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(54) **SYSTEMS AND METHODS FOR ENSEMBLE AVERAGING IN PULSE OXIMETRY**

(71) Applicant: **COVIDIENT LP**, Mansfield, MA (US)

(72) Inventor: **Daniel Lisogurski**, Boulder, CO (US)

(73) Assignee: **Covidient LP**, Mansfield, MA (US)

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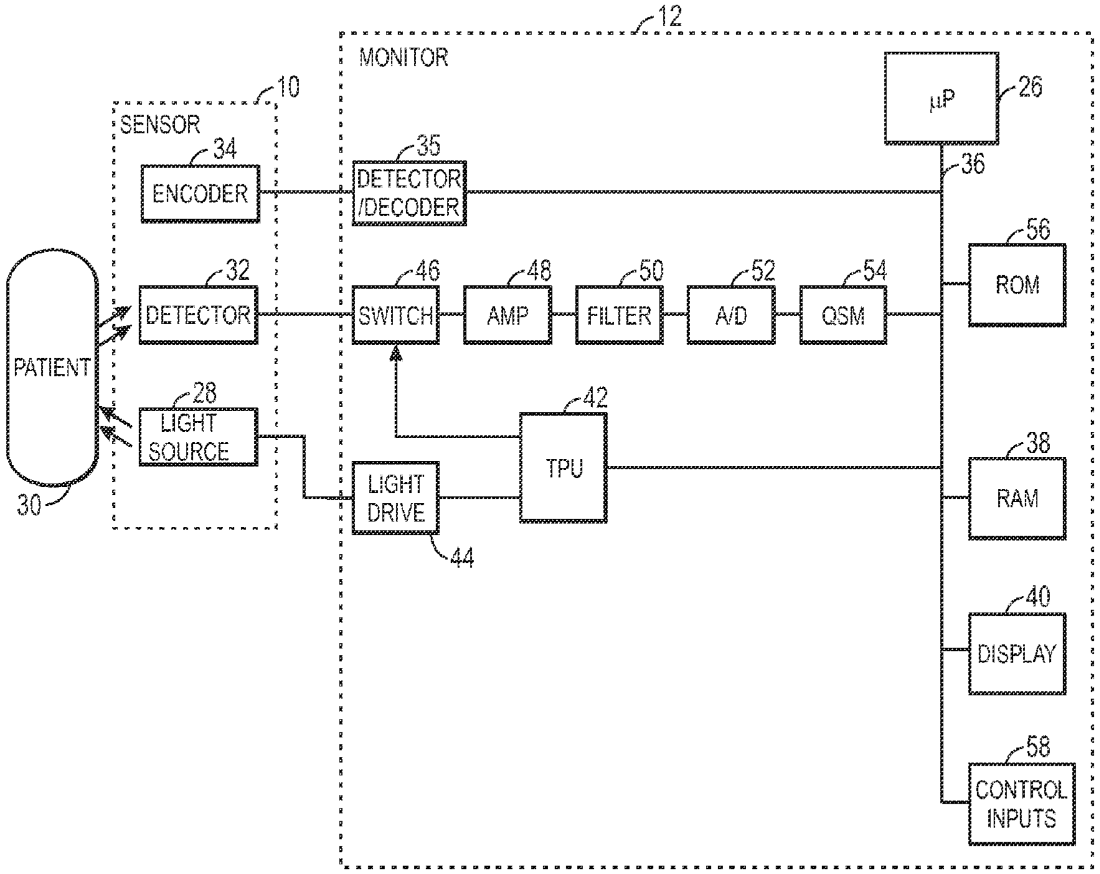
USPC **600/324**

(57) **ABSTRACT**

Various methods and systems for ensemble averaging signals in a pulse oximeter are provided. An ensemble averaging method includes receiving an ensemble average signal corresponding to an ensemble average of electromagnetic radiation signals detected from a blood perfused tissue of a patient and receiving a pulse signal corresponding to a pulse detected by the pulse oximeter. The method also includes warping a time axis of the ensemble average signal via dynamic programming, warping a time axis of the pulse signal via dynamic programming, or both to produce a warped ensemble average signal and a warped pulse signal having a substantially uniform width. The method further includes ensemble averaging the warped ensemble average signal and the warped pulse signal to produce an updated ensemble average signal having the substantially uniform width.



