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(54) **ENERGY OPTIMIZED SENSING TECHNIQUES**

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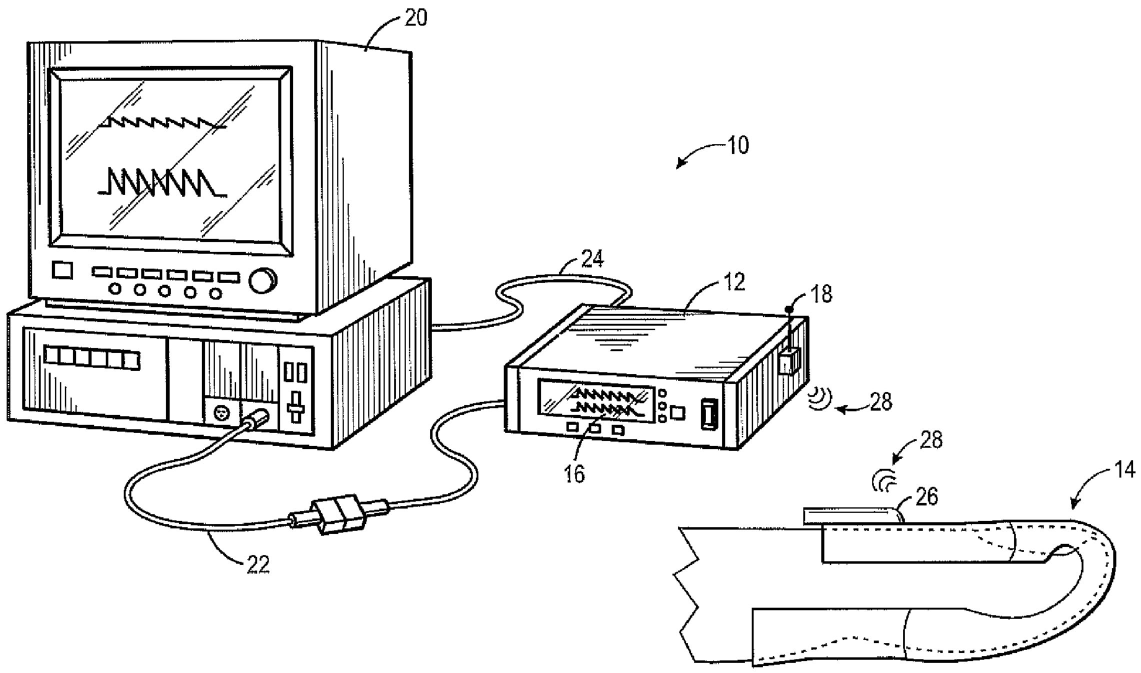
(57) **ABSTRACT**

The present disclosure describes an energy efficient wireless medical sensor that may be capable of optimizing battery life and increasing component life by selectively using only a subset of the sensors and sensor functionality included in the wireless medical sensor at any one time. One or more update factors may be used by the wireless sensor or an external patient monitor to derive a data collection modality, data collection rates, and update interval. The data collection modality, data collection rates, and update interval may be used to selectively gather sensing data in a manner that is more energy efficient.



