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(54) **METHODS AND APPARATUS FOR PROCESSING PHYSIOLOGICAL DATA ACQUIRED FROM AN AMBULATORY PHYSIOLOGICAL MONITORING UNIT**

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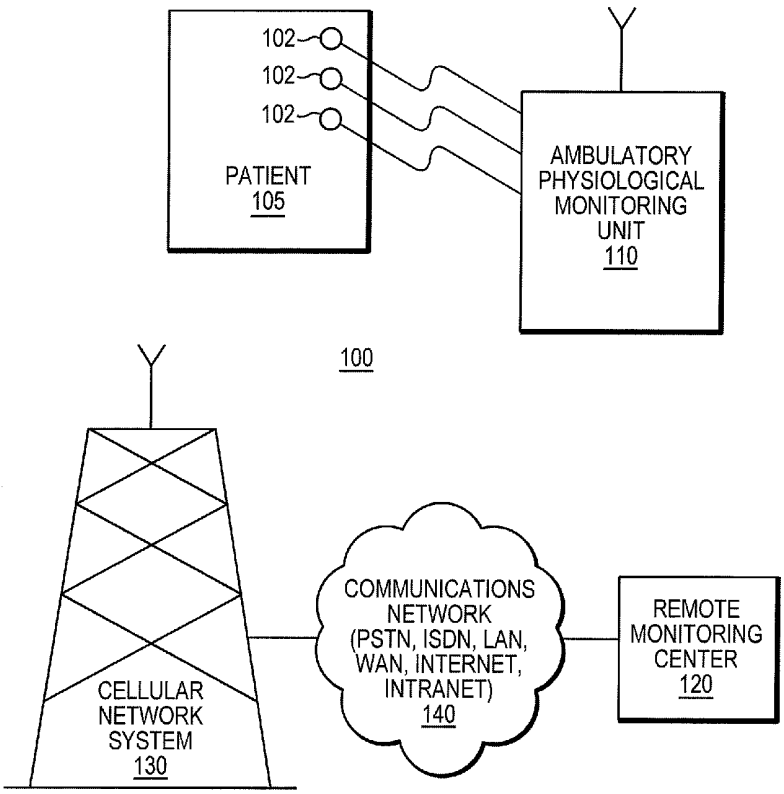
(57) **ABSTRACT**

A physiologic monitoring system and corresponding methods provide rapid and detailed analysis of data for one or more physiologic parameters to achieve a quick and accurate medical diagnosis. An ambulatory physiological monitoring unit acquires physiologic data, automatically analyzes it to detect an event, and transmits information regarding the event and physiologic data associated with the event across a communications network to a monitoring center, where the event information is analyzed and triaged. The monitoring center can also perform a retrospective analysis based on the physiological data associated with the event to provide an in-depth analysis of the detected event and an accurate diagnosis. The monitoring center can also request additional or different physiological data to refine the analysis. As a result, the physiological monitoring system and corresponding methods can ensure that timely and appropriate intervention is taken to reduce a patient's discomfort, pain, injury, or risk of death.



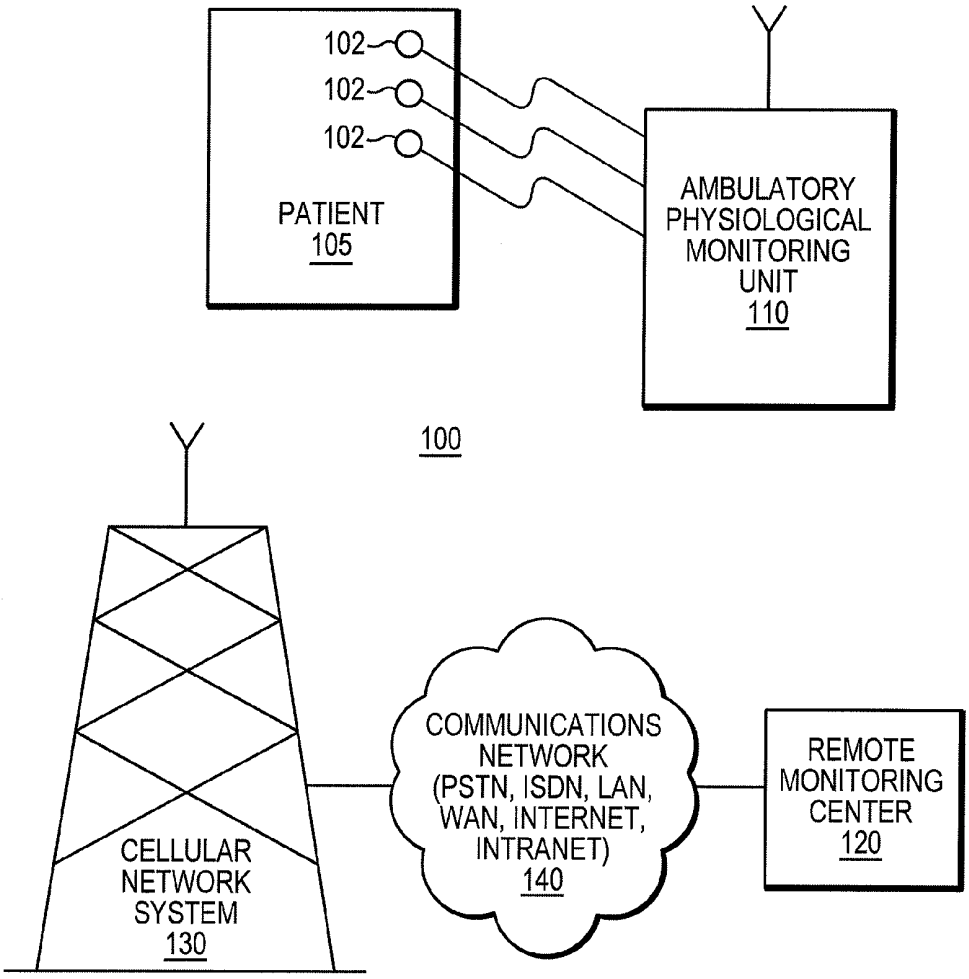

102
102
102
PATIENT
105
AMBULATORY
PHYSIOLOGICAL
MONITORING
UNIT
110
100
CELLULAR
NETWORK
SYSTEM
130
COMMUNICATIONS
NETWORK
(PSTN, ISDN, LAN,
WAN, INTERNET,
INTRANET)
140
REMOTE
MONITORING
CENTER
120