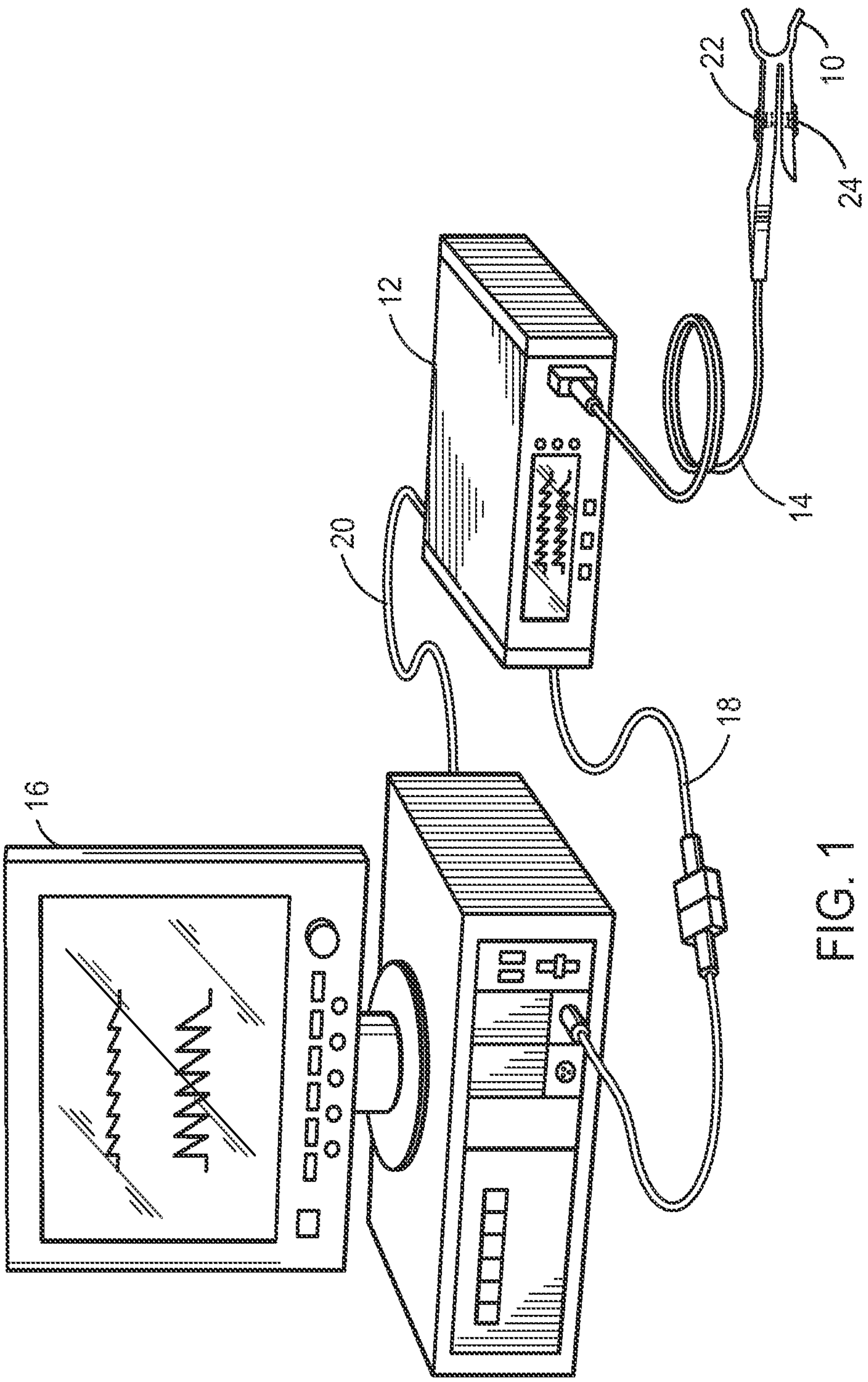


FIG. 1

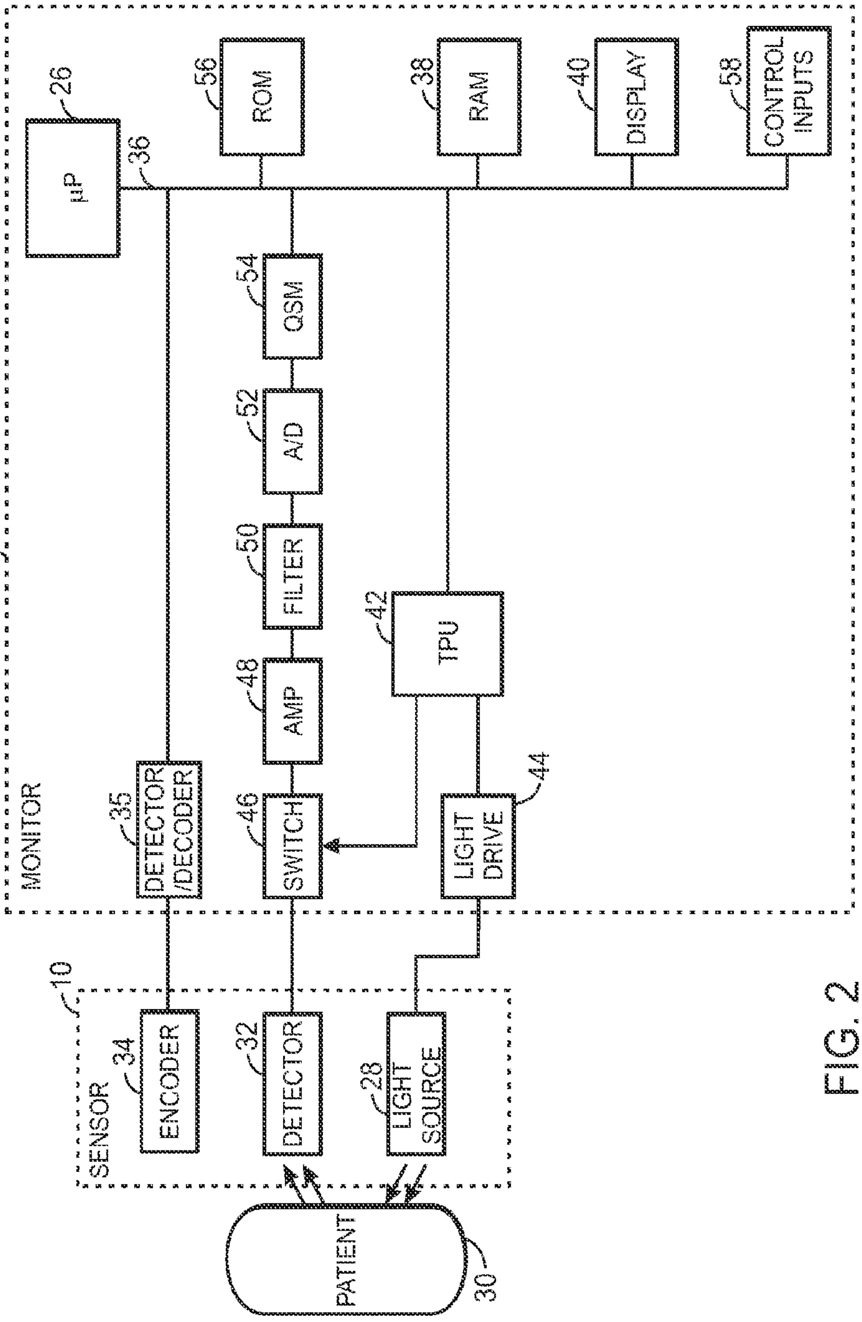

12
MONITOR
μP
26
36
ROM
56
RAM
38
DISPLAY
40
CONTROL INPUTS
58
QSM
54
A/D
52
FILTER
50
AMP
48
SWITCH
46
TPU
42
LIGHT DRIVE
44
DETECTOR /DECODER
35
10
SENSOR
ENCODER
34
DETECTOR
32
LIGHT SOURCE
28
PATIENT
30

FIG. 2

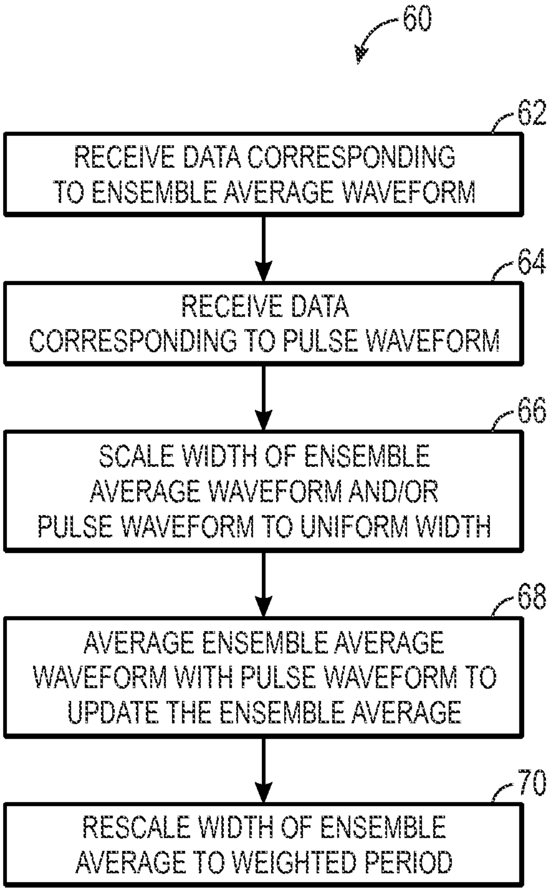

60
62
RECEIVE DATA CORRESPONDING TO ENSEMBLE AVERAGE WAVEFORM
64
RECEIVE DATA CORRESPONDING TO PULSE WAVEFORM
66
SCALE WIDTH OF ENSEMBLE AVERAGE WAVEFORM AND/OR PULSE WAVEFORM TO UNIFORM WIDTH
68
AVERAGE ENSEMBLE AVERAGE WAVEFORM WITH PULSE WAVEFORM TO UPDATE THE ENSEMBLE AVERAGE
70
RESCALE WIDTH OF ENSEMBLE AVERAGE TO WEIGHTED PERIOD

FIG. 3

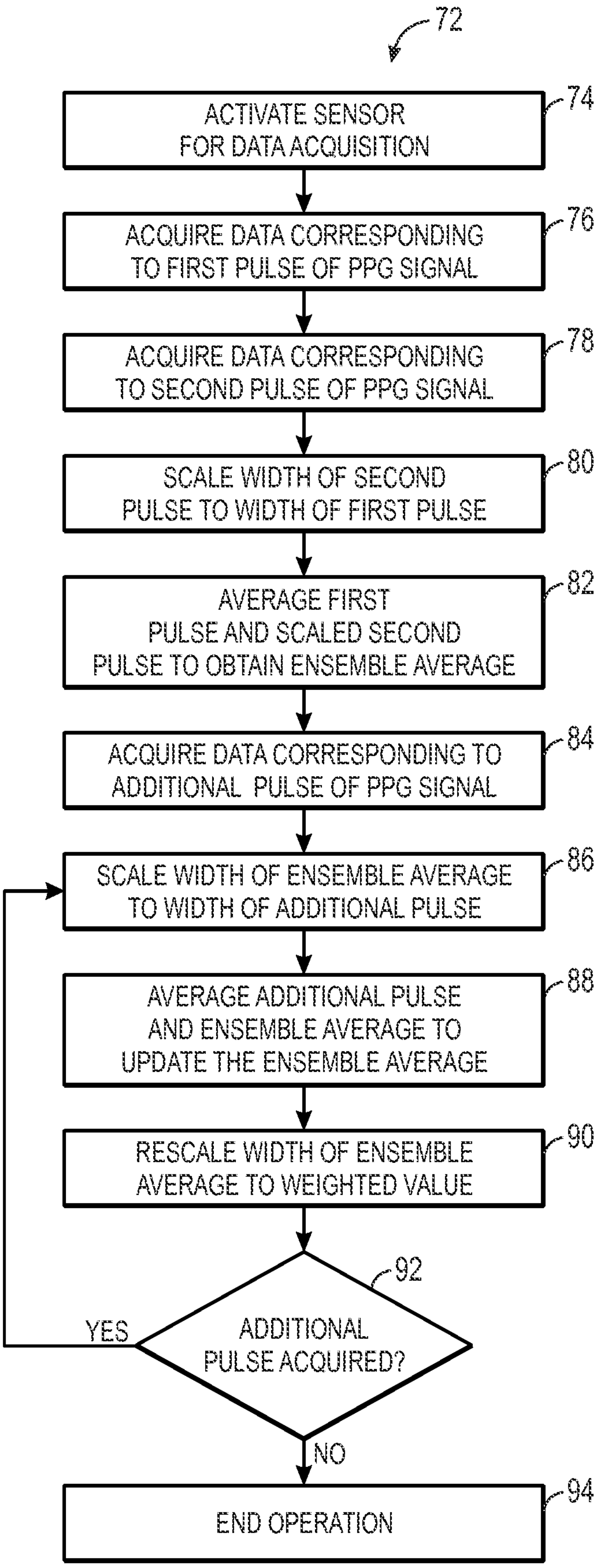

72
74
ACTIVATE SENSOR FOR DATA ACQUISITION
76
ACQUIRE DATA CORRESPONDING TO FIRST PULSE OF PPG SIGNAL
78
ACQUIRE DATA CORRESPONDING TO SECOND PULSE OF PPG SIGNAL
80
SCALE WIDTH OF SECOND PULSE TO WIDTH OF FIRST PULSE
82
AVERAGE FIRST PULSE AND SCALED SECOND PULSE TO OBTAIN ENSEMBLE AVERAGE
84
ACQUIRE DATA CORRESPONDING TO ADDITIONAL PULSE OF PPG SIGNAL
86
SCALE WIDTH OF ENSEMBLE AVERAGE TO WIDTH OF ADDITIONAL PULSE
88
AVERAGE ADDITIONAL PULSE AND ENSEMBLE AVERAGE TO UPDATE THE ENSEMBLE AVERAGE
90
RESCALE WIDTH OF ENSEMBLE AVERAGE TO WEIGHTED VALUE
92
ADDITIONAL PULSE ACQUIRED?
YES
NO
94
END OPERATION

FIG. 4

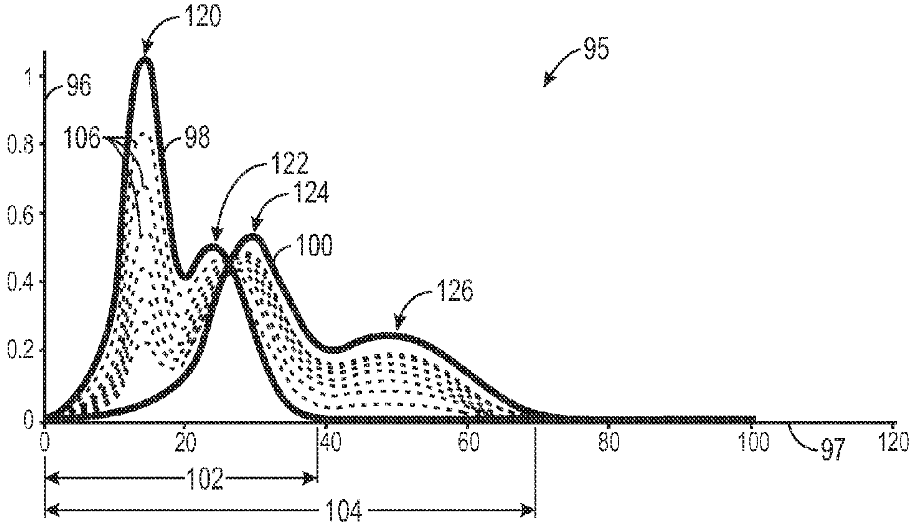

120
95
1
96
0.8
106
98
122
0.6
124
100
0.4
126
0.2
0
0
20
40
60
80
100
97
120
102
104