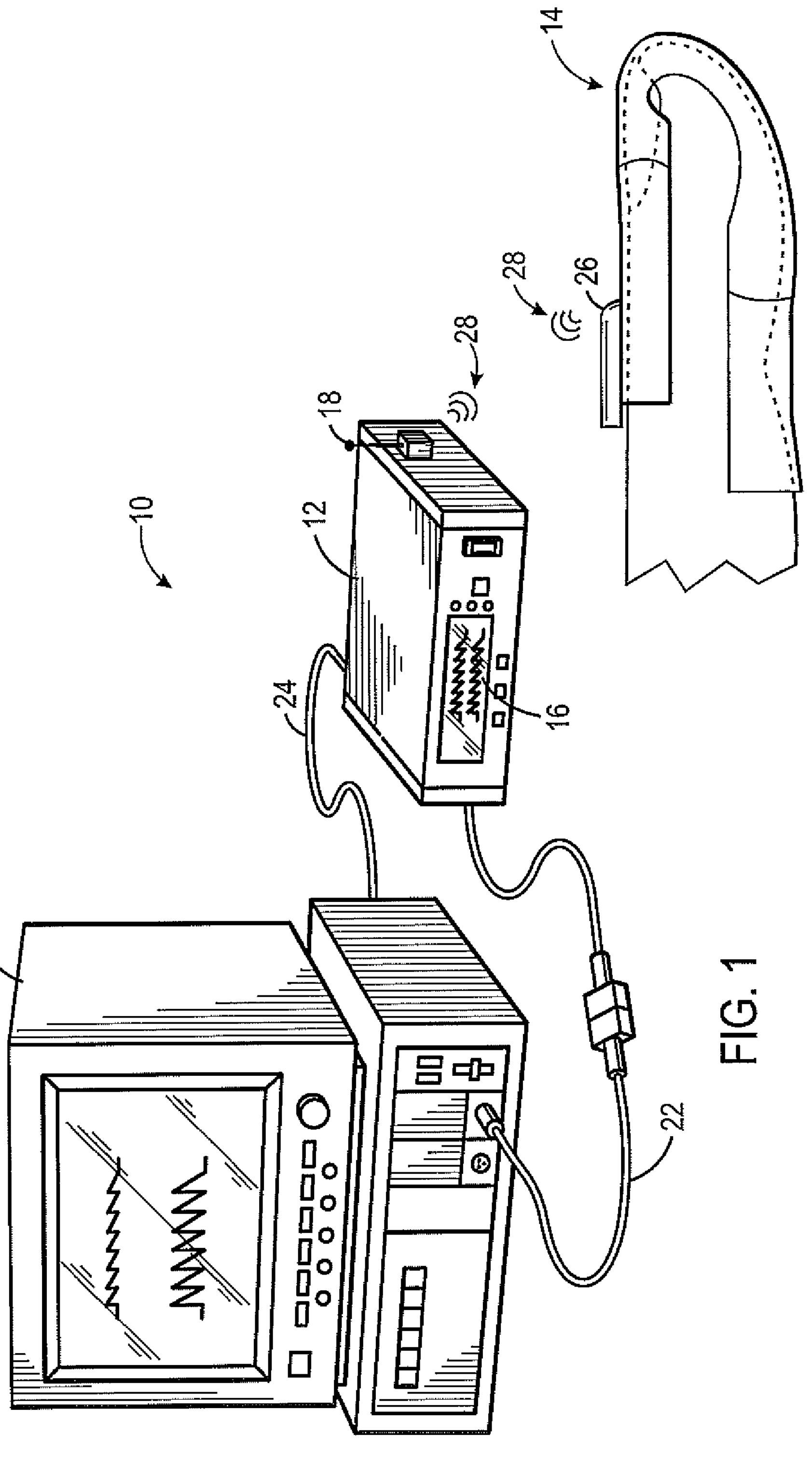


FIG. 1

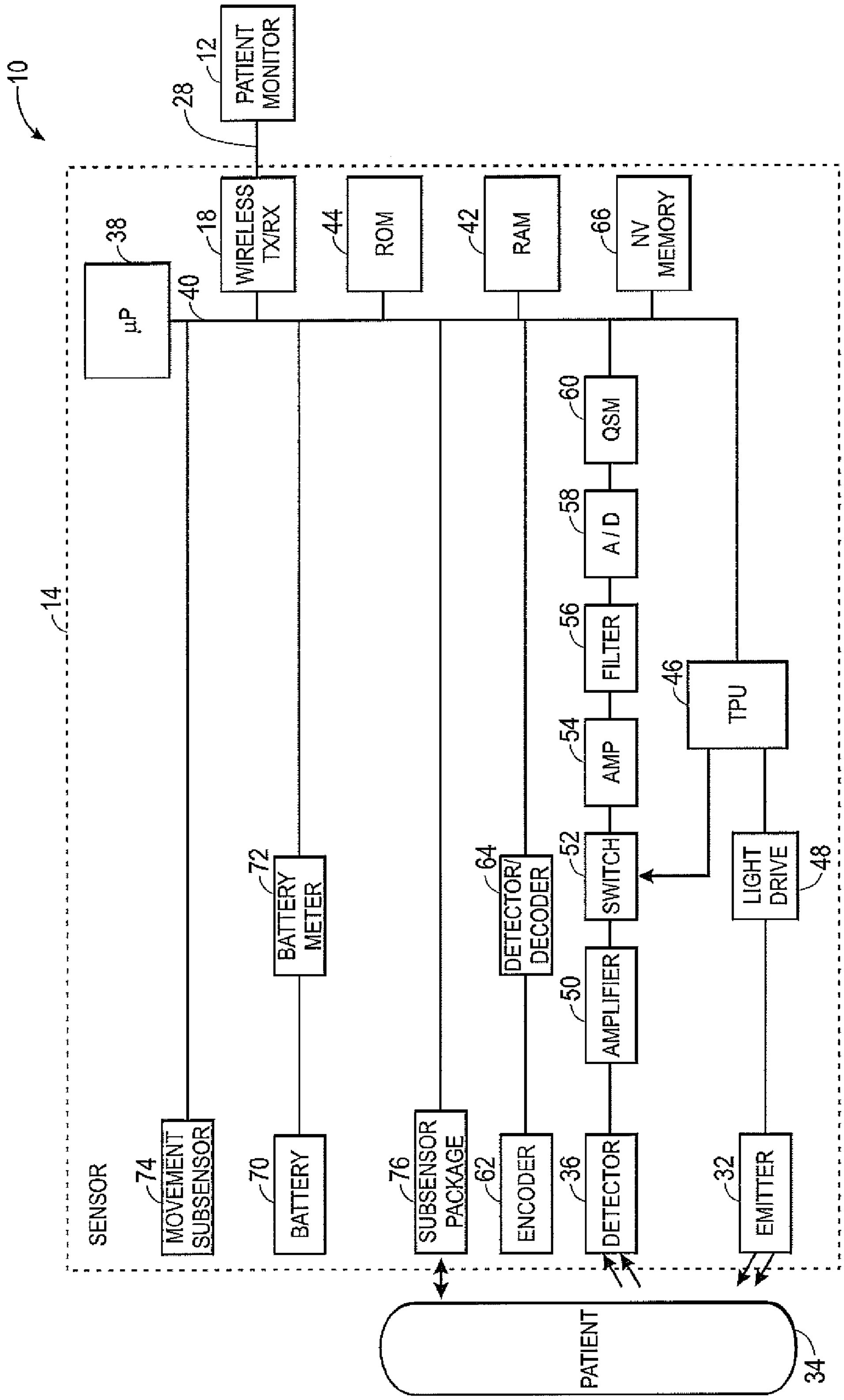

10
12
PATIENT MONITOR
28
14
SENSOR
38
µP
40
18
WIRELESS TX/RX
44
ROM
42
RAM
66
NV MEMORY
60
QSM
58
A / D
56
FILTER
54
AMP
52
SWITCH
50
AMPLIFIER
46
TPU
48
LIGHT DRIVE
72
BATTERY METER
64
DETECTOR/ DECODER
74
MOVEMENT SUBSENSOR
70
BATTERY
76
SUBSENSOR PACKAGE
62
ENCODER
36
DETECTOR
32
EMITTER
PATIENT
34

FIG. 2

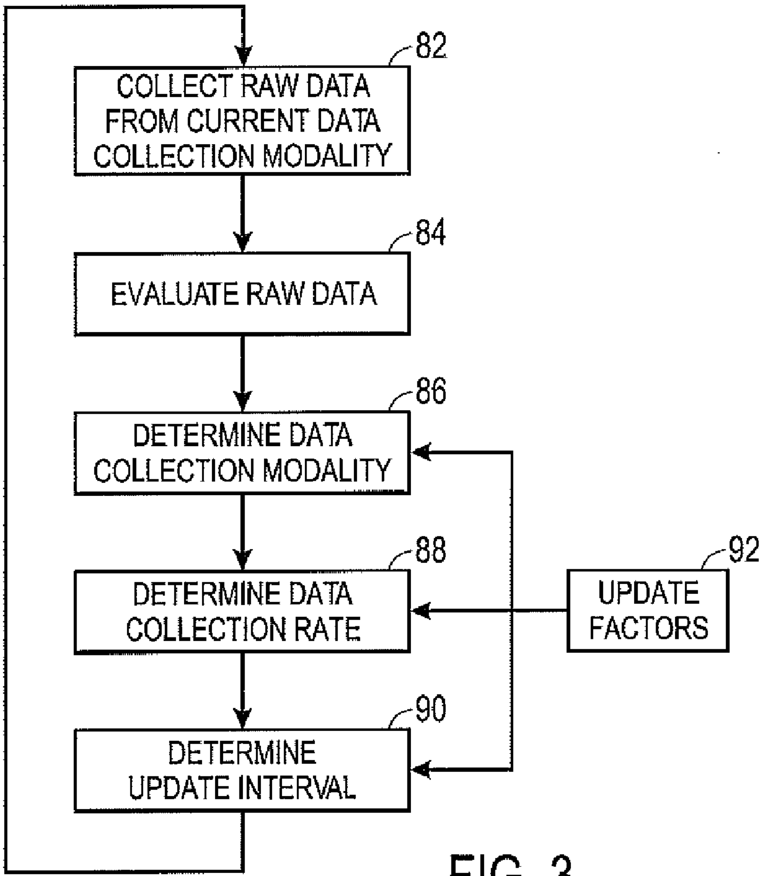

COLLECT RAW DATA FROM CURRENT DATA COLLECTION MODALITY
82
EVALUATE RAW DATA
84
DETERMINE DATA COLLECTION MODALITY
86
DETERMINE DATA COLLECTION RATE
88
DETERMINE UPDATE INTERVAL
90
UPDATE FACTORS
92

FIG. 3

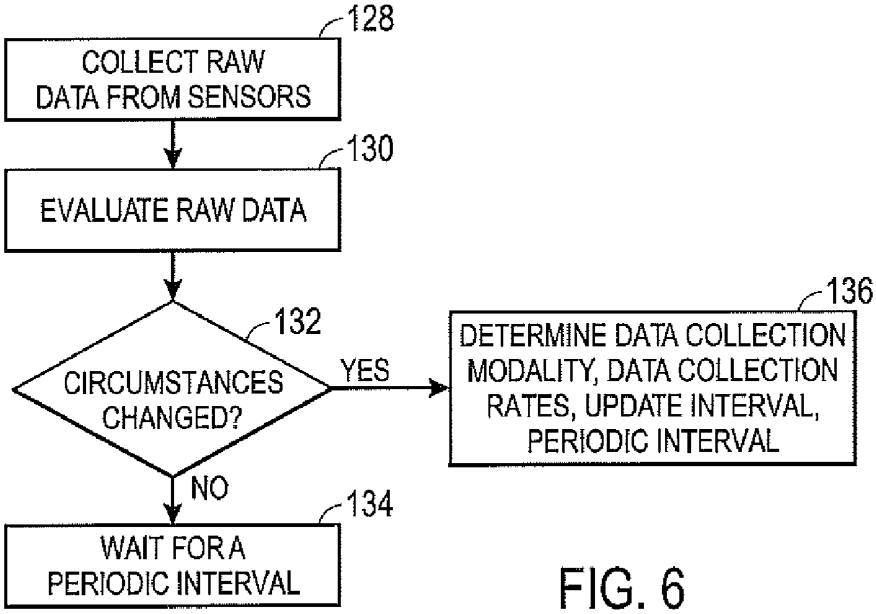

COLLECT RAW DATA FROM SENSORS
128
EVALUATE RAW DATA
130
CIRCUMSTANCES CHANGED?
132
YES
NO
DETERMINE DATA COLLECTION MODALITY, DATA COLLECTION RATES, UPDATE INTERVAL, PERIODIC INTERVAL
136
WAIT FOR A PERIODIC INTERVAL
134