FIG. 1

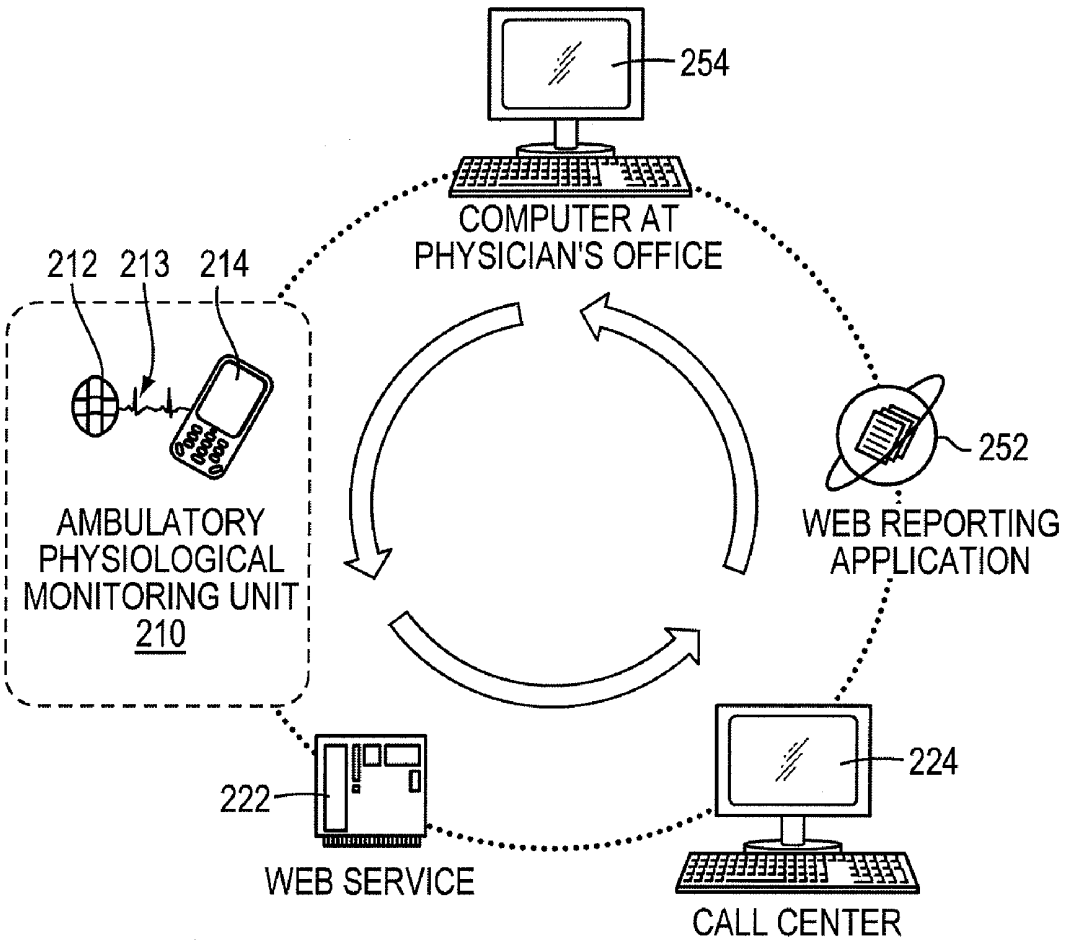

254
COMPUTER AT PHYSICIAN'S OFFICE
212 213 214
AMBULATORY PHYSIOLOGICAL MONITORING UNIT 210
252
WEB REPORTING APPLICATION
222
WEB SERVICE
224
CALL CENTER