FIG. 5

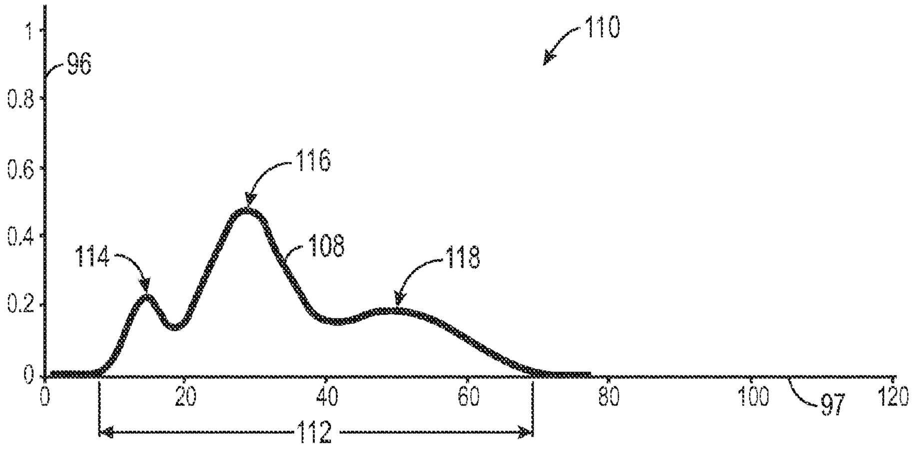

110
1
96
0.8
0.6
116
0.4
114
108
118
0.2
0
0
20
40
60
80
100
97
120
112

FIG. 6

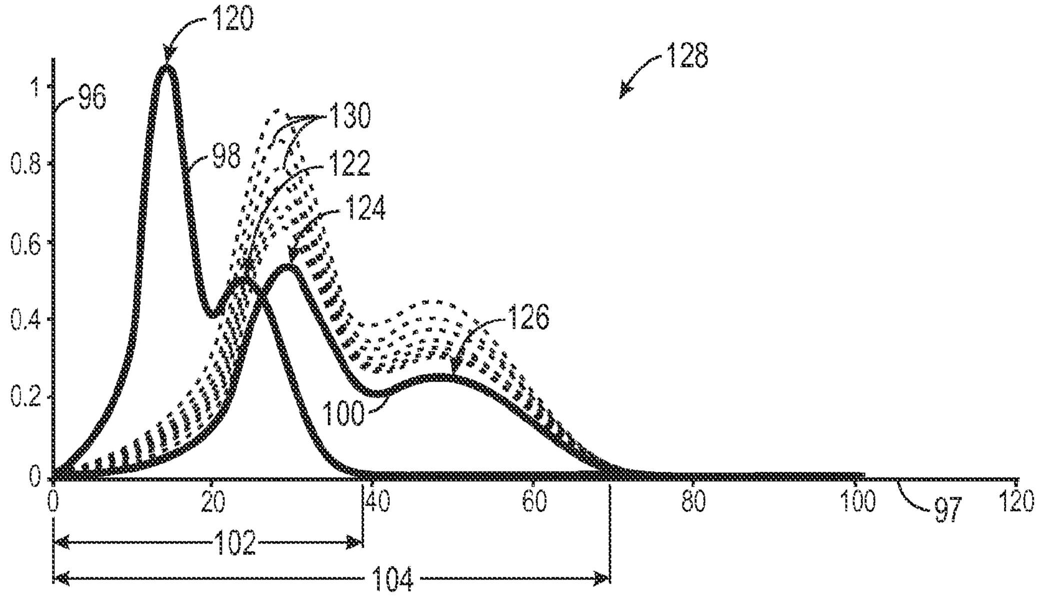

120
128
1
0.8
0.6
0.4
0.2
0
96
98
130
122
124
126
100
0
20
40
60
80
100
120
97
102
104

FIG. 7

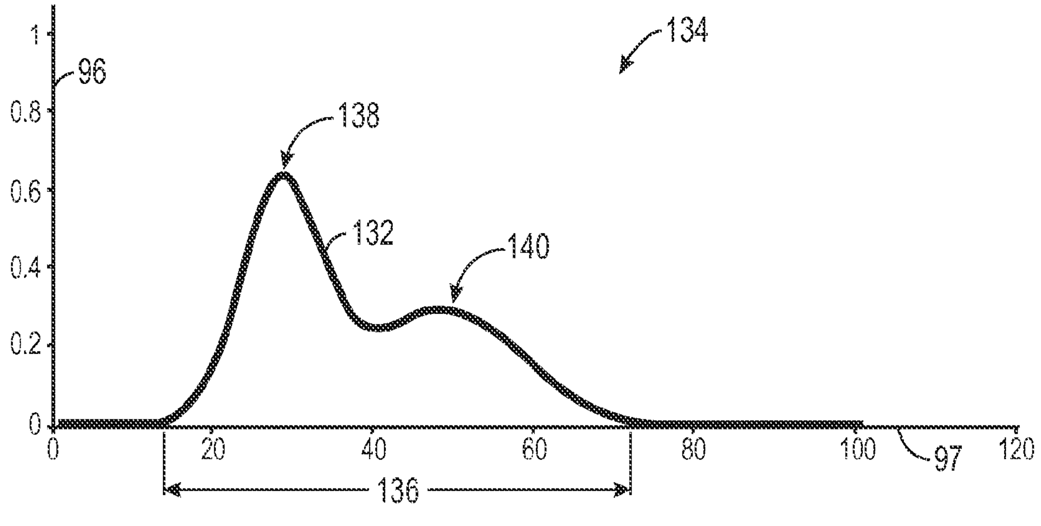

134
1
0.8
0.6
0.4
0.2
0
96
138
132
140
0
20
40
60
80
100
120
97
136

FIG. 8

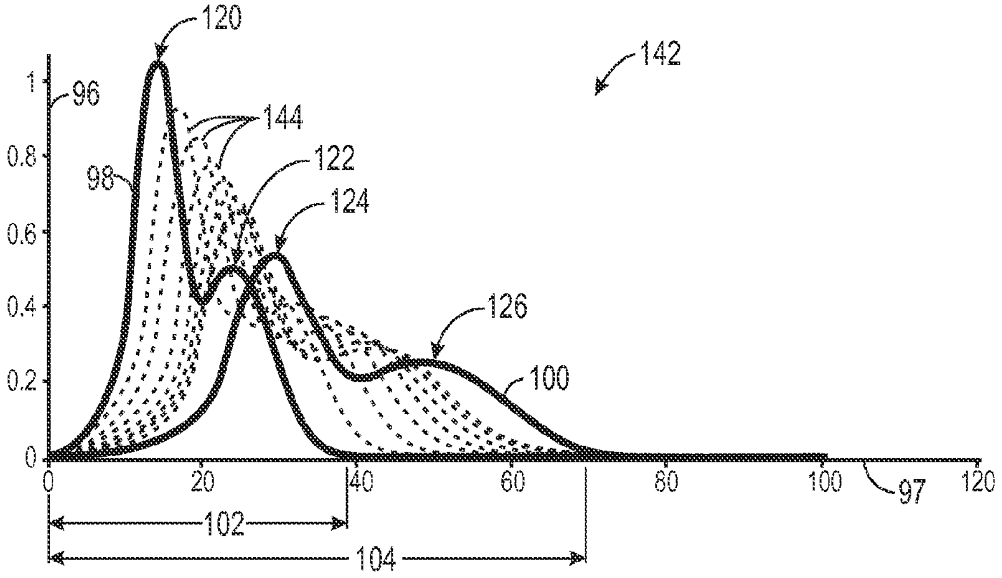

120
142
1
96
144
0.8
98
122
0.6
124
0.4
126
0.2
100
0
0
20
40
60
80
100
97
120
102
104