FIG. 6

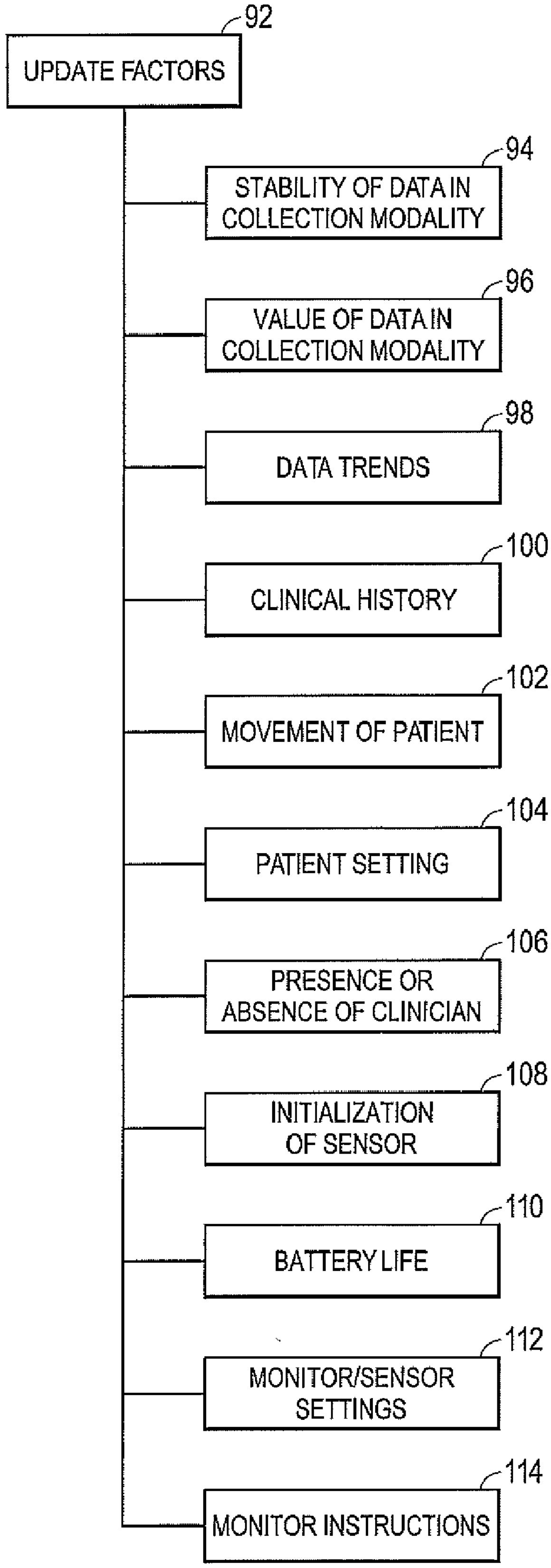

92
UPDATE FACTORS
94
STABILITY OF DATA IN COLLECTION MODALITY
96
VALUE OF DATA IN COLLECTION MODALITY
98
DATA TRENDS
100
CLINICAL HISTORY
102
MOVEMENT OF PATIENT
104
PATIENT SETTING
106
PRESENCE OR ABSENCE OF CLINICIAN
108
INITIALIZATION OF SENSOR
110
BATTERY LIFE
112
MONITOR/SENSOR SETTINGS
114
MONITOR INSTRUCTIONS

FIG. 4

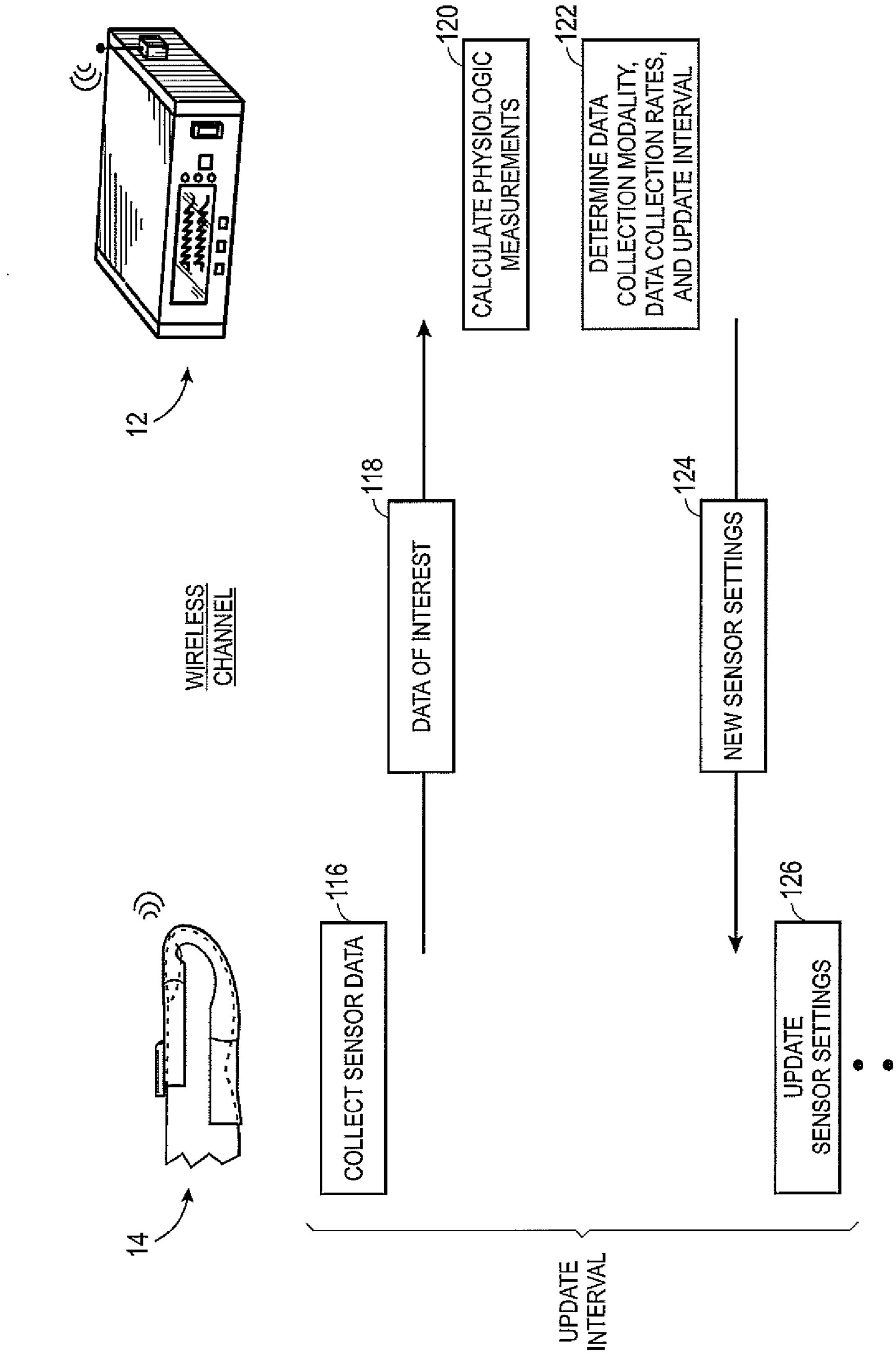

12
14
WIRELESS
CHANNEL
COLLECT SENSOR DATA
116
DATA OF INTEREST
118
CALCULATE PHYSIOLOGIC
MEASUREMENTS
120
DETERMINE DATA
COLLECTION MODALITY,
DATA COLLECTION RATES,
AND UPDATE INTERVAL
122
NEW SENSOR SETTINGS
124
UPDATE
SENSOR SETTINGS
126
UPDATE
INTERVAL

FIG. 5

ENERGY OPTIMIZED SENSING TECHNIQUES

BACKGROUND

[0001] The present disclosure relates generally to medical sensors and, more particularly, to wireless medical sensors.

[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, doctors often desire to monitor and sense certain physiological characteristics of their patients. Accordingly, a wide variety of devices have been developed for monitoring and sensing many such physiological characteristics. For example, one category of monitoring and sensing devices includes spectrophotometric monitors and sensors. This category of device studies the electromagnetic spectra (e.g., wavelengths of light) and can monitor a suite of physiological parameters. Such devices provide doctors and other healthcare personnel with the information they need to provide the best possible healthcare for their patients. As a result, such monitoring and sensing devices have become an indispensable part of modern medicine.