FIG. 2

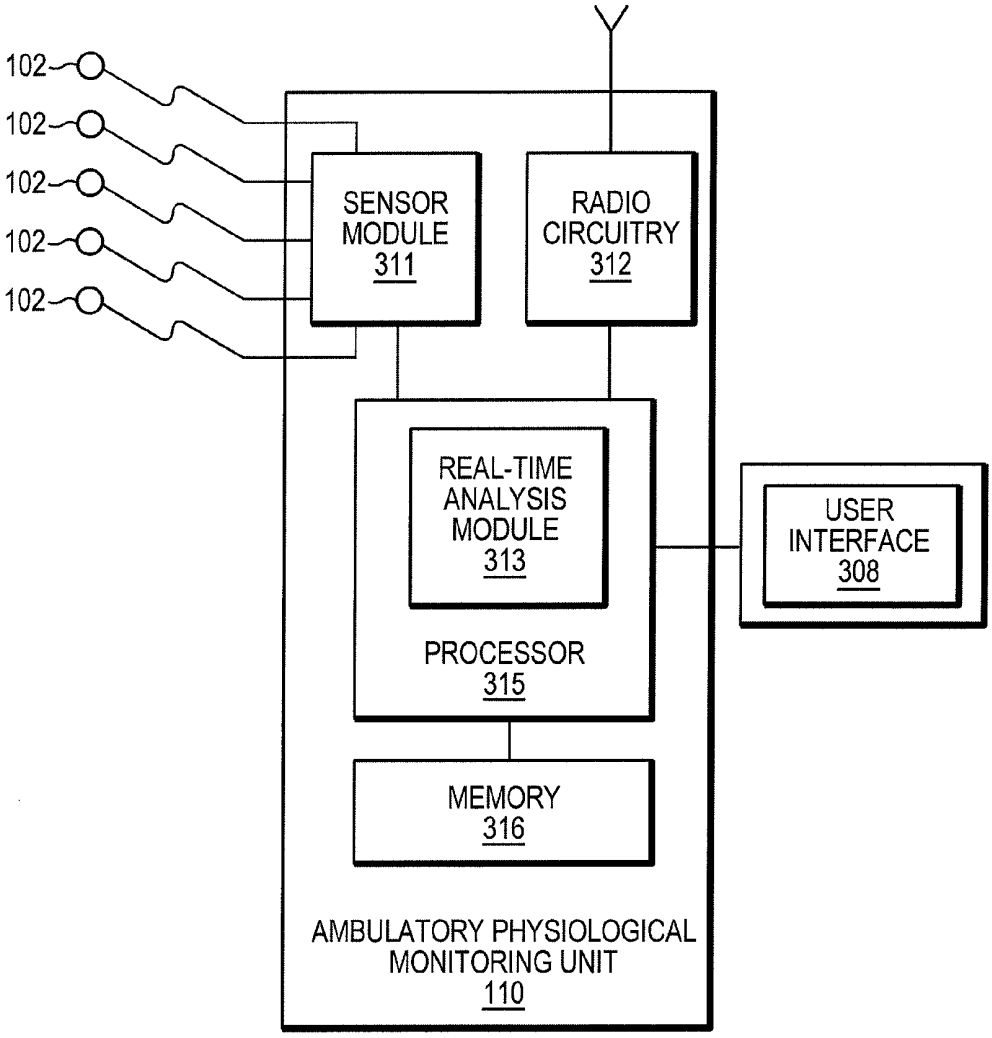

102
102
102
102
102
SENSOR MODULE 311
RADIO CIRCUITRY 312
REAL-TIME ANALYSIS MODULE 313
PROCESSOR 315
USER INTERFACE 308
MEMORY 316
AMBULATORY PHYSIOLOGICAL MONITORING UNIT 110

FIG. 3A

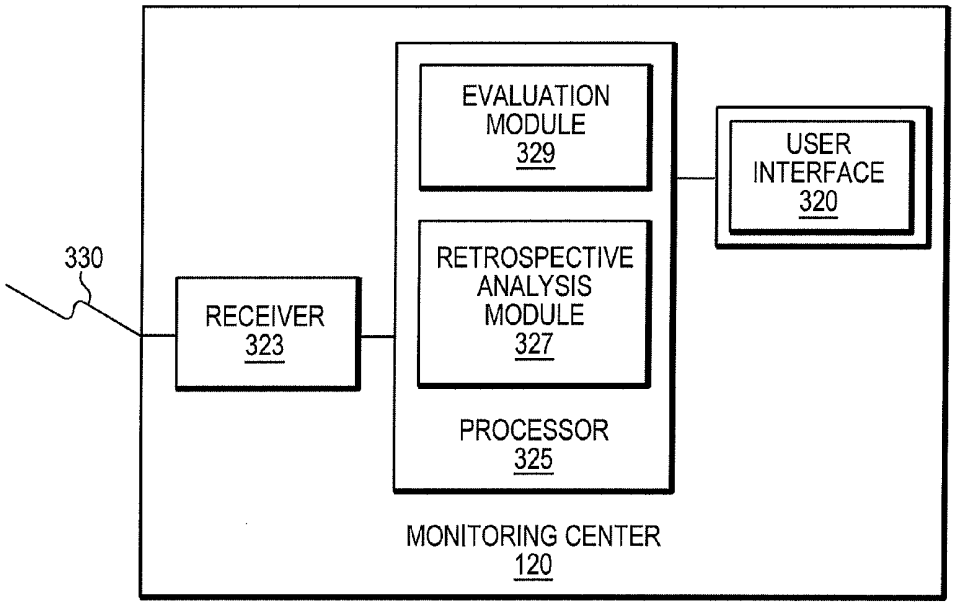

330
RECEIVER
323
EVALUATION
MODULE
329
RETROSPECTIVE
ANALYSIS
MODULE
327
PROCESSOR
325
USER
INTERFACE
320
MONITORING CENTER
120