FIG. 9

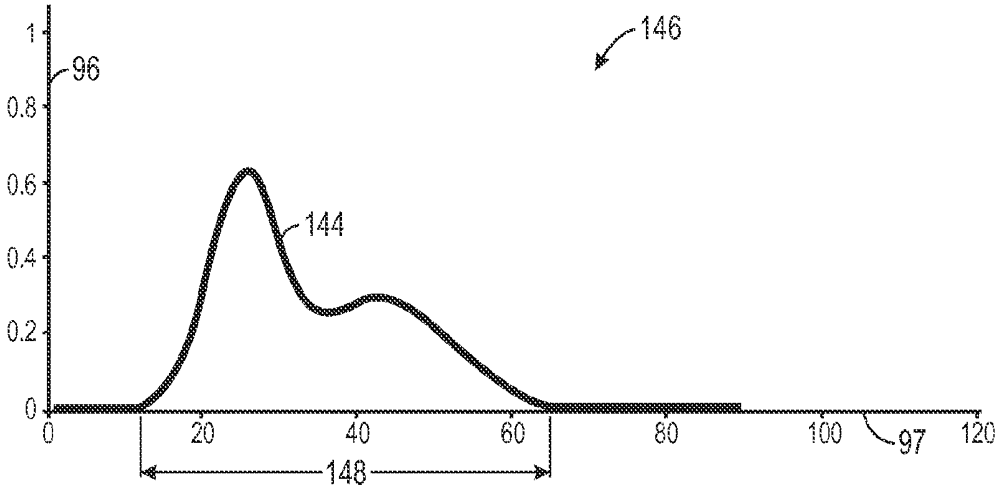

1
146
96
0.8
0.6
144
0.4
0.2
0
0
20
40
60
80
100
97
120
148

FIG. 10

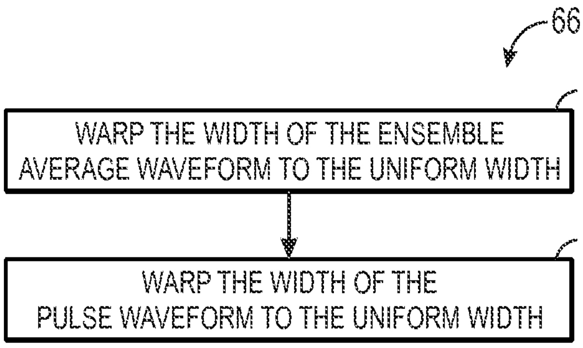


FIG. 11

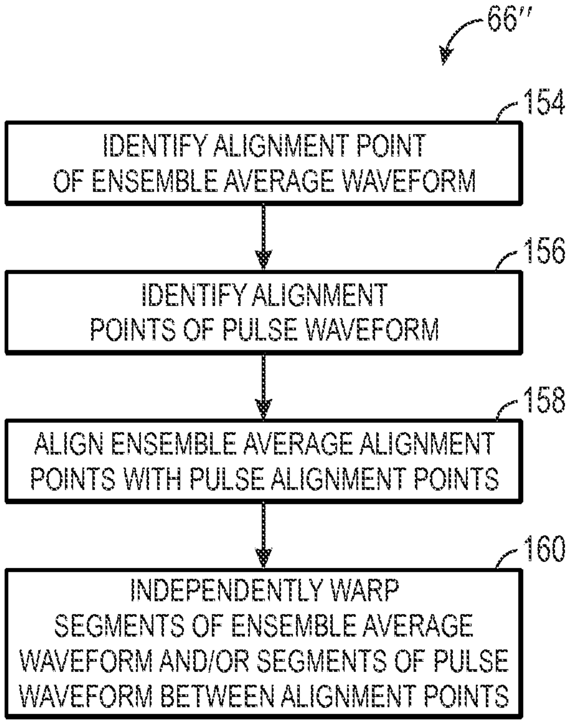


FIG. 12

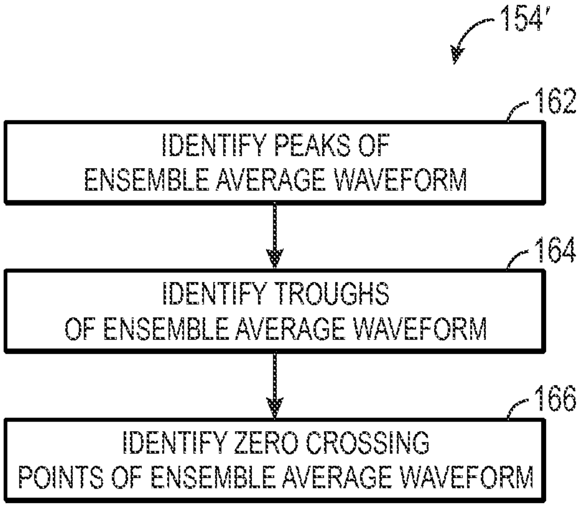


FIG. 13

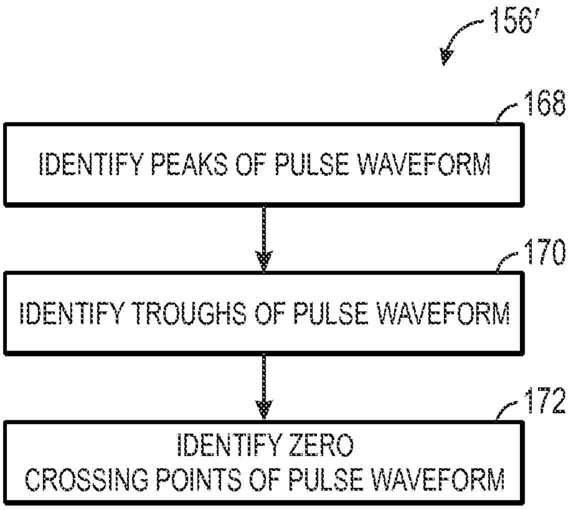

156'
168
IDENTIFY PEAKS OF PULSE WAVEFORM
170
IDENTIFY TROUGHS OF PULSE WAVEFORM
172
IDENTIFY ZERO CROSSING POINTS OF PULSE WAVEFORM

FIG. 14

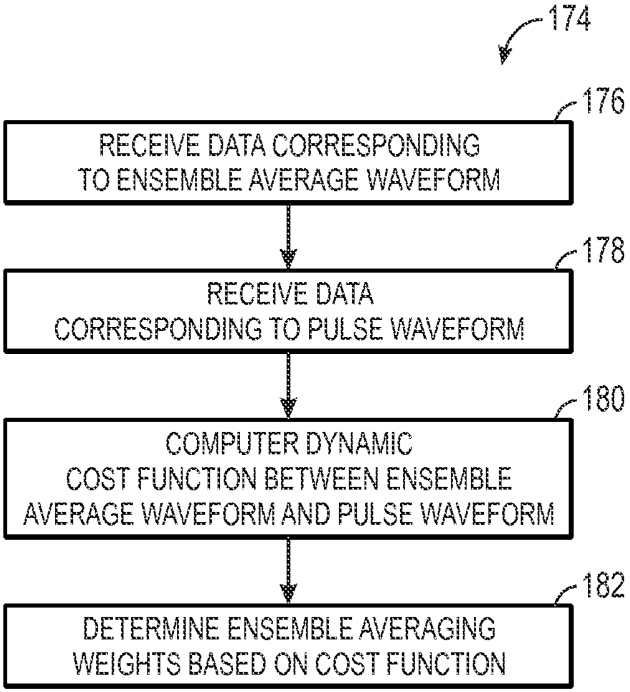

174
176
RECEIVE DATA CORRESPONDING TO ENSEMBLE AVERAGE WAVEFORM
178
RECEIVE DATA CORRESPONDING TO PULSE WAVEFORM
180
COMPUTER DYNAMIC COST FUNCTION BETWEEN ENSEMBLE AVERAGE WAVEFORM AND PULSE WAVEFORM
182
DETERMINE ENSEMBLE AVERAGING WEIGHTS BASED ON COST FUNCTION

FIG. 15

SYSTEMS AND METHODS FOR ENSEMBLE AVERAGING IN PULSE OXIMETRY

BACKGROUND

[0001] The present disclosure relates generally to pulse oximetry and, more particularly, to ensemble averaging of pulses in a detected waveform from a pulse oximeter.

[0002] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0003] In the field of medicine, medical practitioners often desire to monitor certain physiological characteristics of their patients. Accordingly, a wide variety of devices have been developed for monitoring physiological characteristics. Such devices provide doctors and other healthcare personnel with the information they need to provide healthcare for their patients. As a result, such monitoring devices have become an indispensable part of modern medicine. One technique for monitoring certain physiological characteristics of a patient is commonly referred to as pulse oximetry, and the devices built based upon pulse oximetry techniques are commonly referred to as pulse oximeters.

[0004] A pulse oximeter is typically used to measure various physiological characteristics, such as the blood oxygen saturation of hemoglobin in arterial blood and the pulse rate of the patient. Measurement of these characteristics has been accomplished by use of a non-invasive sensor that passes light through a portion of a patient's blood perfused tissue and photo-electrically senses the absorption and scattering of light in such tissue. The amount of light absorbed and scattered is then used to estimate the amount of blood constituent in the tissue using various algorithms known in the art. The "pulse" in pulse oximetry comes from the time varying amount of arterial blood in the tissue during a cardiac cycle. The signal processed from the sensed optical measurement is the plethysmographic waveform, which corresponds to the cyclic attenuation of optical energy through a portion of a patient's blood perfused tissue.

[0005] Ensemble averaging is a temporal averaging scheme that may be utilized to combine similar signals or similar portions of the same signal in order to improve the signal-to-noise ratio of the acquired data. In a pulse oximeter, ensemble averaging is used to calculate a weighted average of new samples and previous ensemble-averaged samples from one pulse-period earlier, and this weighted average may be utilized to determine a desired blood characteristic. For example, during a typical ensemble averaging operation, different weights may be assigned to different pulses, and a composite, averaged pulse waveform may be used to determine blood oxygen saturation.

[0006] A variety of techniques have been developed to attempt to improve the obtainable signal-to-noise ratio when ensemble averaging is utilized in pulse oximetry. For example, because the weights used for ensemble averaging have a significant effect on the ensemble averaging process, some implementations base the selected weights on the characteristics of the signals that are being ensemble averaged. In one implementation, when a new sample is suspected to have a high signal-to-noise ratio, the weight of the new sample may be increased, and when a new sample is suspected to be noisy, the weight of the sample may be decreased. Unfortunately, while these techniques may be advantageous in certain instances, in other instances, the weighted average obtained via ensemble averaging may still be prone to averaging errors due to physiological factors. For example, when the heart rate of a patient varies with time, the ensemble average waveform and the new sample may have different lengths, thus blurring the computed ensemble average waveform. In many instances, healthy subjects have a Respiratory Sinus Arrhythmia (RSA) where the heart rate changes slightly during the inhalation and exhalation phases of respiration. Changing pulse durations may also become problematic with frequent ectopic beats. Accordingly, there exists a need for ensemble averaging techniques that address these drawbacks.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Advantages of the disclosed techniques may become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0008] FIG. **1** illustrates an embodiment of a patient monitoring system including a patient monitor and a sensor;

[0009] FIG. **2** is a block diagram illustrating an embodiment of a patient monitoring system including a sensor and a pulse oximeter;

[0010] FIG. **3** is a flow chart illustrating an embodiment of an ensemble averaging method that may be implemented to ensemble average pulses in a detected waveform from a pulse oximeter;

[0011] FIG. **4** is a flow chart illustrating an embodiment of an ensemble averaging method that may be implemented to generate and update an ensemble average waveform throughout a pulse oximetry data collection operation;

[0012] FIG. **5** is a plot illustrating examples of pulse waveforms that may be detected by a pulse oximeter and examples of ensemble average waveforms that may be generated through traditional ensemble averaging methods;

[0013] FIG. **6** is a plot illustrating an example ensemble average waveform that may be generated through a traditional ensemble averaging method;

[0014] FIG. **7** is a plot illustrating a series of ensemble average waveforms that may be generated throughout a pulse oximetry data collection operation via an embodiment of a presently disclosed ensemble averaging method;

[0015] FIG. **8** is a plot illustrating an ensemble averaging waveform generated after a pulse oximetry data collection operation commences and having a width corresponding to the latest pulse acquired in the collection operation in accordance with an embodiment of the presently disclosed technique;

[0016] FIG. **9** is a plot illustrating a series of ensemble average waveforms that may be generated throughout a pulse oximetry data collection operation via an embodiment of a presently disclosed ensemble averaging method;

[0017] FIG. **10** is a plot illustrating an ensemble averaging waveform generated after a pulse oximetry data collection operation commences and having a rescaled width in accordance with an embodiment of the presently disclosed technique;

[0018] FIG. **11** is a flow chart illustrating an embodiment of a method that may be implemented to make uniform the width of an ensemble average waveform and a pulse waveform through dynamic time warping of the time axes of the ensemble average and pulse waveforms;

[0019] FIG. **12** is a flow chart illustrating an embodiment of a method that may be implemented to make uniform the width of an ensemble average waveform and a pulse waveform through dynamic time warping of corresponding sections of the time axes of the ensemble average and pulse waveforms;

[0020] FIG. **13** is a flow chart illustrating an embodiment of a method that may be implemented to identify fiducial points in an ensemble average waveform;

[0021] FIG. **14** is a flow chart illustrating an embodiment of a method that may be implemented to identify fiducial points in a pulse waveform; and

[0022] FIG. **15** is a flow chart illustrating an embodiment of a method that may be implemented to determine ensemble averaging weights based on a dynamic cost function.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0023] One or more specific embodiments of the present techniques will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0024] As described in detail below, the methods and systems provided herein are directed toward the ensemble averaging of pulses in a detected waveform from a pulse oximeter. Presently disclosed embodiments include one or more features capable of accommodating pulses having different lengths during the ensemble averaging process. As compared to traditional processes, the disclosed ensemble averaging techniques may reduce or prevent the likelihood of blurring of the ensemble average waveform due to the averaging of pulses having different lengths. For example, in some embodiments, a patient's heart rate may be time-varying, thus giving rise to pulse periods that include a varying number of waveform samples, and features of the disclosed methods may accommodate this physiological variability during the ensemble averaging of the detected pulses. The foregoing feature may improve the quality of the generated ensemble average waveform, thus possibly improving the likelihood that the ensemble average waveform may be utilized to accurately determine a physiological parameter of interest, such as blood oxygen saturation, blood pressure, pulse rate, and so forth.