[0004] Conventional spectrophotometric sensors are typically connected to a monitor via a cable. The cable provides the sensor with power and acts as a conduit for the transmission of signals between the sensor and the monitor. However, the cable also acts to tether the patient to the monitor, preventing unencumbered motion by the patient. As a result, such cable-based systems may not be suitable for ambulatory patients or for applications that require remote monitoring in non-clinical environments. Accordingly, various systems have been proposed which include a patient sensing device connected to a local monitor by way of a wireless link. Unfortunately, sensors that incorporate a wireless link may be limited to that power which is provided on the sensor itself, which may be drained very quickly.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Advantages of the disclosed techniques may become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0006] FIG. **1** illustrates components of a wireless medical system, in accordance with one embodiment of the present disclosure;

[0007] FIG. **2** depicts a diagram of a wireless sensor and monitor, in accordance with one embodiment of the present disclosure;

[0008] FIG. **3** is a flowchart describing an embodiment of a method for sensing data using the system of FIG. **1**, in accordance with an embodiment;

[0009] FIG. **4** is a schematic diagram of various update factors that may be employed with the method of FIG. **3**, in accordance with an embodiment;

[0010] FIG. **5** is a communication diagram illustrating communication between a wireless sensor and a patient monitor of the system of FIG. **1**, in accordance with an embodiment, and;

[0011] FIG. **6** is a flowchart describing an embodiment of another method for sensing data using the system of FIG. **1**, in accordance with an embodiment.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0012] 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.

[0013] Present embodiments relate to systems, methods, and devices for balancing power consumption and lifespan of medical sensors systems. For example, a medical sensor system may include a sensor device, a patient monitor, and wireless transmission circuitry. The sensor device may be capable of obtaining a sensor measurement from a patient and of sampling the measurement at certain data collection rates to obtain discrete values. Further, the sensor device and/or the patient monitor may also be capable of determining certain sensor settings based at least in part on update factors associated with a status of the patient, and the wireless transmission circuitry may be capable of wirelessly transmitting and receiving data between the sensor device and the monitoring device. Because the embodiments presently disclosed may reduce the amount of time that the sensor device spends in sensing the patient, the sensor device may expend less power and, accordingly, may have a longer battery life and overall lifespan.

[0014] With the foregoing in mind, FIG. **1** depicts an embodiment of a medical system **10** that may efficiently sense patient status, thereby conserving power. Although the embodiment of the system **10** illustrated in FIG. **1** relates to photoplethysmography, the system **10** may be configured to obtain a variety of medical measurements with a suitable medical sensor. For example, the system **10** may, additionally or alternatively, be configured to measure patient temperature, transvascular fluid exchange volumes, tissue hydration, blood flow, blood microcirculation, bilirubin levels, non-invasive blood pressures (NIBP), and/or a pulse transit time, and so forth. The system **10** may include a patient monitor **12** that communicates wirelessly with a wireless sensor **14**. One or more additional subsensors may also be present in the wireless sensor **14**. It is to be understood that the term "subsensor" is used herein to denote any type of sensor or sensing modality that may be included as a component of the wireless sensor **14**. Some subsensors include, for example, a Doppler subsensor that may be used to measure a blood flow at a patient tissue site, a photoacoustic subsensor that may be used for measuring microcirculation, a photon density subsensor that may be used for measuring various blood-related parameters, and so forth. Indeed, a wide variety of sensors may be included as subsensor components of the wireless sensor **14**.

[0015] The patient monitor **12** may include a display **16**, a wireless module **18** for transmitting and receiving wireless data, a memory, a processor, and various monitoring and control features. Based on subsensor data received from the wireless sensor **14**, the patient monitor **12** may display patient measurements and perform various measurement or processing algorithms. For example, when the system **10** is configured for pulse oximetry, the patient monitor **12** may perform blood oxygen saturation calculations, pulse measurements, and other measurements based on the received wireless sensor **14** data. Furthermore, to upgrade conventional operation provided by the monitor **12** to provide additional functions, monitor **12** may be coupled to a multi-parameter patient monitor **20** via a cable **22** connected to a sensor input port or via a cable **24** connected to a digital communication port, for example.

[0016] In one embodiment of the system **10**, the wireless sensor **14** may include a pulse oximeter subsensor. However, the sensor **14** may also include other types of patient subsensors, capable of obtaining any of a variety of medical measurements. For example, as discussed above, the wireless sensor **14** may include subsensors capable of measuring patient temperature, transvascular fluid exchange volumes, tissue hydration, blood flow, pulse rate, respiration, bilirubin levels, non-invasive blood pressures (NIBP), and/or a pulse transit time, and so forth. As described further below, in one embodiment the wireless sensor **14** may collect subsensor measurements, such as a light intensity for pulse oximetry applications, patient temperature, and others, based in part on certain sensor settings that depend on one more or more update factors relating to the status of a patient. By selectively collecting subsensor measurements from one or more subsensors, the sensor **14** may optimize the battery usage and improve the lifespan of sensor components.

[0017] Like the patient monitor **12**, the wireless sensor **14** may include a wireless module **26**. The wireless module **26** of the wireless sensor **14** may establish a wireless communication **28** with the wireless module **18** of the patient monitor **12** using any suitable protocol. By way of example, the wireless module **26** may be capable of communicating using the IEEE 802.15.4 standard, and may communicate, for example, using ZigBee, WirelessHART, or MiWi protocols. Additionally or alternatively, the wireless module **26** may be capable of communicating using the Bluetooth standard or one or more of the IEEE 802.11 standards.

[0018] FIG. **2** is a block diagram of an embodiment of the wireless medical sensor system **10** that may be configured to implement the techniques described herein. By way of example, embodiments of the system **10** may be implemented with any suitable medical sensor and patient monitor, such as those available from Nellcor Puritan Bennett LLC. The system **10** may include the patient monitor **12** and the wireless sensor **14**, which may be configured to obtain, for example, a plethysmographic signal from patient tissue at certain predetermined wavelengths. The wireless sensor **14** may be communicatively connected to the patient monitor **12** via wireless communication **28** (shown in FIG. **1**). When the system **10** is operating, light from an emitter **32** may pass into a patient **34** where the portions of the light may be differentially scattered, absorbed, and/or transmitted. Light that emerges from the patient tissue may detected by a detector **36**.

[0019] The sensor **14** may include a microprocessor **38** connected to an internal bus **40**. Also connected to the bus **40** may be a RAM memory **42** and a ROM memory **44**. A time processing unit (TPU) **46** may provide timing control signals to a light drive circuitry **48** which may control when the emitter **32** is illuminated, and if multiple wavelengths are emitted, the multiplexed timing for the different wavelengths. The TPU **46** may also control the gating-in of signals from the detector **36** through an amplifier **50** and a switching circuit **52**. These signals may be sampled at the proper time, depending upon which of multiple wavelengths of light is emitted, if multiple wavelengths are used. In one embodiment, the received signal from the detector **36** may be passed through an amplifier **54**, a low pass filter **56**, and/or an analog-to-digital converter **58**.

[0020] The digital data may then be stored in a queued serial module (QSM) **60**, for later downloading to the RAM **42** as the QSM **60** fills up. In one embodiment, there may be multiple parallel paths of separate amplifier, filter and/or A/D converters for multiple light wavelengths or spectra received. This raw digital data may be further processed by the circuitry of the wireless medical sensor **14** into specific data of interest, such as pulse rate, blood oxygen saturation, and so forth.

[0021] In an embodiment, the sensor **14** may also contain an encoder **62** that encodes information indicating the wavelength of one or more light sources of the emitter **32**, which may allow for selection of appropriate calibration coefficients for calculating a physiological parameter such as blood oxygen saturation. The encoder **62** may, for instance, be a coded resistor, EEPROM or other coding devices (such as a capacitor, inductor, PROM, RFID, parallel resonant circuits, or a colorimetric indicator) that may provide a signal to the processor **38** related to the characteristics of the wireless sensor **14** that may allow the processor **38** to determine the appropriate calibration characteristics for the photoplethysmographic components of the wireless sensor **14**. Further, the encoder **62** may include encryption coding that prevents a disposable or replaceable part of the wireless sensor **14** from being recognized without corresponding adjustment or replacement of the information encoded by the encoder **62**. In some embodiments, the encoder **62** and/or the detector/decoder **64** may not be present. Additionally or alternatively, the processor **38** may encode processed sensor data before transmission of the data to the patient monitor **12**.