FIG. 3B

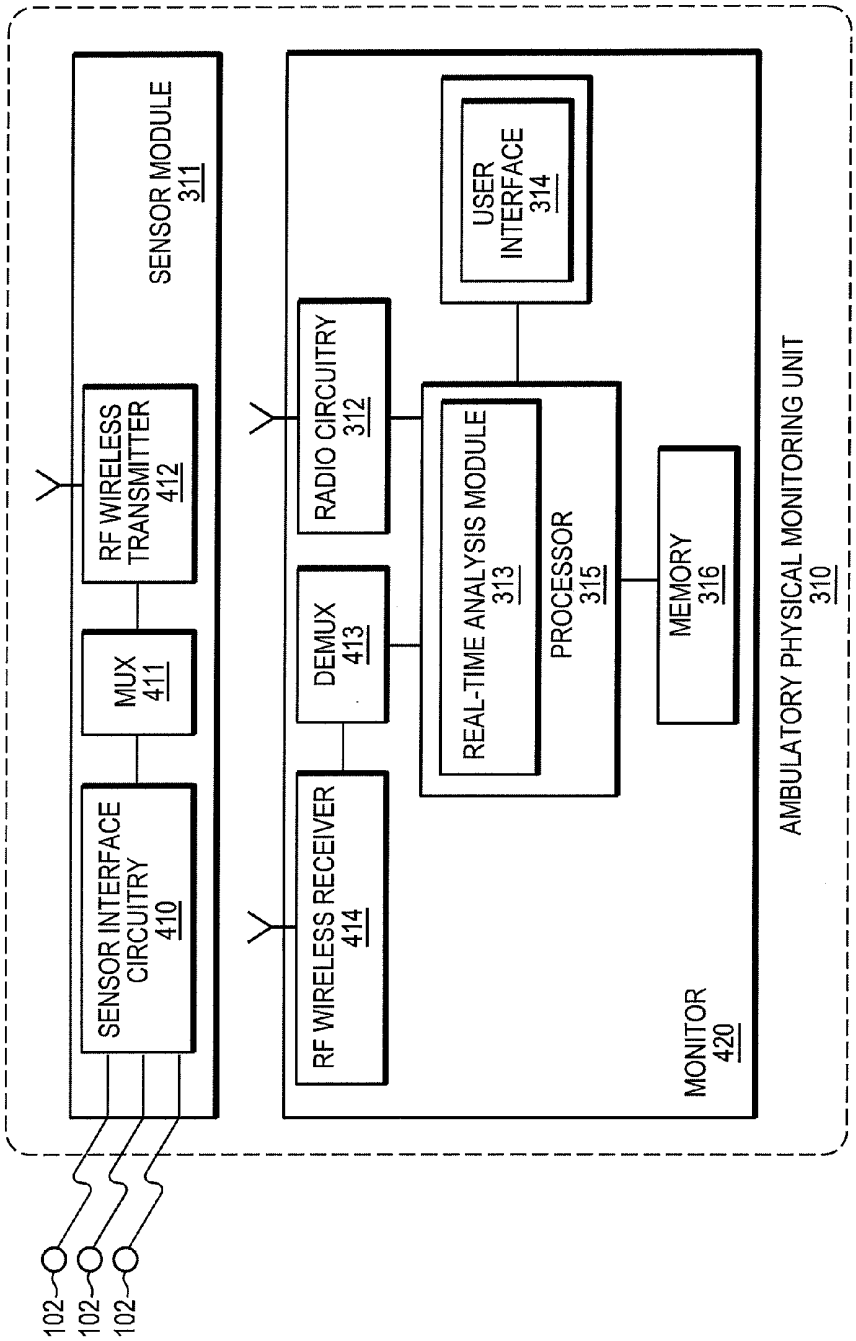

AMBULATORY PHYSICAL MONITORING UNIT
310
SENSOR MODULE
311
SENSOR INTERFACE CIRCUITRY
410
MUX
411
RF WIRELESS TRANSMITTER
412
RF WIRELESS RECEIVER
414
DEMUX
413
RADIO CIRCUITRY
312
PROCESSOR
315
REAL-TIME ANALYSIS MODULE
313
USER INTERFACE
314
MEMORY
316
MONITOR
420
102
102
102

FIG. 4

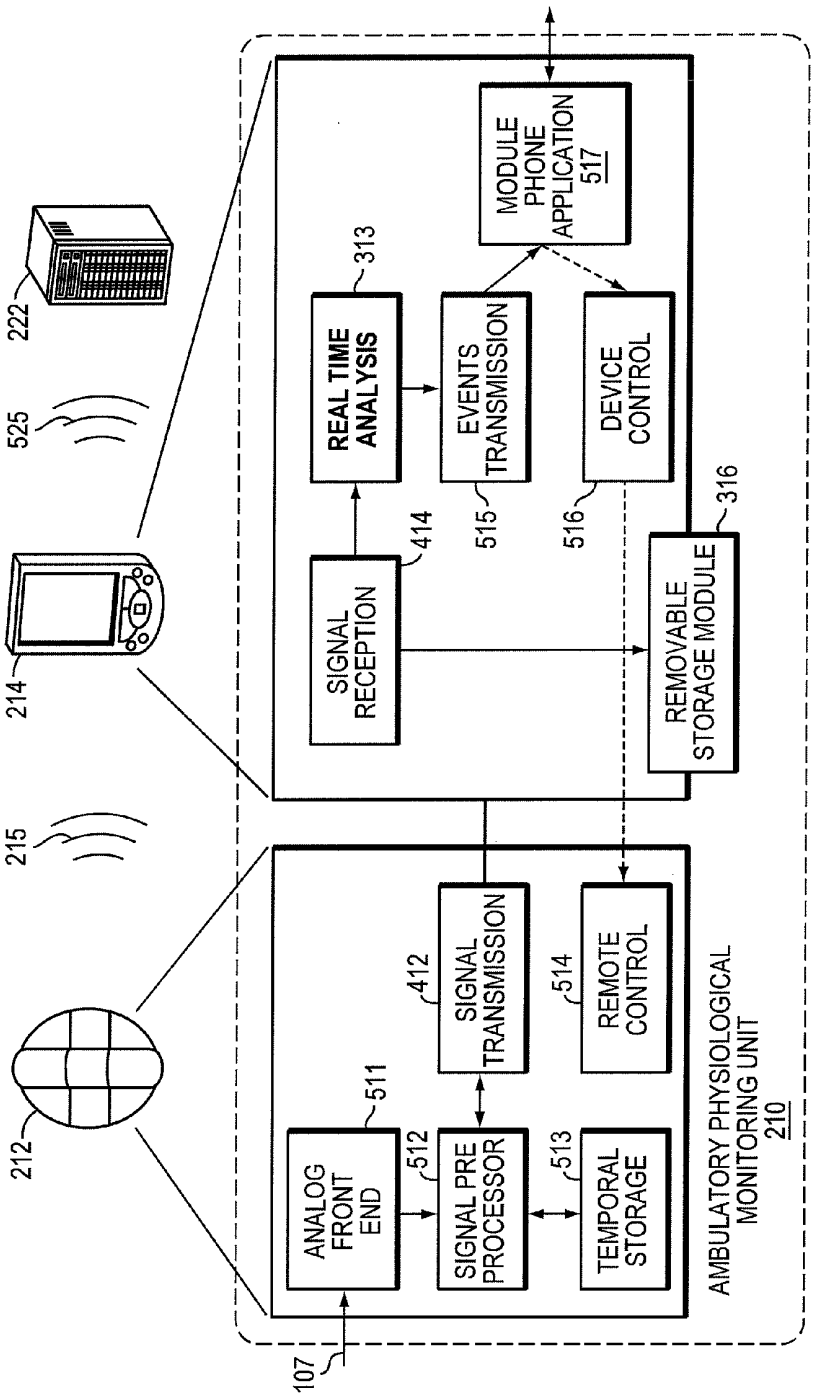

222
525
214
215
212
107
313
414
515
516
316
511
512
513
412
514
REAL TIME ANALYSIS
EVENTS TRANSMISSION
DEVICE CONTROL
MODULE PHONE APPLICATION 517
SIGNAL RECEPTION
REMOVABLE STORAGE MODULE
ANALOG FRONT END
SIGNAL PRE PROCESSOR
TEMPORAL STORAGE
SIGNAL TRANSMISSION
REMOTE CONTROL
AMBULATORY PHYSIOLOGICAL MONITORING UNIT 210