[0025] Embodiments of the provided systems and methods for ensemble averaging may include features capable of decoupling the morphological and temporal averaging of components of each pulse of the detected waveform from the pulse oximeter. For example, a variety of linear or non-linear scaling methods may be utilized to scale or warp the width of the ensemble average waveform, the most recent pulse, or both, such that when the most recent pulse and the ensemble average waveform are combined, time axis uniformity has been established. Rescaling methods may include, for example, utilizing dynamic programming to warp the time axis of the ensemble average waveform to the width of the most recent pulse such that the morphological characteristics of the ensemble average waveform are preserved. This may be achieved in certain embodiments, for example, by identifying fiducial points (e.g., peaks, troughs, and so forth) and warping portions of the waveform between the identified fiducial points. However, it is presently contemplated that a variety of scaling methods may be utilized alone or in combination to establish a uniform time axis before ensemble averaging. Further, it should be noted that the particular scaling methods implemented in a given system by one skilled in the art are subject to a variety of implementation-specific variations.

[0026] Turning now to the drawings, FIG. **1** illustrates a patient monitoring system that may utilize ensemble averaging in the process of monitoring a physiological characteristic of a patient. More specifically, the illustrated system may be capable of acquiring signals that correspond to detected waveforms from a sensor and further processing the signals to extract information that may be useful in the physiological monitoring process. To that end, the following description of the patient monitoring system serves as a basis for describing the ensemble averaging techniques described in more detail below.

[0027] The patient monitoring system of FIG. **1** includes a sensor **10** and a patient monitor **12**. In the illustrated embodiment, a cable **14** connects the sensor **10** to the patient monitor **12**. As will be appreciated by those of ordinary skill in the art, the sensor **10** and/or the cable **14** may include or incorporate one or more integrated circuit devices or electrical devices, such as a memory, processor chip, or resistor, that may facilitate or enhance communication between the sensor **10** and the patient monitor **12**. Likewise, the cable **14** may be an adaptor cable, with or without an integrated circuit or electrical device, for facilitating communication between the sensor **10** and various types of monitors, including older or newer versions of the patient monitor **12** or other physiological monitors. In other embodiments, the sensor **10** and the patient monitor **12** may communicate via wireless means, such as using radio, infrared, or optical signals. In such embodiments, a transmission device (not shown) may be connected to the sensor **10** to facilitate wireless transmission between the sensor **10** and the patient monitor **12**. As will be appreciated by those of ordinary skill in the art, the cable **14** (or corresponding wireless transmissions) are typically used to transmit control or timing signals from the monitor **12** to the sensor **10** and/or to transmit acquired data from the sensor **10** to the monitor **12**. In some embodiments, however, the cable **14** may be an optical fiber that allows optical signals to be conducted between the monitor **12** and the sensor **10**.

[0028] In one embodiment, the patient monitor **12** may be a suitable pulse oximeter, such as those available from Nellcor Puritan Bennett LLC. In other embodiments, the patient monitor **12** may be a monitor suitable for measuring tissue water fractions, or other body fluid related metrics, using spectrophotometric or other techniques. Furthermore, the monitor **12** may be a multi-purpose monitor suitable for performing pulse oximetry and measurement of tissue water fraction, or other combinations of physiological and/or biochemical monitoring processes, using data acquired via the sensor **10**. Furthermore, to upgrade conventional monitoring functions provided by the monitor **12** to provide additional functions, the patient monitor **12** may be coupled to a multiparameter patient monitor **16** via a cable **18** connected to a sensor input port and/or via a cable **20** connected to a digital communication port.

[0029] In embodiments in which the patient monitor **12** is a pulse oximeter, the pulse oximeter may be operated to detect a waveform having a variety of pulses. It may be desirable to utilize ensemble averaging to combine these pulses by averaging the most recent pulse with an ensemble average of the previous pulses throughout operation. Again, as described in more detail below, presently disclosed embodiments provide for establishment of uniformity of the length of the time axis of the most recent pulse and the ensemble average waveform before averaging, thus better preserving the morphological integrity of the pulses of the detected waveform during ensemble averaging. The foregoing feature offers an advantage over traditional systems in instances in which the lengths of the pulses in the detected waveform vary due to physiological factors (e.g., a patient's heart rate), thereby increasing the reliability of the ensemble average waveform when determining the physiological parameters of interest (e.g., blood oxygen saturation, heart rate, etc.).

[0030] In the example shown in FIG. **1**, the sensor **10** is a clip-style sensor including an emitter **22** and a detector **24** which may be of any suitable type. For example, the emitter **22** may be one or more light emitting diodes capable of transmitting one or more wavelengths of light, such as in the red to infrared range, and the detector **24** may be a photodetector, such as a silicon photodiode package, selected to receive light in the range emitted from the emitter **22**. In the illustrated embodiment, the sensor **10** is coupled to the cable **14** that is responsible for transmitting electrical and/or optical signals to and from the emitter **22** and detector **24** of the sensor **10**. The cable **14** may be permanently or removably coupled to the sensor **10**, depending on features of the implementation. For example, in instances in which the sensor **10** is disposable, the cable **14** may be removably coupled, for example, for cost efficiency purposes.

[0031] The sensor **10** described above is generally configured for use as a "transmission type" sensor for use in spectrophotometric applications, though in some embodiments it may instead be configured for use as a "reflectance type sensor." Further, in other embodiments, the sensor **10** may be any suitable oximeter. For example, the sensor **10** may be an in-vivo optical spectroscopy oximeter capable of measuring changes in oxygen levels of a patient. Indeed, the sensor **10** may be any of a variety of types of sensors employed by those skilled in the art, not limited to the particular sensors that are described in detail herein.

[0032] Transmission type sensors include an emitter and detector that are typically placed on opposing sides of the sensor site. If the sensor site is a fingertip, for example, the sensor **10** is positioned over the patient's fingertip such that the emitter and detector lie on either side of the patient's nail bed. For example, the sensor **10** is positioned so that the emitter is located on the patient's fingernail and the detector is located opposite the emitter on the patient's finger pad. During operation, the emitter shines one or more wavelengths of light through the patient's fingertip, or other tissue, and the light received by the detector is processed to determine various physiological characteristics of the patient.

[0033] Reflectance type sensors generally operate under the same general principles as transmittance type sensors. However, reflectance type sensors include an emitter and detector that are typically placed on the same side of the sensor site. For example, a reflectance type sensor may be placed on a patient's fingertip such that the emitter and detector are positioned side-by-side. Reflectance type sensors detect light photons that are scattered back to the detector.

[0034] For pulse oximetry applications using either transmission or reflectance type sensors, the oxygen saturation of the patient's arterial blood may be determined using two or more wavelengths of light, most commonly red and near infrared wavelengths. Similarly, in other applications, a tissue water fraction (or other body fluid related metric) or a concentration of one or more biochemical components in an aqueous environment may be measured using two or more wavelengths of light, most commonly near infrared wavelengths between about 1,000 nm and about 2,500 nm. It should be understood that, as used herein, the term "light" may refer to one or more of infrared, visible, ultraviolet, or even X-ray electromagnetic radiation, and may also include any wavelength within the infrared, visible, ultraviolet, or X-ray spectra.

[0035] Pulse oximetry and other spectrophotometric sensors, whether transmission-type or reflectance-type, are typically placed on a patient in a location conducive to measurement of the desired physiological parameters. For example, pulse oximetry sensors are typically placed on a patient in a location that is normally perfused with arterial blood to facilitate measurement of the desired blood characteristics, such as arterial oxygen saturation measurement (SpO_2). Common pulse oximetry sensor sites include a patient's fingertips, toes, forehead, or earlobes. Regardless of the placement of the sensor **10**, the reliability of the pulse oximetry measurement is related to the accurate detection of transmitted light that has passed through the perfused tissue and has not been inappropriately supplemented by outside light sources or modulated by subdermal anatomic structures. Such inappropriate supplementation and/or modulation of the light transmitted by the sensor can cause variability in the resulting pulse oximetry measurements.

[0036] FIG. **2** is a block diagram of an embodiment in which the patient monitor is a pulse oximeter **12** that may be capable of implementing presently disclosed embodiments. That is, various embodiments of the presently disclosed ensemble averaging methods may be implemented as data processing algorithms that are executed by a microprocessor **26**, which is provided as a component of the pulse oximeter **12** in the illustrated embodiment. Further, it should be noted that the embodiments of the present invention may be implemented as a part of a larger signal processing system used to process signals for the purpose of determining a desired physiological characteristic. As such, the microprocessor **26** may be operated alone or in conjunction with other processors in the signal processing system to implement the presently disclosed ensemble averaging methods. Again, presently contemplated algorithms that the microprocessor **26** may execute are described in more detail below.

[0037] Turning now to operation of the illustrated system, light from a light source **28** passes into a blood perfused tissue of a patient **30** and is scattered and detected by photodetector **32**. The sensor **10** containing the light source **28** and the photodetector **32** may also contain an encoder **34** that provides signals indicative of the wavelength of light source **28** to a decoder **35** to allow the pulse oximeter **12** to select appropriate calibration coefficients for calculating oxygen saturation. In some embodiments, the encoder **34** may, for example, be a resistor. For further example, in other embodiments, the encoder **34** may be a memory device.

[0038] The sensor **10** is connected to the pulse oximeter **12**. The pulse oximeter **12** includes the microprocessor **26** connected to an internal bus **36**. A random access memory (RAM) memory **38** and a display **40** are also connected to the bus **36**. A time processing unit (TPU) **42** provides timing control signals to light drive circuitry **44**, which controls when light source **28** is illuminated and, if multiple light sources are used, the multiplexed timing for the different light sources. The TPU **42** also controls the gating-in of signals from photodetector **32** through a switching circuit **46**. These signals are sampled at the proper time, depending upon which of multiple light sources is illuminated, if multiple light sources are used. The received signal is passed through an amplifier **48**, a low pass filter **50**, and an analog-to-digital converter **52**. The digital data is then stored in a queued serial module (QSM) **54**, for later downloading to RAM **38** as QSM **54** approaching its capacity. In one embodiment, there may be multiple parallel paths of separate amplifier, filter and A/D converters for multiple light wavelengths or spectra received.