[0022] In various embodiments, based at least in part upon the value of the received signals corresponding to the light received by detector **36**, the microprocessor **38** may calculate a physiological parameter of interest using various algorithms. These algorithms may utilize coefficients, which may be empirically determined, corresponding to, for example, the wavelengths of light used. These may be stored in the ROM **44** or non-volatile memory **66**. In a two-wavelength system, the particular set of coefficients chosen for any pair of wavelength spectra may be determined by the value indicated by an encoder **62** corresponding to a particular light source of the emitter **32**. For example, the first wavelength may be a wavelength that is highly sensitive to small quantities of deoxyhemoglobin in blood, and the second wavelength may be a complimentary wavelength. Specifically, for example, such wavelengths may be produced by orange, red, infrared, green, and/or yellow LEDs. Different wavelengths may be selected based on instructions or protocols received from the patient monitor **12**, based on preferences stored in a nonvolatile storage **66**, or based on user input. The instructions from the patient monitor **12** may be transmitted wirelessly to the sensor **14** and may be selected at the patient monitor **12** by a user interface provided as part of the patient monitor **12** or via a port providing instructions from a remote host computer.

[0023] A nonvolatile memory **66** may store caregiver preferences, patient information, or various parameters, discussed below, which may be used in the operation of the sensor **14**. Software for performing the configuration of the sensor **14** and for carrying out the techniques described herein may also be stored on the nonvolatile memory **66** and/or on the ROM **44**. The nonvolatile memory **66** and/or RAM **42** may also store historical values of various discrete medical data points. By way of example, the nonvolatile memory **66** and/or RAM **42** may store values of instantaneous pulse rate for every second of the most recent five minutes.

[0024] A battery **70** may supply the wireless medical sensor **14** with operating power. By way of example, the battery **70** may be a rechargeable battery, such as a lithium ion or lithium polymer battery, or may be a single-use battery such as an alkaline or lithium battery. Due to the techniques described herein to reduce battery consumption, the battery **70** may be of a much lower capacity, and accordingly much smaller and/or cheaper, than a battery needed to power a similar wireless sensor **14** that does not employ these techniques. A battery meter **72** may provide the expected remaining power of the battery **70** to a user and/or to the microprocessor **38**. The remaining battery life indicated by the battery meter **72** may be used as a factor in determining the update interval, as discussed in greater detail below.

[0025] The wireless sensor **14** may also include a movement subsensor **74**, such as one or more accelerometers, that may sense when the patient **34** moves the wireless sensor **14**. Whether the patient is at rest or moving, as indicated by the movement subsensor **74**, may also be used as a factor in determining the wireless sensor's **14** data collection modality (i.e., how many subsensors in the wireless sensor **14** are activated and the subsensor functions used), the data collection rate for each subsensor in the wireless sensor **14**, and the update interval for reconfiguring the wireless sensor **14** settings, as discussed in greater detail below. In certain embodiments, a package of subsensors **76** may be included for performing specific medical measurements, for example, for measuring or monitoring temperature, photoacoustics, pressure, pH, Doppler shift, photon density, and others.

[0026] To conserve the amount of power used by the wireless sensor **14**, the microprocessor **38** may set the data collection modality, the data collection rate for each one of the subsensors in the data collection modality, and the update interval for reconfiguring the wireless sensor's **14** settings, as described in greater detail below. The microprocessor **38** may carry out these techniques based on instructions executed by the microprocessor **38** and stored in the RAM **42**, the ROM **44**, the nonvolatile memory **66**, and/or based on instructions received from the patient monitor **12**. Specifically, because continuously sensing data from all the subsensors may consume a substantial amount of power, several or all subsensors may generally remain deactivated during a specific update interval. Depending on the current data collection modality, only some of the different subsensors may be temporarily activated. Because the subsensors may only be in use at specific times, less power may be consumed and the life of the battery **70** may be extended. In selecting which of the subsensors to activate/deactivate, the subsensor functions to use, the data collection rate to use for each subsensor, and the update interval, the microprocessor **38** and/or the monitor **12** may consider a variety of update factors including the sub-sensor data currently being obtained from the patient **36** by the active subsensors in the current data collection modality **14**. These various update factors are described in greater detail below with reference to FIGS. **3**, **4**.

[0027] FIG. **3** illustrates a flowchart describing an embodiment of a method that may be implemented by the microprocessor **38** and/or the monitor **12** to efficiently use energy by turning on and utilizing only a subset of the subsensors in the wireless sensor **14** during an update interval. Each one of the subsensors in the wireless sensor **14** may have one or more different sensing functions. For example, a spectrophotometric subsensor may have functions to sense pulse rate, SpO_2, and others. The method described by the flowchart may derive which one of the subsensors in the wireless sensor **14** to use (i.e., flag as active) as well as which one of the sensing functions in each active subsensor to use. The subset of subsensors that have been flagged as active and the sensing functions that will be used is known as a "data collection modality". The method described by the flowchart may also establish the data collection rate for each subsensor in the wireless sensor **14** and a new update interval which specifies the time interval to wait before updating the data collection modality and the data collection rate for each subsensor. Thus, the amount of time spent in sensing activities may be significantly reduced as compared to continuously sensing and processing data using all available sensing components. Accordingly, the consumption of battery power as well as the wear on sensor components may be significantly reduced.

[0028] As depicted in the flowchart of FIG. **3**, the wireless sensor **14** may collect (block **82**) raw data from all the subsensors **32**, **36**, **74**, **76** participating in the current data collection modality. For example, a current collection modality may include subsensors and sensing functionality that measure temperature, pulse rate, and arterial oxygen saturation. All other subsensors that are not members of the current data collection modality are turned off and are deemed non-participating subsensors. Raw data being received from the subsensors in the current collection modality is evaluated (block **84**). The evaluation of the raw data may be performed by the wireless sensor's **14** microprocessor **38** or the raw data may be wirelessly communicated to the monitor **12** for evaluation by the monitor **12**. The microprocessor **38** and/or the monitor **12** may first convert the raw data into discrete, meaningful points of data based on the sensing functions selected as part of the current data collection modality. For example, the microprocessor **38** and/or the monitor **12** may process a raw photoplethysmographic data set and derive a pulse rate, respiration rate data, blood oxygen saturation data, etc.

[0029] Such discrete data may then be evaluated with respect to certain update factors **92** of FIG. **4** and used to determine (block **86**) or update the data collection modality. In some embodiments it may be advantageous to have the monitor **12** evaluate some or all of the discrete data because the monitor **12** may have more processing power, resulting in faster and more powerful computational abilities for the medical system. In other embodiments it may be advantageous to have the microprocessor **38** evaluate some or all of the discrete data because these embodiments may allow for increased patient mobility to locations where the wireless sensor **14** and the monitor **12** may not be communicatively connected. In yet other embodiments it may be advantageous to have both the microprocessor **38** and the monitor **12** evaluate some or all of the discrete data because these embodiments allow for a sharing of the computational burden between the wireless sensor **14** and the monitor **12**.

[0030] The microprocessor **38** and/or the monitor **12** may maintain the current data collection modality or may determine a new data collection modality (i.e., a new group of subsensors that will be flagged as active as well as the sensing functions from each subsensor that will be used) based on the discrete data derived at step **84**, the current data collection modality, the update factors **92** of FIG. **4**, and the particular medical application for which the sensor **14** is used. Any number of suitable update factors **92** may be considered, many of which may be described with reference to FIG. **4** below. By way of example, if during patient monitoring the current data collection modality is a temperature modality (i.e., temperature sensing only) and the temperature has remained stable over a recent historical period (e.g., 5 minutes) the next data collection modality may remain a temperature modality. However, if the measured temperature has changed beyond a predetermined threshold then the next collection modality may include subsensors and sensing functions for measuring temperature and pulse rate.