FIG. 5A

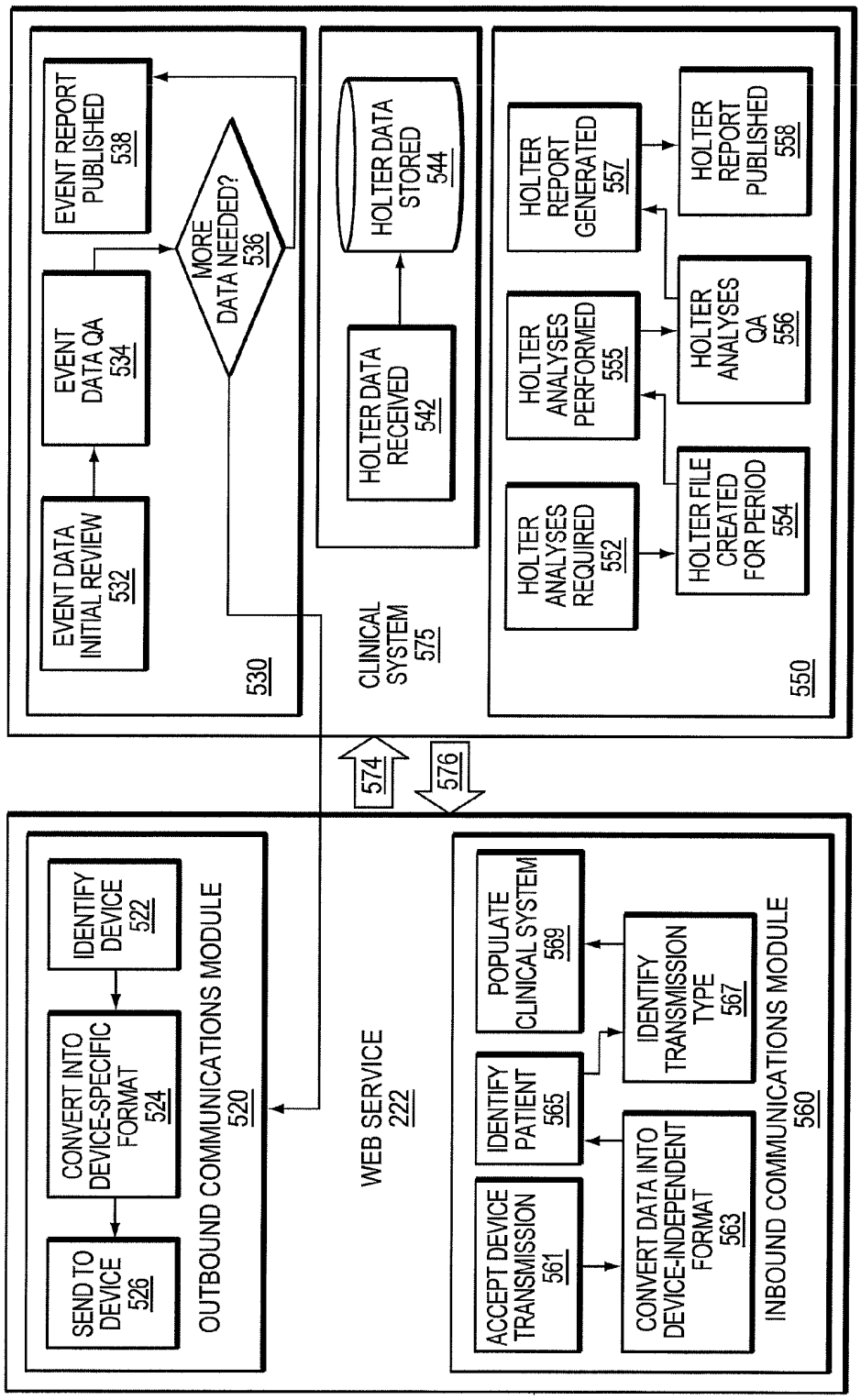

EVENT REPORT PUBLISHED 538
MORE DATA NEEDED? 536
EVENT DATA QA 534
EVENT DATA INITIAL REVIEW 532
530
HOLTER DATA STORED 544
HOLTER DATA RECEIVED 542
CLINICAL SYSTEM 575
HOLTER REPORT GENERATED 557
HOLTER REPORT PUBLISHED 558
HOLTER ANALYSES PERFORMED 555
HOLTER ANALYSES QA 556
HOLTER ANALYSES REQUIRED 552
HOLTER FILE CREATED FOR PERIOD 554
550
574
576
IDENTIFY DEVICE 522
CONVERT INTO DEVICE-SPECIFIC FORMAT 524
SEND TO DEVICE 526
OUTBOUND COMMUNICATIONS MODULE 520
WEB SERVICE 222
POPULATE CLINICAL SYSTEM 569
IDENTIFY TRANSMISSION TYPE 567
IDENTIFY PATIENT 565
ACCEPT DEVICE TRANSMISSION 561
CONVERT DATA INTO DEVICE-INDEPENDENT FORMAT 563
INBOUND COMMUNICATIONS MODULE 560