[0039] Based on the value of the received signals corresponding to the light received by photodetector **32**, microprocessor **26** will calculate the desired blood characteristics, such as blood oxygen saturation, using various algorithms. These algorithms may require coefficients, which may be empirically determined, corresponding to, for example, the wavelengths of light used. These and other parameters, constants, and so forth, may be stored in a read only memory (ROM) **56**. In a two-wavelength system, the particular set of coefficients chosen for any pair of wavelength spectra is determined by the value indicated by encoder **34** corresponding to a particular light source in a particular sensor **10**. Additionally, a variety of control inputs **58** may be utilized in the calculation of the desired blood characteristics. Control inputs **58** may be, for instance, a switch on the pulse oximeter, a keyboard, or a port providing instructions from a remote host computer. Furthermore, any number of methods or algorithms may be used to determine a patient's pulse rate, oxygen saturation or any other desired physiological parameter.

[0040] The brief description of the embodiment of the pulse oximeter **12** set forth above serves as a basis for describing presently disclosed embodiments of ensemble averaging methods for accommodating a width of the most recent pulse that is different from the width of the current ensemble average, which are described below in conjunction with FIG. **2**. Specifically, FIG. **3** illustrates an embodiment of a method **60** that may be stored to memory and implemented by processing circuitry (e.g., microprocessor **26**) to ensemble average a detected waveform from a pulse oximeter that has pulses of varying lengths, for example, due to a time-varying heart rate of a patient.

[0041] In particular, the method **60** includes receiving data corresponding to an ensemble average waveform (block **62**). In some embodiments, the received ensemble average waveform may be an ensemble average of a variety of previously acquired pulses in the detected waveform acquired by the pulse oximeter. However, in other embodiments, the ensemble average waveform may be the waveform corresponding to a single pulse of the detected waveform, for example, during startup of the pulse oximeter when only a single pulse has been acquired at the time that the data is received. Still further, it should be noted that the ensemble average waveform may not be generated and displayed in some embodiments. Instead, in some embodiments, the values of the points in the ensemble average waveform may be stored and utilized for further processing.

[0042] The method **60** proceeds by receiving data corresponding to a pulse waveform (block **64**). For example, the pulse waveform may correspond to a particular section of the waveform detected by the pulse oximeter **12** corresponding to the most recent pulse. That is, the pulse waveform may be derived from the detected waveform from the pulse oximeter **12**. As previously mentioned, the period of the pulse waveform may differ from the period of the ensemble average waveform, for example, due to a time-varying heart rate. Accordingly, the method **60** proceeds by scaling the width of the ensemble average waveform and/or the width of the pulse waveform to a uniform width (block **66**).

[0043] For example, in an instance in which the width of the pulse waveform is larger than the width of the ensemble average, a presently disclosed embodiment may provide for stretching of the time axis of the ensemble average waveform to the width of the pulse waveform. In such an embodiment, after the step of block **66** is performed, the uniform width of the ensemble average waveform and the pulse waveform is equal to the width of the received pulse waveform. For further example, in other embodiments, the time axis of the pulse waveform may be altered to match the width of the ensemble average waveform, or the time axes of both the pulse waveform and the ensemble average waveform may be squeezed or stretched to a uniform length not corresponding to the natural length of either waveform.

[0044] After a uniform time axis length has been established, the pulse waveform may be averaged with the ensemble average waveform to generate an updated ensemble average waveform (block **68**). Again, because of the uniformity of the time axes of the pulse waveform and the ensemble average waveform, the averaging step of block **68** produces an updated ensemble average for which the likelihood of the introduction of noise due to mismatched periods is significantly reduced or eliminated. The foregoing feature may increase the reliability of the updated ensemble average as compared to traditional systems that may average waveforms having different widths, thus introducing noise and error to the updated ensemble average.

[0045] In some embodiments, the method **60** proceeds by rescaling the width of the updated ensemble average to a weighted period (block **70**). However, it should be noted that step **70** may be eliminated in some embodiments, for example, if step **66** scales the waveform to the desired time scale and the ensemble average is already at this time scale. In embodiments in which step **70** is included, this step may enable the morphological and temporal components of the pulse waveform to be independently ensemble averaged. For example, in one embodiment, the period of the updated and rescaled ensemble average (T_D) may be given by the following equation:

$$T_{D[n]}=T_{D(old)[n]}+w_t*(T_{p[k]}-T_{D(old)[n]}); \quad (1)$$

where $T_{D(old)}$ is the previously determined uniform width, w_t is the time rescaling weight, T_p is the time period of the most recent pulse waveform, n is an index (sample number) in the waveform where the ensemble average $T_{D[n]}$ has N points and n ranges from 0 to N−1, k is the index (sample number) of the most recent pulse which has K samples ranging from 0 to K−1. In this way, the weighted period to which the updated ensemble average is rescaled reflects a weighted average of the periods of the pulses that make up the ensemble average. It should be noted that the equation above is merely an example, and any of a variety of methods may be utilized by those skilled in the art to rescale the updated ensemble average to an appropriate weighted period. Further, the time rescaling weight may be determined based on a variety of physiological or operational factors, such as whether or not a sampling error occurred during that pulse, the presence of signal noise, the similarity of the pulse shape to previously received pulse shapes, and so forth.

[0046] Still further, in certain presently disclosed embodiments, N and K may be related such that the average signal and the new signal are warped to an equal number of points. For example, in one embodiment, this may be achieved by maintaining the ratio of n/N equal to the ration of k/K. Alternatively, in other embodiments, certain fiducial points may be scaled such that n and k both hit the peak, foot, or dicrotic notch of the averaged and new waveforms concurrently such that corresponding peaks in the waveforms are added even if the patient's heart rate has changed.

[0047] FIG. **4** illustrates an embodiment of a method **72** that may be implemented by a suitable controller, such as microprocessor **26**, throughout a pulse oximetry monitoring operation to ensemble average a plurality of pulses in a detected waveform. The method **72** includes the step of activating the sensor (e.g., pulse oximeter **12**) for data acquisition (block **74**), for example, by turning on the sensor **10**. The method **72** proceeds by acquiring data corresponding to a first pulse of the PPG signal (block **76**) and a second pulse of the PPG signal (block **78**). Once acquired, the width of the second pulse waveform is scaled to the width of the first pulse waveform (block **80**), for example, by squeezing or stretching the time axis of the second pulse waveform to the time axis of the first pulse waveform. It should be noted that in other embodiments, the time axis of the first pulse waveform may be rescaled to the width of the second pulse waveform, or both the first pulse waveform and the second pulse waveform may be squeezed or stretched to a predetermined uniform width.

[0048] In the illustrated embodiment, after a uniform width has been established, the method **72** proceeds by averaging the first pulse waveform and the scaled second pulse waveform to generate an ensemble average waveform (block **82**). As understood by those skilled in the art, the ensemble average waveform may be generated, for example, by assigning a weight to each pulse and combining the weighted pulses to generate the ensemble average. For example, in one embodiment, the new ensemble average pulse ($P_{e(new)}$) may be given by the following equation:

$$P_{e(new)[n]}=[(1-w_a)*P_{e[n]}]+(w_a*P_{p[k]}); \tag{2}$$

[0049] where w_a is the assigned weight taking on a value between 0 and 1, P_p is the most recent pulse, and P_e is the current ensemble average. However, any of a variety of weighted or non-weighted ensemble averaging methods known to those skilled in the art may be employed to combine the first pulse waveform and the second pulse waveform in the step indicated by block **82**. Further, it should be noted that the weight may vary along the pulse. For example, if the peak and foot substantially line up, a large portion of the new pulse may be used for averaging, but if the dicrotic notch appears out of alignment, less of this part of the signal may be used for averaging.

[0050] The method **72** proceeds by acquiring data corresponding to an additional pulse of the PPG signal (block **84**). That is, an additional pulse waveform is acquired, for example, by the pulse oximeter coupled to the patient. Here again, it should be noted that the additional pulse waveform may be an additional pulse of a single waveform, which may also include the first pulse waveform and the second pulse waveform, detected by the pulse oximeter throughout operation. The method **72** proceeds by scaling the width of the ensemble average waveform to the width of the additional pulse waveform (block **86**). In certain embodiments, however, the width of the additional pulse waveform may be scaled to the width of the ensemble average waveform, or both waveforms may be scaled to a predetermined width. Regardless of the chosen width, the step indicated by block **86** results in an additional pulse waveform and an ensemble average waveform having a uniform width.

[0051] Once a uniform width has been established, the additional pulse waveform and the ensemble average waveform are averaged to produce an updated ensemble average waveform (block **88**). As before, the width of the updated ensemble average waveform may then be rescaled to a weighted period (block **90**), thus enabling the morphological and temporal components of the pulse waveform to be independently ensemble averaged. However, here again, it should be noted that this step may be eliminated in some embodiments, for example, if the waveform is already scaled to the desired time scale and the ensemble average is already at this time scale. The method **72** proceeds by checking for additional acquired pulses (query block **92**) and if no additional pulses are acquired (e.g., the sensor has been deactivated and data collection commenced), the operation is ended (block **94**). However, if additional pulses are acquired, the ensemble average is updated throughout the operation to reflect the additional data. That is, for each additional acquired pulse waveform, the ensemble average waveform is rescaled to the width of the additional pulse (block **86**), averaged with the additional pulse waveform (block **88**), and rescaled to a weighted value (block **90**).

[0052] Embodiments of the foregoing methods **60** and **72** and the advantages of these methods over existing systems may be better understood through the following discussion of FIGS. **5-8**. Specifically, FIG. **5** illustrates a plot **95** including a pulse waveform **98** and a pulse waveform **100** that may be acquired in an example pulse oximetry operation during which a pulse oximeter collects a series of pulse waveforms. The plot **95** includes an amplitude axis **96** and a time axis **97**. In the example, the shapes of the acquired pulse waveforms transition over time from the pulse waveform **98** having a width **102** to the pulse waveform **100** having a width **104** throughout the collection of data by the pulse oximeter. In certain embodiments, the start of the waveforms shown in FIGS. **5**, **7**, **9** (e.g. waveform **98** or waveform **100**) may be described by a trigger point determined from the waveform (e.g. a waveform's trough minimum) or from an external trigger (e.g., an electrocardiography monitor detecting an R-wave may be communicated through any suitable interface). This trigger point may be used to synchronize the waveforms (e.g. waveform **98** or waveform **100**) when computing an ensemble average, such as in the embodiment of the described method.

