiration waveform comprises a desired acoustic volume of the patient's respiratory sounds;

wherein the processor is configured to:

illuminate the value indicator responsive to changes in the amplitude of the respiration waveform to expand at least partway toward ends of both the first and second extremity portions during inspiration and to contract at least partway toward the reference position during expiration, and

illuminate the first and second goal indicators.

2. The system of claim **1**, wherein the first and second goal indicators are configured to blink when the amplitude of the respiration waveform achieves the goal value.

3. The system of claim **1**, wherein the processor is configured to:

determine a value of the amplitude of the respiration waveform at a time corresponding to when an inspiratory phase of the patient has reached its peak value; and

compare the peak value to the goal value.

4. The system of claim **3**, wherein the processor is configured to, in response to determining that the peak value exceeds the goal value, output an acknowledgement that the goal value has been reached.

5. The system of claim **4**, wherein the acknowledgement comprises an audible sound.

6. The system of claim **4**, wherein the acknowledgement comprises a change in appearance to one or both of the first and second goal indicators.

7. The system of claim **3**, wherein the processor is configured to, in response to determining that the peak value does not equal or exceed the goal value, expand the value indicator toward the first and second goal indicators.

8. The system of claim **1**, wherein the visual element comprises a bar graph, and wherein the first and second goal indicators each comprise a segment of the bar graph.

9. The system of claim **1**, wherein the processor is configured to illuminate the first and second goal indicators using a different color than that used for the value indicator.

10. The system of claim **1**, wherein the processor is configured to illuminate the value indicator and the first and second goal indicators while the patient is conducting breathing exercises.

11. A physiological monitor comprising:

a processor configured to receive physiological information comprising a respiration waveform from one or more sensors coupled with a patient; and

a display configured to display a visual element for representing values of an amplitude of the respiration waveform, the visual element comprising:

a middle portion corresponding to a reference position representative of a transition between inspiration and expiration cycles of the patient,

first and second extremity portions, the first extremity portion extending from the middle portion in a first direction, and the second extremity portion extending from the middle portion in a second direction,

a value indicator configured to visually depict values of the amplitude of the respiration waveform, wherein the amplitude of the respiration waveform comprises an acoustic volume of the patient's respiratory sounds,

a first goal indicator positioned along the first extremity portion, and

a second goal indicator positioned along the extremity portion, the first and second goal indicators visually indicating a goal value of the amplitude of the respiration waveform during inspiration, wherein the goal value of the amplitude of the respiration waveform comprises a desired acoustic volume of the patient's respiratory sounds;

wherein the processor is configured to:

illuminate the value indicator responsive to changes in the amplitude of the respiration waveform to expand at least partway toward ends of both the first and second extremity portions during inspiration and to contract at least partway toward the reference position during expiration, and

illuminate the first and second goal indicators.

12. The physiological monitor of claim **11**, wherein the first and second goal indicators are configured to blink when the amplitude of the respiration waveform achieves the goal value.

13. The physiological monitor of claim 11, wherein the processor is configured to:

determine a value of the amplitude of the respiration waveform at a time corresponding to when an inspiratory phase of the patient has reached its peak value; and

compare the peak value to the goal value.

14. The physiological monitor of claim 13, wherein the processor is configured to, in response to determining that the peak value exceeds the goal value, output an acknowledgement that the goal value has been reached.

15. The physiological monitor of claim 14, wherein the acknowledgement comprises an audible sound.

16. The physiological monitor of claim 14, wherein the acknowledgement comprises a change in appearance to one or both of the first and second goal indicators.

17. The physiological monitor of claim 13, wherein the processor is configured to, in response to determining that the peak value does not equal or exceed the goal value, expand the value indicator toward the first and second goal indicators.

18. The physiological monitor of claim 11, wherein the visual element comprises a bar graph, and wherein the first and second goal indicators each comprise a segment of the bar graph.

19. The physiological monitor of claim 11, wherein the processor is configured to illuminate the first and second goal indicators using a different color than that used for the value indicator.

20. The physiological monitor of claim 11, wherein the processor is configured to illuminate the value indicator and the first and second goal indicators while the patient is conducting breathing exercises.

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专利名称(译)	双向生理信息显示		
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[标]申请(专利权)人(译)	梅西莫股份有限公司		
申请(专利权)人(译)	Masimo公司		
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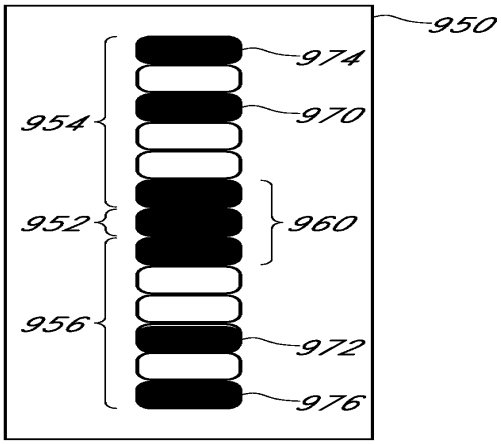
摘要(译)

用于显示生理信号的患者监测器可以包括视觉元件，该视觉元件具有指示生理状态之间的生理信号的转变的中间部分。视觉元件还可包括第一和第二末端部分，第一末端部分沿第一方向从中间部分延伸，第二末端部分沿第二方向从中间部分延伸。视觉元素还可以包括可动作值指示符，以指定关于中间部分以及第一和第二末端部分的值。患者监测器还可以包括处理器，该处理器被配置为根据生理信号的变化使值指示器在第一和第二方向上致动。