FIG. 5B

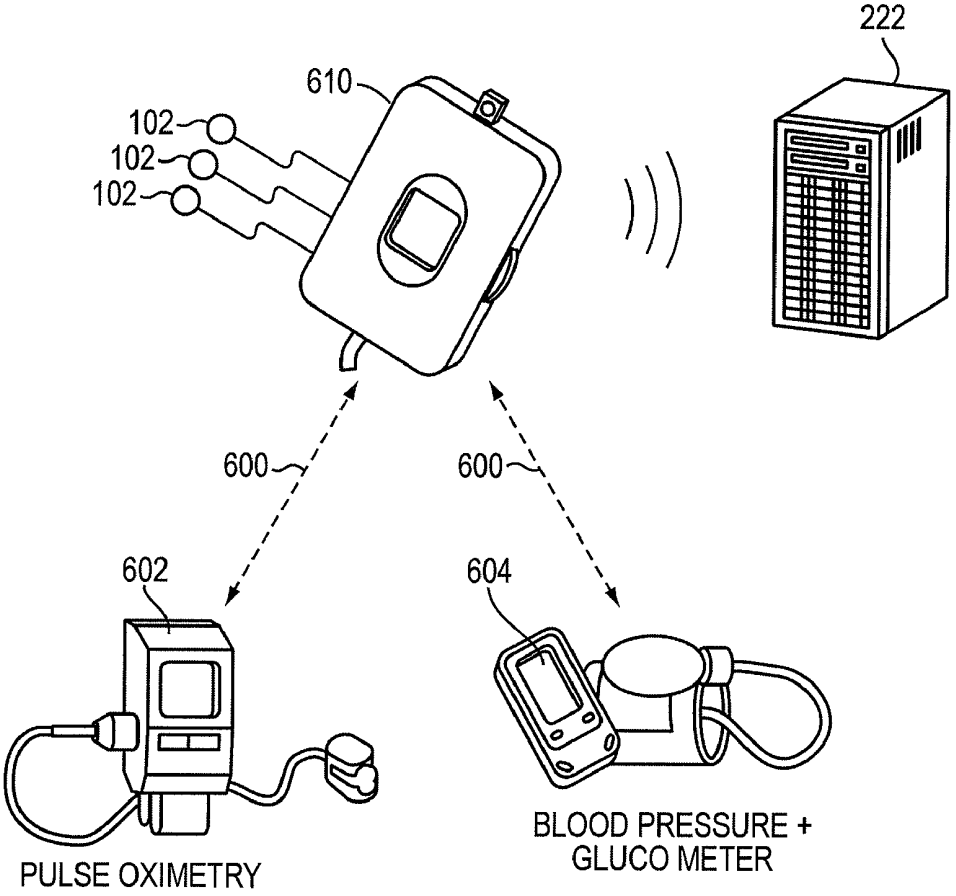

222
610
102
102
102
600
600
602
604
PULSE OXIMETRY
BLOOD PRESSURE +
GLUCO METER

FIG. 6

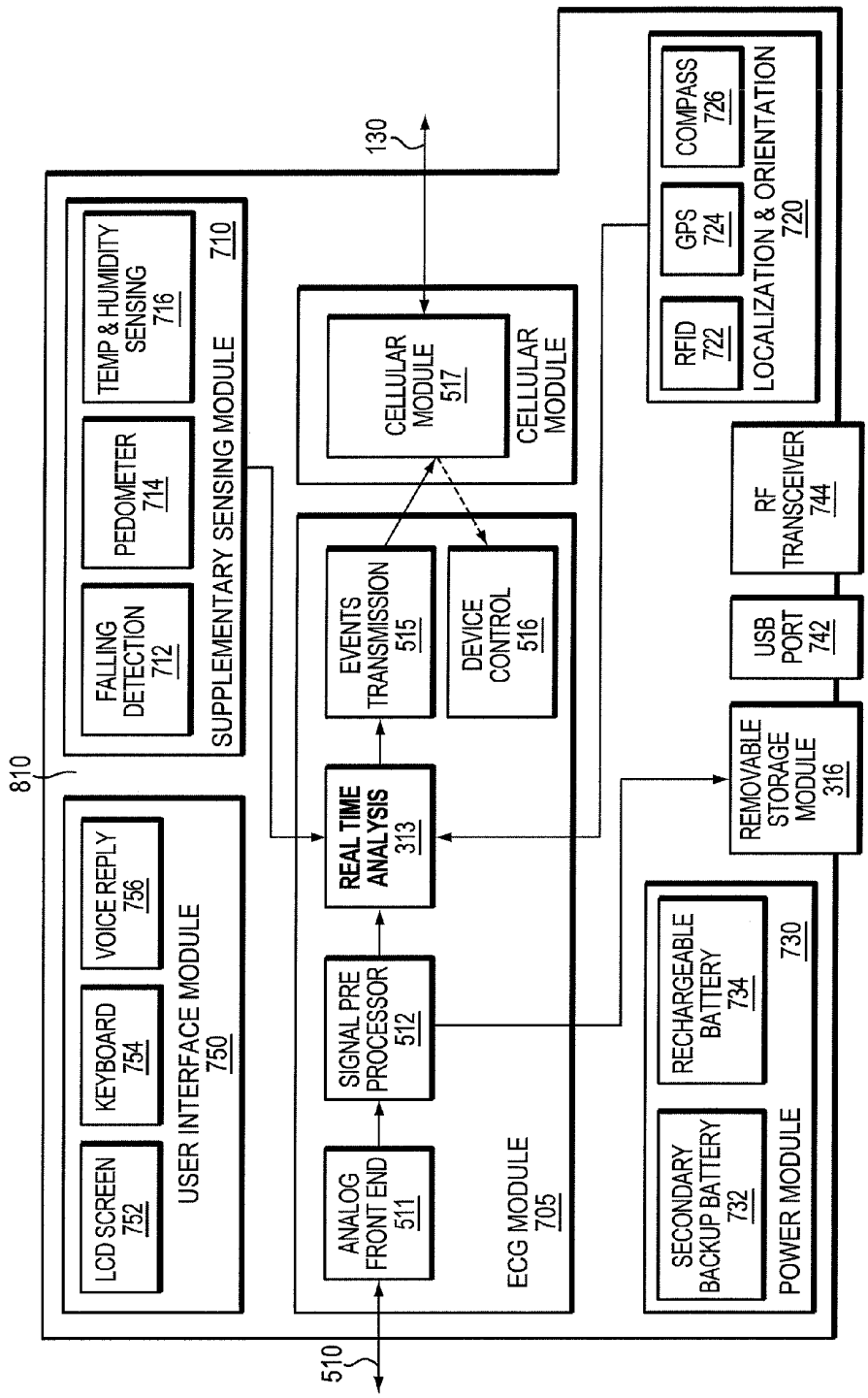

810
USER INTERFACE MODULE 750
LCD SCREEN 752
KEYBOARD 754
VOICE REPLY 756
SUPPLEMENTARY SENSING MODULE 710
FALLING DETECTION 712
PEDOMETER 714
TEMP & HUMIDITY SENSING 716
ECG MODULE 705
ANALOG FRONT END 511
SIGNAL PRE PROCESSOR 512
REAL TIME ANALYSIS 313
EVENTS TRANSMISSION 515
DEVICE CONTROL 516
CELLULAR MODULE
CELLULAR MODULE 517
130
510
POWER MODULE 730
SECONDARY BACKUP BATTERY 732
RECHARGEABLE BATTERY 734
REMOVABLE STORAGE MODULE 316
USB PORT 742
RF TRANSCEIVER 744
LOCALIZATION & ORIENTATION 720
RFID 722
GPS 724
COMPASS 726