[0053] According to a traditional ensemble averaging method that does not accommodate for the changing width of the pulse waveforms during data collection, a series of intermediate ensemble average waveforms **106** may be generated throughout the pulse oximetry data collection operation. At the end of the pulse oximetry data collection operation, an ensemble average waveform **108** shown in plot **110** of FIG. **6** and having a width **112** is generated. The ensemble average waveform **108** represents the result of the ensemble averaging of the series of pulses acquired during the data collection operation by the pulse oximeter as the pulse shapes transitioned from the pulse waveform **98** to the pulse waveform **100**. As shown in FIG. **6**, the morphological characteristics of the acquired pulse waveforms **98** and **100** are not preserved in the ensemble average waveform **108**. For example, the ensemble average waveform **108** includes three peaks **114**, **116**, and **118**, while the pulse waveform **98** includes two peaks **120** and **122**, and the pulse waveform **100** also includes two peaks **124** and **126**.

[0054] FIG. **7** illustrates a plot **128** that again includes the example pulse waveforms **98** and **100** acquired in a data collection operation in which the shapes of a series of pulse waveforms converge from the shape of waveform **98** to the shape of waveform **100** over time. However, by utilizing presently disclosed embodiments of ensemble averaging methods, such as the methods **60** and **72** described in FIGS. **3** and **4**, a series of intermediate ensemble average waveforms **130** are generated throughout the pulse oximetry data collection operation. At the end of the pulse oximetry data collection operation, an ensemble average waveform **132** shown in plot **134** of FIG. **8** and having a width **136** is generated.

[0055] As shown in FIG. **8**, by utilizing the presently disclosed ensemble averaging methods, the morphological characteristics of the pulse waveforms **98** and **100** are conserved throughout the ensemble averaging and are reflected in the ensemble average waveform **132**. Specifically, as compared to the ensemble average waveform **108** obtained through traditional methods, the ensemble average waveform **132** obtained via presently disclosed embodiments includes only two peaks **138** and **140**, thus better preserving the features of the pulse waveforms **98** and **100**. Again, the morphological characteristics of the pulse waveforms **98** and **100** may be better preserved in presently disclosed embodiments because each time the ensemble average waveform is updated to include a newly acquired pulse, the widths of the ensemble average waveform and the new acquired pulse waveform are scaled to a uniform width.

[0056] As in FIG. **7**, a plot **142** shown in FIG. **9** includes the example pulse waveforms **98** and **100** acquired in a data collection operation in which the shapes of a series of pulse waveforms converge from the shape of the waveform **98** to the shape of the waveform **100** over time. However, in this embodiment, a series of intermediate ensemble average waveforms **144** are generated, and each of the waveforms in the series **144** is located in a different position along the time axis **97** with respect to the other waveforms in the series **144**. That is, as compared to the series of intermediate ensemble average waveforms **130** of FIG. **7**, the width of each of the ensemble average waveforms **144** shown in FIG. **9** has been rescaled to a weighted value after averaging with the most recent pulse waveform has been completed (e.g., as in the method step of block **70** of the method **60**). Accordingly, at the end of the pulse oximetry data collection operation, an ensemble average waveform **144** shown in plot **146** of FIG. **10** is generated. A width **148** of the ensemble average waveform **144** of FIG. **10** is different than the width **136** of the ensemble average waveform **132** because the width **148** of the waveform **144** has been rescaled after the last pulse waveform has been averaged with the latest ensemble average waveform.

[0057] In some embodiments, the foregoing feature may enable the temporal component of the detected signal from the pulse oximeter to be decoupled from the morphological component of the detected signal, but for both the morphological and temporal components to be incorporated into the ensemble average waveform. Specifically, by rescaling the ensemble average waveform to the width of the latest pulse waveform before averaging, the morphological characteristics of the acquired pulse waveforms may be preserved in the ensemble average waveform. Additionally, the periods of the pulse waveforms may also be reflected in the ensemble average waveform, for example, by rescaling the ensemble average waveform to a weighted period that takes into account the periods of each of the pulse waveforms that have been averaged to form the ensemble average waveform.

[0058] As noted above, a variety of the ensemble averaging methods disclosed herein may utilize non-linear rescaling methods to obtain time axis uniformity between the ensemble average waveform and the most recent pulse before ensemble averaging occcurs. For example, a variety of non-linear scaling methods may be utilized to warp the width of the ensemble average waveform, the most recent pulse, or both, such that when the most recent pulse and the ensemble average waveform are combined, time axis uniformity has been established. FIG. **11** illustrates an embodiment of a method **66'** that may be stored to memory and implemented by processing circuitry (e.g., microprocessor **26**), for example, during block **66** of FIG. **3**, to ensemble average a detected waveform from a pulse oximeter that has pulses of varying lengths, for example, due to a time-varying heart rate of a patient.

[0059] In particular, the method **66'** includes non-linearly warping the width of the ensemble average waveform (block **150**) and warping the width of the waveform corresponding to the most recent pulse (block **152**). For example, in one embodiment, dynamic programming may be utilized to warp the time axis of one or both of the waveforms to produce a warped ensemble average waveform and a warped pulse waveform having a substantially uniform width. For further example, in one embodiment, dynamic time warping may be implemented to non-linearly expand or contract the time axis of the ensemble average waveform and/or the pulse waveform.

[0060] As appreciated by one skilled in the art, any of a variety of dynamic programming methods currently known in the art may be utilized to warp the time axes of one or both of the waveforms. However, in some presently contemplated embodiments, the dynamic programming techniques may be implemented in accordance with generally known methods, such as those taught by the following, which is hereby incorporated by reference: Hiroaki Sakoe and Seibi Chiba. February 1978. Dynamic Programming Algorithm Optimization for Spoken Word Recognition. IEEE ASSP-26: No. 1. That is, in certain embodiments, the dynamic time warping may include non-linear expansion or contraction of one of the ensemble average time axis or the pulse waveform time axis to achieve maximum coincidence with the other of the ensemble average time axis or the pulse waveform time axis, and, subsequently, dynamic programming matching may be performed to minimize the time-normalized distance between the two waveforms. It should be noted that this dynamic programming matching may be performed asymmetrically or symmetrically, depending on implementation-specific considerations.

[0061] Further, in some embodiments, segments of the ensemble average waveform may be warped with corresponding segments of the pulse waveform, but independent of the remaining segments of the ensemble average waveform. For example, portions of the waveforms corresponding to particular biological events may be concurrently warped, and portions of the waveforms corresponding to different biological events may be separately warped. FIG. **12** illustrates an embodiment of a method **66"** that may be stored to memory and implemented by processing circuitry, for example, during block **66** of FIG. **3**, to warp corresponding segments of the ensemble average waveform and the pulse waveform.

[0062] More specifically, the method **66"** calls for identifying one or more alignment points in the ensemble average waveform (block **154**) and identifying one or more alignment points in the pulse waveform (block **156**). For example, the alignment points may be distinguishing shapes or other waveform characteristics that are expected to be present in both waveforms, for example, based on biological factors, but may be present in different locations along the time axes of the waveforms due to the patient's changing heart rate during the respiration cycle. Examples of suitable alignment points are discussed in more detail below with respect to FIGS. **13** and **14**.

[0063] Method **66"** proceeds with alignment of the alignment points identified in the ensemble average waveform with corresponding alignment points identified in the pulse waveform (block **158**). Once the alignment points are matched in this manner, corresponding segments of the waveforms may be warped together, but independent of others segments in the respective waveform (block **160**). For example, in one embodiment, an alignment point may be identified in the ensemble average waveform, which may be called "EA point," and a corresponding alignment point may be identified in the pulse waveform, which may be called "pulse point." The EA point and the pulse point may correspond, for example, to a single biological event. However, the EA point and the pulse point may be located at different positions along the lengths of the respective time axes due to the patient's changing heart rate.

[0064] In some embodiments, it may be desirable to warp the segment of the ensemble average waveform from time zero to the EA point along with the segment of the pulse waveform from time zero to the pulse point, and, independent from this first warping, to warp the segment of the ensemble average waveform from the EA point to the next alignment point in the ensemble average waveform along with the segment of the pulse waveform from the pulse point to the next alignment point in the pulse waveform. In such a way, corresponding segments of the ensemble average waveform and the pulse waveform may be warped together while segments within each of the respective waveforms may be warped independent of one another. In some embodiments, the foregoing feature may reduce or prevent the likelihood that distinctive features of the waveforms will not be preserved in the updated ensemble average.

[0065] FIG. **13** illustrates an embodiment of a method **154'** that may be stored to memory and implemented by processing circuitry to identify alignment points in the ensemble average waveform. In particular, the method **154'** includes identifying peaks in the ensemble average waveform (block **162**), indentifying troughs in the ensemble average waveform (block **164**), and identifying zero crossing points associated with the ensemble average waveform (block **166**). As understood by those skilled in the art, in some embodiments, one or more derivatives of the ensemble average waveform may be taken to identify one or more zero crossing points, which may correspond to minimums, maximums, and inflection points present in the ensemble average waveform. In certain embodiments, one or more of these locations along the time axis of the ensemble average waveform may be selected and utilized as an alignment point in the method **66"** of FIG. **12**. For example, in one embodiment, the absolute maximums and absolute minimums identified via this technique may be designated alignment points for the purposes of dynamic time warping.

[0066] Further, it should be noted that peaks and troughs (i.e., local minima and maxima) of a waveform may be utilized as fiducial points. Additionally, the local minimum and maximum points or zero crossings in the 1^{st}-4^{th} derivatives of the waveform may be utilized. For example, the 1^{st} derivative crosses zero at a minimum or maximum in the signal. For further example, the 2^{nd} derivative reaches zero when the waveform has an inflection point, which may, in some embodiments, indicate the presence of a dicrotic notch.