[0031] Thus, in one embodiment, the updated data collection modality may escalate the number of subsensors placed in service (i.e., flagged as active subsensors) and/or the increase the amount of data processing (i.e., add more sensing functions) if the currently monitored conditions cross a threshold. For example, the first collection modality (i.e. when the wireless sensor **14** is first turned on) may typically have only a single active subsensor, for example, a temperature subsensor sensing patient temperature. As the patient temperature changes beyond a predetermined threshold, the next collection modality may activate a second subsensor, for example, a pulse oximetry subsensor which may derive pulse rate using a single LED in addition to using the temperature subsensor to sense temperature. A further change in the heart rate of the patient triggering another set of thresholds may result in the next collection modality turning on a second LED in the pulse oximetry subsensor for calculating SpO_2, in addition to the pulse rate and temperature sensing. Conversely, if measured parameters return to a normal range, various subsensors on the wireless sensor **14** that had been activated might be deactivated. While the above scenario describes one implementation in which the wireless sensor **14** initially activates a single subsensor and progressively activates additional subsensors if the measured parameters are determined to be outside of prescribed tolerance ranges, in a different implementation the wireless sensor **14** may initially activate all or almost all available subsensors and progressively deactivate subsensors if the measured parameters are determined to be in prescribed tolerance ranges. Accordingly, the medical system is able to more efficiently use available power and increase the lifecycle of the system's components by not continuously maintaining the subsensors and sensing functions in an active state.

[0032] The microprocessor **38** and/or the monitor **12** may determine (block **88**) a new data collection rate for each subsensor type based on the specified collection modality, and the update factors **92**, some which are shown in FIG. **4**. The data collection rate determines the rate at which the respective active subsensors of the data collection modality collect data. A faster data collection rate will result in more data points being collected but will also increase the energy usage of the wireless sensor **14**. Accordingly, the data collection rate that may result in an efficient balance between the need to observe the patient and the need to conserve battery power may be determined. Typically, a faster data collection rate may be used as the patient condition changes beyond certain predetermined thresholds or if there are indications that the patient condition is changing. By way of example, if the SpO_2 calculations derived from the spectrophotometric subsensors have remained stable over the recent historical period (e.g., 5 minutes) then the data collection rate may remain unchanged. However, if the SpO_2 calculations show, for example, a decreasing SpO_2 value, then the data collection rate may be increased so that readings of arterial oxygen saturation are taken more often. It is to be understood that the threshold values used to increase or decrease the data collection rate may depend on the type of subsensor used and the particular type of medical application for which the wireless sensor **14** is being used. For example, cardiac monitoring applications may require that a pulse oximetry subsensor collect data every few milliseconds while temperature monitoring applications may require that the temperature subsensors collect data every few seconds or minutes.

[0033] The microprocessor **38** and/or the monitor **12** may determine (block **90**) a new update interval based on the specified data collection modality and data collection rate. The determined update interval may specify the length of time the data collection modality and data collection rate are employed before the suitability of the modality and rate are again evaluated. For example, an update interval of 3 minutes would result in the wireless sensor **14** collecting data and processing data from all the subsensors in the current data collection modality for three minutes at the respective specified rates. At the end of the update interval, e.g. three minutes, the wireless sensor **14** may reevaluate the data collected from the current collection modality and select or leave unchanged the data collection modality, data collection rate, and/or update interval. In one embodiment where the update interval is derived by the monitor **12**, the monitor **12** may be constantly evaluating the data collection modality and/or the data collection rate so as to optimize data gathering activities and wireless sensor **14** energy use. In this embodiment, the update interval duration may be very small, consisting of a few CPU cycles.

[0034] In certain other embodiments where the update interval is derived by the monitor **12** and/or the microprocessor **38**, the monitor **12** and/or the microprocessor **38** may establish longer update interval. In these embodiments the update interval may have a longer duration in order to, for example, save on energy usage. The update interval in these embodiments may be predetermined or may be derived based on the current data collection modality, the data collection rate, and/or the update factors **92** discussed herein. The monitor **12** and/or the microprocessor **38** may lengthen the update interval in situations where the current data readings are stable and shorten the update interval in situations where the current data readings are changing. By way of example, if the SpO_2 calculations derived from the spectrophotometric subsensor have remained stable over the recent historical period (e.g., 5 minutes) then the update interval may remain unchanged. However, if the SpO_2 calculations show, for example, a decreasing SpO_2 value, then the update interval may be decreased so that the evaluations of the optimum data collection modality and the optimum data collection rate may be made more often. The process depicted in FIG. **3** may be performed iteratively during the length of time the wireless sensor **14** is worn by the patient.

[0035] As mentioned above, the microprocessor **38** and/or the monitor **12** may use a set of update factors **92** in determining the data collection modality, the data collection rate, and/or the update interval. FIG. **4** illustrates a block diagram of many such update factors **92**. As should be appreciated, precisely which update factors **92** are considered by the microprocessor **38** may be predetermined, may be determined based on the current subsensor package (i.e. based on all the subsensors included in a wireless sensor **14** device), may be determined based on the current patient condition, and/or may be determined based on the particular medical application for which the wireless sensor **14** is being used.

[0036] One example of an update factor may be the stability **94** of the data received by the active subsensors in the current data collection modality. As mentioned above, a data collection modality may flag as active any number of subsensors that are included in the wireless sensor device **14** shown in FIG. **2**. The current data collection modality may be configured to use various sensing functions to sense patient conditions such as temperature, respiration rate, pulse rate, pulse transit time, blood pressure, pH, blood microcirculation, blood flow, and/or SpO_2, among others. If the data from the subsensors in the current data collection modality is within a predetermined variability or standard deviation threshold over a recent historical period (e.g., 5 minutes), the stability factor **94** may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality used in sensing patient condition from the next data collection modality.

[0037] For example, if the patient's heart rate is varying, going up and then coming down repeatedly, then the heart rate data would be deemed unstable. Accordingly, the factor **94** may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of more subsensors and sensing functionality for sensing the patient condition. In determining the data collection modality, data collection rate, and/or update interval based at least in part on the factor **94**, a further consideration may be how much the subsensor data has varied. For example, the greater the variability of the subsensor data, the more the factor **94** may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the inclusion of more subsensors and sensing functionality in the next data collection modality.

[0038] A second example of an update factor **92** may be the actual values **96** derived from the raw data from each subsensor in the current data collection modality (e.g., patient temperature, pulse rate, respiration rate, and others). If a value is within an acceptable range of values, this factor may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functions sensing the patient condition from the next data collection modality.

[0039] By way of example, if the measured values include a temperature value, an acceptable range of values for an adult patient may be a range of 96.4° F. to 100.4° F. A temperature value less than 96.4° F. or greater than 100.4° F. may be evaluated by the microprocessor or the monitor as weighing in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of more subsensors and sensing functionality sensing the patient condition. In determining the data collection modality, the data collection rate, and/or the update interval based at least in part on the values **96**, the microprocessor **38** or the monitor **12** may further consider how much the value of the data of interest is outside or inside the acceptable range. For example, the greater the extent by which the value is outside the acceptable range, the more the value factor **96** may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of more subsensors and sensing functions sensing the patient condition.

[0040] A third example of an update factor **92** may be data trends **98** observed in data measured by the various subsensors. For example, if the patient pulse rate is going up and the patient systolic/diastolic pressure is also going up, then this data trend combination may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition. Similarly, if measured data derived using subsensors in the current data collection modality show a trend towards normalcy of the data, then the data trend may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality from the next data collection modality.

[0041] Data trends **98** may also include trends based on the rate of change for a given parameter. For instance, heart rate may change relatively quickly while body temperature may take longer to show a measurable change. Accordingly, each subsensor may monitor the rate of change of a plurality of physiological parameters. If the rate of change of a parameter trends toward normalcy, then the data trend may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality from the next data collection modality. A rate of change outside of normalcy for the parameter may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition. Additionally, each subsensor may further optimize energy usage by including minimum and maximum data collection and/or data update rates based on, for example, the expected rate of change of the physiological parameters under observation. That is, the data collection and data update rates may be adjusted to correspond to expected rates of change of the physiological parameter being monitored. For example, body temperature may change relatively slowly; accordingly, it may be more efficient to sample temperature data at relatively low data collection and data update rates. Heart rate may change relatively quickly; accordingly, better monitoring may be obtained by sampling data at relatively high data collection and data update rates.