FIG. 7

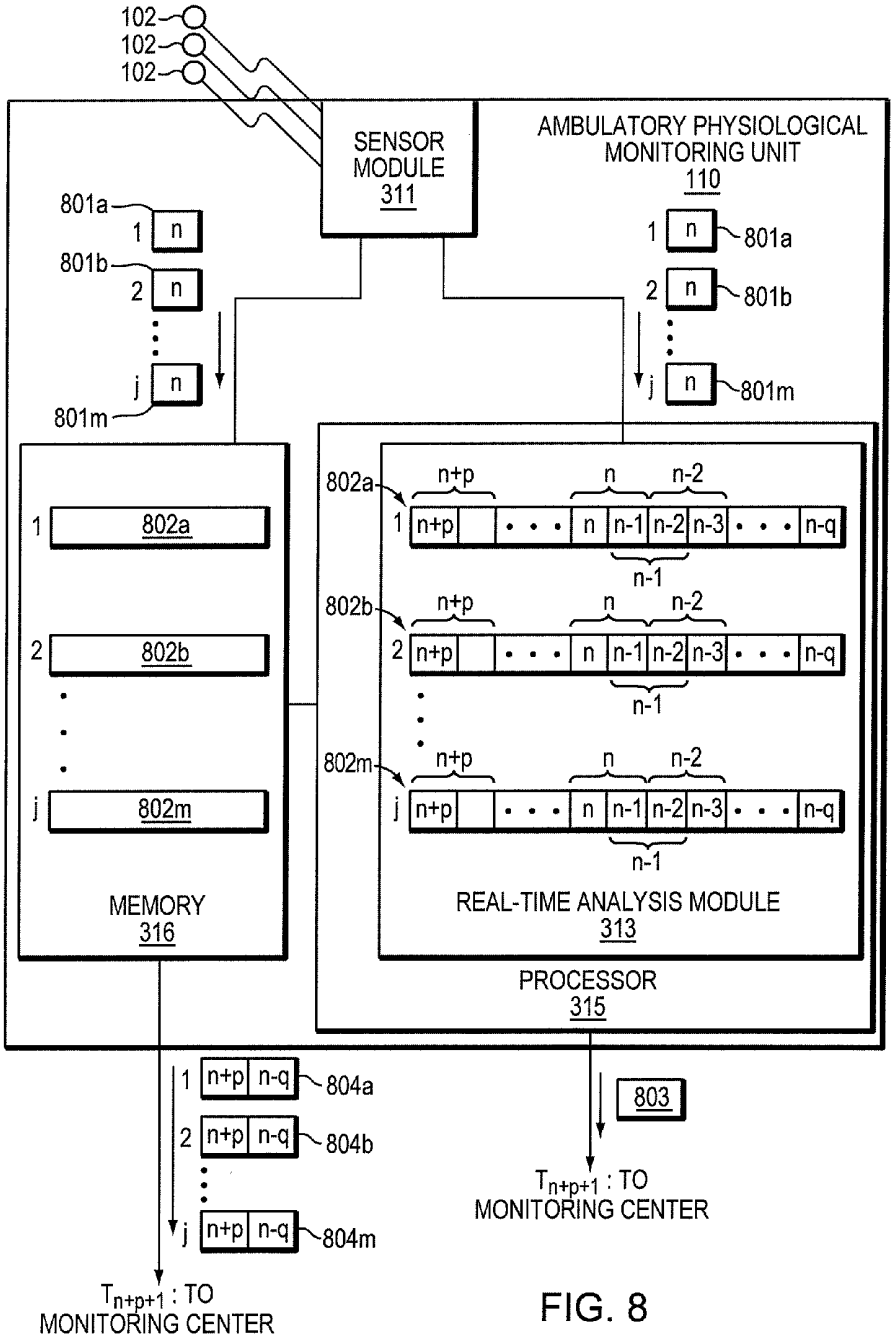

102
102
102
SENSOR MODULE 311
AMBULATORY PHYSIOLOGICAL MONITORING UNIT 110
801a
801b
801m
802a
802b
802m
MEMORY 316
REAL-TIME ANALYSIS MODULE 313
PROCESSOR 315
804a
804b
804m
803
T_{n+p+1} : TO MONITORING CENTER
T_{n+p+1} : TO MONITORING CENTER