[0067] FIG. **14** illustrates an embodiment of a method **156'** similar to method **154'** that may be stored to memory and implemented by processing circuitry to identify alignment points in the pulse waveform. The method **156'** includes identifying peaks in the pulse waveform (block **168**), indentifying troughs in the pulse waveform (block **170**), and identifying zero crossing points associated with the pulse waveform (block **172**). As understood by those skilled in the art, in some embodiments, one or more derivatives of the pulse waveform may be taken to identify one or more zero crossing points, which correspond to minimums, maximums, and inflection points present in the pulse waveform. In certain embodiments, one or more of these locations along the time axis of the pulse waveform may be selected and utilized as an alignment point in the method **66"** of FIG. **12**. The alignment points may be selected, for example, by comparing the quantity or relative location along respective time axes of the points identified in the method **154'** for the ensemble average waveform.

[0068] It should be noted that in certain embodiments, the dynamic cost function between the ensemble average waveform and the pulse waveform that is computed, for example, during implementation of the chosen dynamic programming technique, may be further utilized to partially or fully determine one or more weights utilized in the ensemble averaging process. FIG. **15** illustrates an embodiment of a method **174** that may be stored to memory and implemented by processing circuitry to determine one or more ensemble averaging weights based on a dynamic cost function.

[0069] Specifically, the method **174** includes receiving data corresponding to the ensemble average waveform (block **176**) and receiving data corresponding to the pulse waveform (block **178**). A dynamic cost function is then computed between the ensemble average waveform and the pulse waveform (block **180**). For example, as appreciated by one skilled in the art, the dynamic cost function may be the distance function that defines the distance between the matrix of data encoding the ensemble average waveform and the matrix of data encoding the pulse waveform, and may be computed during the dynamic programming technique of the previously described methods.

[0070] The method **174** further calls for determining the weight assigned to the most recent pulse based on the dynamic cost function (block **182**). That is, in some embodiments, the distance between the most recent pulse and the ensemble average may be used to partially or fully determine the value of the most recent pulse. For example, in one embodiment, if the cost function evaluation reveals that the most recent pulse is substantially different than the ensemble average, the weight of the most recent pulse may be reduced. Similarly, if the cost function evaluation reveals that the most recent pulse is substantially similar to the ensemble average, the weight of the most recent pulse may be increased. As such, the dynamic cost function may be employed as an indicator of the suitability of the most recent pulse for averaging.

[0071] Again, the presently disclosed linear and non-linear rescaling embodiments disclosed herein may enable accommodation of pulses having different lengths when performing the ensemble averaging process. As compared to traditional processes, the disclosed ensemble averaging techniques may reduce or prevent the likelihood of blurring of the ensemble average waveform due to the averaging of pulses having different lengths, which may be due to factors such as the time-varying nature of a patient's heart rate. The foregoing feature may improve the quality of the generated ensemble average waveform, thus possibly improving the likelihood that the ensemble average waveform may be utilized to accurately determine a physiological parameter of interest, such as blood oxygen saturation, blood pressure, pulse rate, and so forth.

[0072] While the disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the embodiments provided herein are not intended to be limited to the particular forms disclosed. Rather, the various embodiments may cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims.

What is claimed is:

1. A method of ensemble averaging signals in a pulse oximeter, comprising:

receiving an ensemble average signal corresponding to an ensemble average of electromagnetic radiation signals detected from a blood perfused tissue of a patient;

receiving a pulse signal corresponding to a pulse detected by the pulse oximeter;

performing at least one of scaling a time axis of the ensemble average signal via dynamic programming or scaling a time axis of the pulse signal via dynamic programming, to produce a scaled ensemble average signal or a scaled pulse signal having a substantially uniform width; and

ensemble averaging the scaled ensemble average signal and the scaled pulse signal to produce an updated ensemble average signal having the substantially uniform width.

2. The method of claim **1**, wherein the uniform width is defined by the length of the time axis of the ensemble average signal or the length of the time axis of the pulse signal.

3. The method of claim **1**, wherein the warping of the time axis of the ensemble average signal and the warping of the time axis of the pulse signal comprises symmetrically transforming the time axes to a common axis.

4. The method of claim **1**, wherein the ensemble averaging the warped ensemble average signal and the warped pulse signal comprises assigning a weight to the warped pulse signal, multiplying the weight by the warped pulse signal to produce a weighted pulse signal, and averaging the weighted pulse signal with the ensemble average signal.

5. The method of claim **4**, comprising computing a dynamic cost function between the ensemble average signal and the pulse signal and determining the assigned weight based on the computed dynamic cost function.

6. The method of claim **1**, wherein the pulse detected by the pulse oximeter corresponds to a time varying amount of arterial blood in the blood perfused tissue during a cardiac cycle of the patient.

7. A method of ensemble averaging signals in a pulse oximeter, comprising:

receiving an ensemble average signal corresponding to an ensemble average of electromagnetic radiation signals detected from a blood perfused tissue of a patient;

receiving a pulse signal corresponding to a pulse detected by the pulse oximeter;

identifying one or more fiducial points in the ensemble average signal and one or more fiducial points in the pulse signal;

aligning one or more fiducial points in the ensemble average signal with one or more corresponding fiducial points in the pulse signal to identify corresponding sections of the ensemble average signal and the pulse signal;

warping time axes of the corresponding sections of the ensemble average signal and the pulse signal via dynamic programming to produce a warped ensemble average signal having a plurality of independently warped sections and a warped pulse signal having a plurality of independently warped sections, wherein the warped ensemble average signal and the warped pulse signal have a substantially uniform width; and

ensemble averaging the warped ensemble average signal and the warped pulse signal to produce an updated ensemble average signal having the substantially uniform width.

8. The method of claim **7**, wherein the one or more fiducial points in the ensemble average signal comprise peaks or troughs in the ensemble average signal and the one or more fiducial points in the pulse signal comprise peaks or troughs in the pulse signal.

9. The method of claim **7**, wherein each set of corresponding sections of the ensemble average and pulse signals is warped to a time axis width determined based on features present in the corresponding sections to be warped.

10. The method of claim **7**, wherein the substantially uniform width comprises the width of the ensemble average signal or the width of the pulse signal.

11. The method of claim **7**, wherein the ensemble averaging the warped ensemble average signal and the warped pulse signal comprises assigning a weight to the warped pulse signal, multiplying the weight by the warped pulse signal to produce a weighted pulse signal, and averaging the weighted pulse signal with the ensemble average signal.

12. A system, comprising:

a sensor comprising an emitter configured to transmit one or more wavelengths of light and a photodetector configured to receive the one or more wavelengths of light emitted by the emitter; and

a patient monitor configured to receive a detected signal from the sensor that corresponds to light received by the photodetector, wherein the patient monitor comprises:

processing circuitry configured to produce an ensemble average signal by ensemble averaging pulses of the detected signal, to receive a pulse signal from the sensor, and to produce an updated ensemble average signal by warping a width of the ensemble average signal and a width of the received pulse signal to a uniform width via dynamic programming to produce a warped ensemble average signal and a warped pulse signal and ensemble averaging the warped ensemble average signal and the warped pulse signal.

13. The system of claim **12**, wherein the patient monitor comprises a pulse oximeter.

14. The system of claim **12**, wherein the patient monitor comprises memory configured to store the detected signal from the sensor, ensemble averaging code configured to be accessed by the processing circuitry, or both.

15. The system of claim **12**, wherein the processor is further configured to calculate a blood characteristic based on the detected signal, the updated ensemble average signal, or both.

16. The system of claim **12**, wherein the sensor comprises an encoder configured to provide signals to the patient monitor that correspond to the wavelength of the transmitted one or more wavelengths of light.

17. The system of claim **16**, wherein the processing circuitry is further configured to utilize the provided signals to determine appropriate calibration coefficients for an oxygen saturation calculation.

18. A patient monitor system, comprising:

receiving circuitry configured to receive a detected signal corresponding to light received by a photodetector from a blood perfused tissue and to produce a processed signal; and

processing circuitry configured to receive the processed signal, to produce an ensemble average signal by ensemble averaging a first pulse signal and a second pulse signal included in the processed signal, and to produce an updated ensemble average signal by warping a width of the ensemble average signal and a width of a third pulse signal included in the processed signal via dynamic programming to produce a warped ensemble average signal and a warped third pulse signal and ensemble averaging the warped ensemble average signal and the warped third pulse signal.

19. The system of claim **18**, wherein producing the processed signal comprises filtering the detected signal, amplifying the detected signal, performing an analog to digital conversion on the detected signal, or a combination thereof.

20. The system of claim **18**, wherein the receiving circuitry comprises switching circuitry, amplification circuitry, filtering circuitry, an analog-to-digital converter, a queued serial module, or a combination thereof.

21. The system of claim **18**, wherein the light received by the photodetector comprises electromagnetic radiation signals corresponding to at least two different wavelengths of light.

22. A tangible machine readable medium, comprising:

code configured to warp a width of an ensemble average signal based on dynamic programming, a width of a pulse signal based on dynamic programming, or both, to produce a warped ensemble average signal and a warped pulse signal having a substantially uniform width, wherein the ensemble average signal corresponds to an ensemble average of electromagnetic radiation signals detected from a blood perfused tissue of a patient and the pulse signal corresponds to a pulse detected by a pulse oximeter; and

code configured to ensemble average the warped ensemble average signal and the warped pulse signal to produce an updated ensemble average signal having the substantially uniform width.

23. The tangible machine readable medium of claim **22**, comprising code configured to scale the updated ensemble average signal to a width corresponding to a weighted average of the periods of the electromagnetic radiation signals and the pulse signal.

24. The tangible machine readable medium of claim **22**, wherein the code configured to ensemble average the warped ensemble average signal and the warped pulse signal is configured to assign a weight to the pulse signal, to multiply the weight by the pulse signal to produce a weighted pulse signal, and to average the weighted pulse signal with the ensemble average signal.

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专利名称(译)	用于脉搏血氧测定中的整体平均的系统和方法		
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申请(专利权)人(译)	COVIDIENT LP		
当前申请(专利权)人(译)	COVIDIEN LP		
[标]发明人	LISOGURSKI DANIEL		
发明人	LISOGURSKI, DANIEL		
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摘要(译)

提供了用于在脉冲血氧计中对信号进行整体平均的各种方法和系统。整体平均方法包括接收对应于从患者的血液灌注组织检测到的电磁辐射信号的总体平均值的总体平均信号，并接收对应于脉冲血氧计检测到的脉冲的脉冲信号。该方法还包括通过动态编程使整体平均信号的时间轴翘曲，通过动态编程使脉冲信号的时间轴翘曲，或者两者都产生翘曲的整体平均信号和具有基本均匀宽度的翘曲脉冲信号。该方法还包括对弯曲的整体平均信号和弯曲的脉冲信号进行整体平均，以产生具有基本均匀宽度的更新的整体平均信号。