[0042] A fourth example of an update factor **92** may be the patient's clinical history **100**. The clinical history **100** (e.g., patient ages, sex, the treatment or procedure prescribed, the diagnosis, existing medical conditions or previous treatments received, and so forth) may be electronically entered in an external computer (such as an electronic hospital or medical record), communicated to the monitor **12** and or wireless sensor **14**, and used as an update factor. The clinical history **100** (such as the patient's age, recent medical procedures, and so forth) may weigh in favor of a higher or lower data collection rate, a longer or shorter update interval, and/or towards the addition or removal of subsensors and sensing functionality for sensing the patient condition.

[0043] A fifth example of an update factor **92** may be the movement **102** of the patient, which may be indicated to the wireless medical sensor **14** via parameter updates from the patient monitor **12** or via one or more movement subsensors

74 disposed within the wireless sensor **14**. If the patient **34** is currently moving or has undergone recent movement, indicating that the patient **34** is not at rest or is being moved from one room to another, the movement **102** may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition. If the patient is not currently moving or has not undergone recent movement, the movement **102** may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality from the next data collection modality. In one embodiment, the amount (or absence) of patient movement **102** may affect the extent to which the data collection rate, the update interval, and/or the addition or removal of other subsensors and sensing functionality for sensing the patient condition is adjusted.

[0044] A sixth example of an update factor **92** may be the current location **104** of the patient, which may be determined by a user input, by a RFID tag (or other location determining component) provided with the wireless sensor **14**, and/or by a network or wireless communication node accessed by the wireless sensor **14**. For example, it may be desirable that the wireless sensor **14** generate different types or amounts of patient data depending on whether the patient **34** is in surgery, in recovery, or undergoing other diagnostic tests. Thus, the current location of the patient may be considered as one of the update factors **92**. For example, if the patient is currently located in a medical facility room where the patient should be kept under especially close scrutiny, such as an operating room, the setting **104** may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition. If the patient is currently located in a medical facility room where the patient **34** may be kept under less scrutiny, such as a waiting or pre-operative room, the setting **104** may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality from the next data collection modality.

[0045] In determining the data collection modality, the data collection rate, and/or the update interval based at least in part on the setting **104**, the microprocessor **38** and/or monitor **12** may give different locations different weights in favor of the inclusion or exclusion or certain subsensors and sensing functionality, a shorter or longer data collection rate, and a shorter or longer update interval. For example, if the current location is an operating room or a pre- or post-operative setting, the setting **104** may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition. However, the setting **104** may weigh more heavily in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality from the next data collection modality if the current location of the patient is a waiting room or a room where diagnostic testing or imaging is performed.

[0046] A seventh example of an update factor **92** may be the presence or the absence (block **106**) of a clinician or other caregiver proximate to the patient. Such information may be provided as an input to the monitor **12** or wireless sensor **14** when the clinician or caregiver logs into a monitor **12** or when the clinician or caregiver is identified as being in the vicinity of the wireless sensor **14**, such as by accessing or entering a room or wing using an access card. For example, if a clinician enters a room where the patient is currently located, the presence **106** of the clinician may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition. If the clinician exits the room, the absence **106** of the clinician may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality.

[0047] In determining the update interval based at least in part on the presence or absence **106** of a clinician or caregiver, the microprocessor **38** and/or the monitor **12** may weigh the presence or absence **106** based on the number or patient assignment of clinicians present. For example, if a clinician that is not assigned to the patient enters a room where the patient is currently located, the presence of the unassigned clinician may not weigh as heavily in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition as when a clinician that is assigned to the patient enters the room. Thus, the presence or absence **106** factor may take into account who the individual is who is present or absent, their relationship or assignment to the patient, their training or designation (i.e., doctor, nurse, therapist, and so forth), as well as other factors that may be useful in assessing the import of having such a person present or absent with respect to care of the patient.

[0048] An eight example of an update factor **92** may be an initialization status **108** of the wireless sensor **14**. For a period of time while the sensor **14** is being initialized (e.g., 5 minutes), the number of subsensors and sensing functionality in the current data collection modality, the data collection rate and/or the update interval of the wireless sensor **14** may be temporarily increased, and the raw data stream supplied to the patient monitor **12**. By supplying a raw data stream during the initialization of the wireless sensor **14**, a clinician for other medical personnel may properly fit the wireless sensor **14** to the patient. In this way, the sensor initialization **108** may weigh in favor of a high data collection rate, a short update interval, and/or towards the addition of all the subsensors and sensing functionality for sensing the patient condition when the wireless sensor **14** has recently been activated.

[0049] A ninth example of an update factor **92** may be the battery life **110** of the wireless sensor **14**. If the battery **70** of the wireless sensor **14** has more than a predetermined amount of remaining battery life, the battery life **110** may weigh in favor of a higher data collection rate, a shorter update interval, and/or towards the addition of other subsensors and sensing functionality for sensing the patient condition. If the battery **70** has less than the predetermined amount of remaining battery life **110**, this may weigh in favor of a lower data collection rate, a longer update interval, and/or towards the exclusion of some of the subsensors and sensing functionality. In some embodiments, there may not be a single threshold, but may instead be two or more thresholds or a dynamic function or relationship that relates battery life **110** to the data collection rate, the update interval, and/or the number or type of subsensors activated. Further, to the extent that not all of the subsensor types included on the wireless sensor **14** may consume power at the same rate, the power consumption of the various subsensor types may be considered in conjunction with battery life **110** in adjusting the data collection rate, the update interval, and/or the specific subsensors activated.

[0050] A tenth example of an update factor **92** may be the monitor and/or sensor settings **112**. One or both of the monitor **12** and/or the wireless sensor device **14** may include user-selectable settings such as the data collection rate for individual subsensors, the set of subsensors and sensing functionality to include in the data collection modality, and/or the length of the update interval. These settings may be stored in the monitor **12** and/or the wireless sensor device **14** and may be configured by a medical professional for specific patients, medical applications, and/or patient settings, among others.

[0051] Express instructions **114** received by the wireless sensor **14** from the patient monitor **12** may constitute an eleventh example factor of the update factors **92**. As described below with reference to FIG. **5**, in the course of wireless communication with the sensor device **14**, the patient monitor **12** may transmit updates to the wireless sensor **14** settings. These wireless sensor setting updates from the patient monitor **12** may instruct the wireless sensor **14** which subsensors in wireless sensor **14** may be used in the data collection modality (i.e., which subsensors will be actively sensing and the respective sensing functionality), the data collection rate that may be used to collect data from each subsensor, and the update interval at which the next set of subsensor settings may be derived, and others. To provide one example, a caregiver may instruct the patient monitor **12** to instruct the wireless sensor **14** to transmit a raw or processed stream of data from all of the subsensors included on the wireless sensor **14**, from a specified subset of the subsensors included on the wireless sensor **14**, or from a particular subsensor included on the wireless sensor **14**.

[0052] With the foregoing in mind and turning to FIG. **5**, a communication diagram is provided depicting communication between the wireless sensor **14** and the patient monitor **12**. As mentioned above, the patient monitor **12** may be used because the monitor **12** may aid in saving the battery life of the wireless sensor **14** by taking over certain computations such as the derivation of the optimum number of subsensors to have in a data collection modality, the subsensor data collection rates, and the update interval. Additionally, the patient monitor **12** may provided greater processing power, which may allow for faster and/or more precise calculations of various medical measurements such as pulse transit times, pH, Doppler frequency calculations, SpO_2, and others. Accordingly, the wireless sensor **14** may collect (block **116**) data and periodically send (block **118**) data of interest for further processing by the patient monitor **12**.

[0053] In one embodiment, the collected sensor data may include raw sensor data from the subsensors in the current data collection modality (i.e., the set of subsensors that are currently configured to be in an active state). The raw data may be sent to the patient monitor **12** for further processing (block **120**) into discrete measurements. For example, the raw photoplethysmographic data consisting of a stream of light signal values detected by a light detector may be sent as the data of interest to the patient monitor **12** and processed by the monitor **12** to arrive at a pulse transit time. In another embodiment, only some of the collected raw data may be sent as the data of interest to the patient monitor **12**. In this embodiment, the subset of the collected raw data sent to the patient monitor **12** may include only raw data that requires processing by a more powerful processor, for example, Doppler data used to create ultrasound visualizations. In yet another embodiment, already processed data (i.e., discrete patient measurements such as temperature or pulse rate values) may be sent from the wireless sensor **14** to the patient monitor **12**. In this embodiment, the wireless sensor **14** may first collect the raw data, process the raw data into discrete measurements, and send the discrete measurements as the data of interest to the patient monitor **12**.

[0054] In embodiments that transmit raw data, the patient monitor **12** may use the raw data sent by the wireless sensor **14** to calculate (block **120**) various physiologic parameters such as pulse rate, SpO_2, microcirculation, and others. As mentioned above with respect to FIGS. **3** and **4**, in certain embodiments, the monitor **12** may be used to determine the data collection modality (i.e., the subsensors and sensing functions that will be actively sensing patient conditions), the data collection rate for each subsensor in the data collection modality, and/or the next update interval. The patient monitor **12** may use the update factors **92** as discussed herein to determine (block **122**) each of the subsensors that will be active in the next data collection modality, the data collection rate for each of the subsensors, and/or the next update interval for the wireless sensor **14**. Once the patient monitor **12** has derived the data collection modality, the data collection rates, the next update interval, and/or other wireless sensor **14** settings, the patient monitor **12** may transmit (block **124**) the new wireless sensor settings to the wireless sensor **14**. The wireless sensor **14** may then update (block **126**) the wireless sensor **14** settings so that the new data collection modality, data collection rates, and update intervals are used. The communication process of depicted in FIG. **5** may be repeated as needed, such as while the wireless sensor **14** is in use on a patient.

[0055] Turning to FIG. **6**, a method is depicted of periodically collecting raw data from all the subsensors and all of the subsensor functionality in the wireless sensor **14** of FIG. **2**. In this embodiment, raw data from all the subsensors included in the wireless sensor **14** of FIG. **2** is collected (block **128**). The raw data is evaluated (block **130**). As mentioned above, the evaluation of the raw data may be performed by the microprocessor **38** of the wireless sensor **14** of FIG. **2** and/or the monitor **12**. Part of the evaluation process may include conversion of the raw data into discrete values such as a temperature value, a SpO_2 measurement, a pulse rate, and others. For example, the microprocessor **38** and/or the monitor **12** may process a raw photoplethysmographic data set and derive a pulse rate, respiration rate data, blood oxygen saturation data, etc. In a subsequent decision **132**, the microprocessor **38** and/or the monitor **12** may evaluate whether the update factor **92** (shown in FIG. **4**) circumstances have changed. By way of example, if a wireless sensor device includes a temperature subsensor and a spectrophotometric subsensor, and the temperature and spectrophotometric calculations derived from the sensors have remained stable over the recent historical period (e.g., 5 minutes) then the circumstances remain unchanged.

[0056] If circumstances remain unchanged, the process may wait (block **134**) for a periodic interval. The process may then repeat after the periodic time interval has elapsed. If the circumstances have changed, the microprocessor **38** and/or the monitor **12** may determine (block **136**) a new data collection modality, new data collection rates, and/or a new update interval as described with respect to FIGS. **3**, **4**, and **5** above. A new periodic time interval may also be determined. It is to be understood that the periodic time interval and the update interval that may be determined at block **136** need not be the same interval. By periodically querying all of the sensors in the wireless sensor device **14**, the embodiment may be capable of employing the complete set of functionality present in the wireless sensor **14** device but at the same time reducing the energy usage of the device. This method allows for the use of all of the sensing functionality present in a given medical sensor in a periodic fashion.

[0057] 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. Indeed, the various embodiments may cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims.

What is claimed is:

1. A method for operating a wireless sensor, comprising:

operating one or more subsensors of a wireless medical sensor disposed on a patient such that at least one of the one or more subsensors do not operate continuously;

acquiring data from the one or more subsensors when operated;

determining whether to alter the operation of the one or more subsensors based on one or more factors related to at least one of the acquired data, the patient, the wireless medical sensor, or a monitor in communication with the wireless medical sensor; and

altering operation of the one or more subsensors if so determined.

2. The method of claim **1**, wherein altering the operation of the at least one of the one or more subsensors comprises turning on or off one of the one or more subsensors.

3. The method of claim **1**, wherein altering the operation of the at least one of the one or more subsensors comprises changing a collection rate of at least one of the one or more subsensors.

4. The method of claim **1**, wherein altering the operation of the at least one of the one or more subsensors comprises changing an update interval associated with determining whether to alter the operation of the one or more subsensors.

5. The method of claim **1**, wherein the one or more factors related to the acquired data comprise one or more of physiological measurements derived from the acquired data, a measure of data variability or deviation, or a trend in the acquired data or a physiological measurement derived from the acquired data.

6. The method of claim **1**, wherein the one or more factors related to the patient comprise a medical history of the patient, a patient diagnosis, movement of the patient, a patient setting, or the presence or absence of a caregiver relative to the patient.

7. The method of claim **1**, wherein the one or more factors related to the wireless medical sensor comprise an initialization state of the wireless medical sensor, a battery life of the wireless medical sensor, or a setting of the wireless medical sensor.

8. The method of claim **1**, wherein the one or more factors related to the monitor comprise a setting of the monitor or one or more instructions input to the monitor.

9. A method comprising:

determining a data collection modality for a wireless medical sensor comprising a plurality of subsensor types, wherein the data collection modality comprises a set of the plurality of subsensor types that are selected for activation;

determining a data collection rate for each subsensor type of the data collection modality;

operating those subsensor types of the data collection modality at the data collection rate specified for each respective subsensor type; and

updating the data collection modality after an update interval.

10. The method of claim **9**, wherein the plurality of subsensor types comprises at least two of a photoplethysmographic sensor, a respiration sensor, a temperature sensor, a blood pressure sensor, an electrocardiogram (EKG) sensor, a Doppler sensor, a pH sensor, a photon density sensor, a pulse transit time sensor, or any combination thereof.

11. The method of claim **9**, wherein determining one or more of a data collection modality, a data collection rate, or a data collection modality and a data collection rate comprises evaluating one or more update factors.

12. The method of claim **11**, wherein the one or more update factors comprise a factor related to the acquired data, the patient, the wireless medical sensor, or a monitor in communication with the wireless medical sensor.

13. The method of claim **9**, comprising determining the update interval based at least on the evaluation of one or more update factors.

14. The method of claim **9**, wherein determining the data collection modality, the data collection rate, or the data collection modality and the data collection rate is performed by the wireless medical sensor, by a monitor in communication with the wireless medical sensor, or by a combination of the monitor and the wireless medical sensor.

15. The method of claim **9**, comprising determining a periodic interval associated with the operation of all the subsensor types.

16. The method of claim **15**, wherein determining the periodic interval comprises evaluating one or more update factors.

17. A monitoring system, comprising:

a wireless medical sensor, comprising:

a battery;

a plurality of subsensors configured to draw power from the battery, wherein each subsensor is configured to acquire different types of physiological data;

one or more processors configured to execute code that operates the plurality subsensors such that the plurality of sensors is operated discontinuously;

a memory configured to store the code executed by the processor;

a wireless communication component capable of communicating the physiological data.

18. The monitoring system of claim **17**, wherein the plurality of subsensors is operated discontinuously by turning off one or more of the plurality of subsensors.

19. The monitoring system of claim **17**, wherein the plurality of subsensors is operated discontinuously by specifying a data collection rate for one or more of the plurality such that data is not collected continuously.

20. The monitoring system of claim **17**, comprising a monitor in wireless communication with the wireless medical sensor.

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摘要(译)

本公开描述了一种能量有效的无线医疗传感器，其能够通过在任何时间仅选择性地使用无线医疗传感器中包括的传感器和传感器功能的子集来优化电池寿命并增加部件寿命。无线传感器或外部患者监视器可以使用一个或多个更新因子来导出数据收集模态，数据收集速率和更新间隔。数据收集模态，数据收集速率和更新间隔可用于以更节能的方式选择性地收集感测数据。