FIG. 8

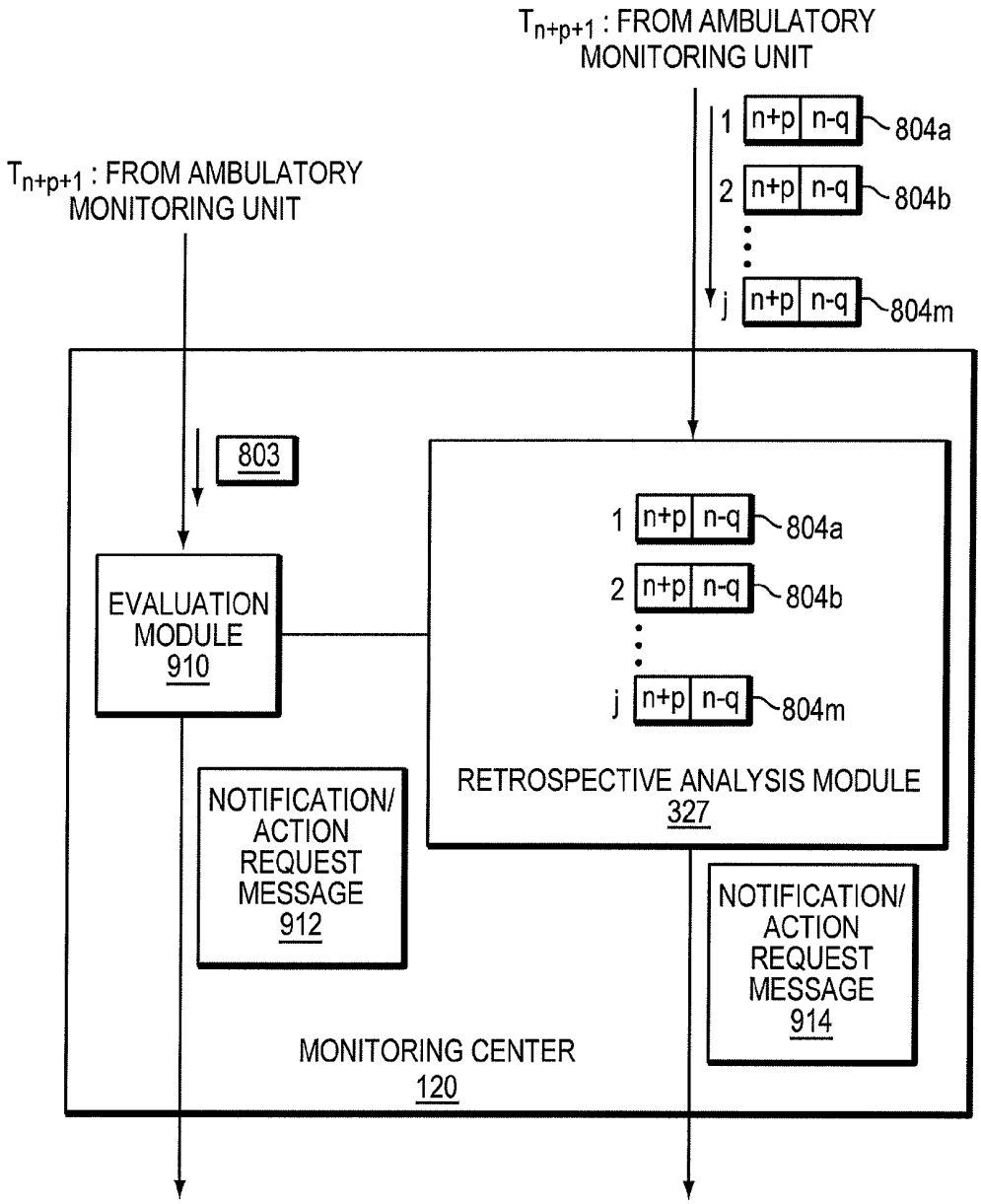

T_{n+p+1} : FROM AMBULATORY MONITORING UNIT
T_{n+p+1} : FROM AMBULATORY MONITORING UNIT
1 n+p n-q 804a
2 n+p n-q 804b
j n+p n-q 804m
803
EVALUATION MODULE 910
1 n+p n-q 804a
2 n+p n-q 804b
j n+p n-q 804m
RETROSPECTIVE ANALYSIS MODULE 327
NOTIFICATION/ ACTION REQUEST MESSAGE 912
NOTIFICATION/ ACTION REQUEST MESSAGE 914
MONITORING CENTER 120

FIG. 9

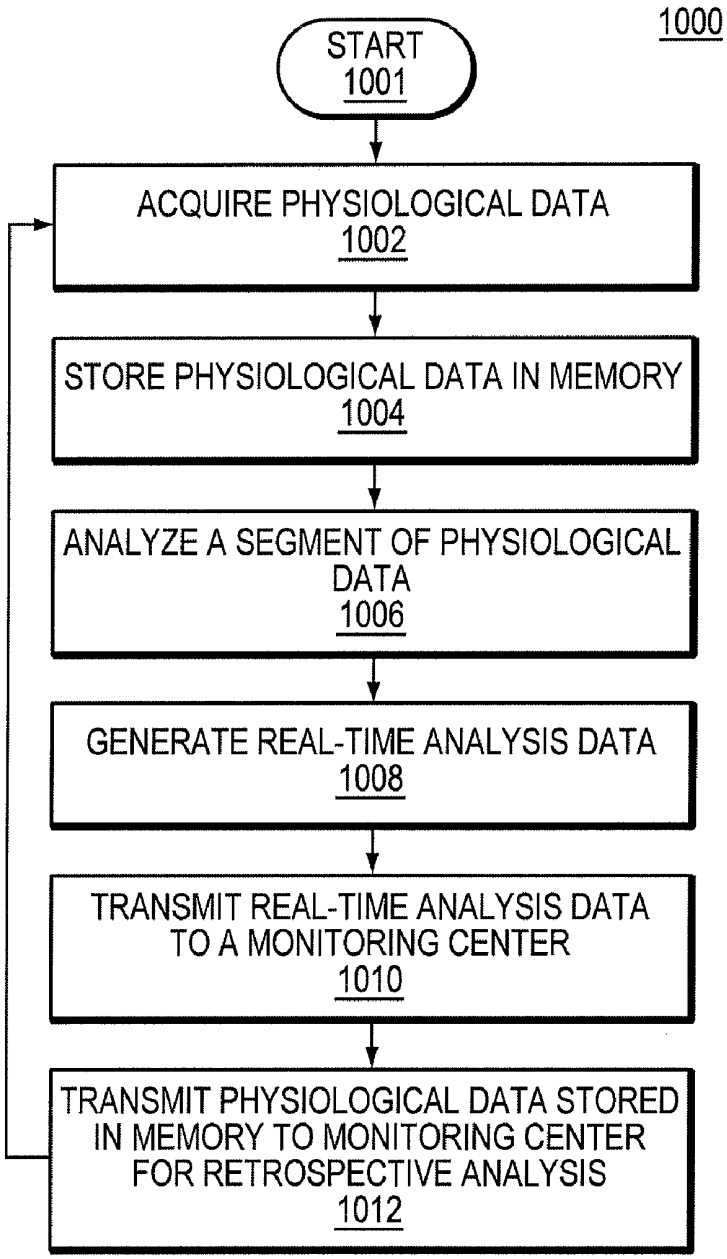

1000
START
1001
ACQUIRE PHYSIOLOGICAL DATA
1002
STORE PHYSIOLOGICAL DATA IN MEMORY
1004
ANALYZE A SEGMENT OF PHYSIOLOGICAL DATA
1006
GENERATE REAL-TIME ANALYSIS DATA
1008
TRANSMIT REAL-TIME ANALYSIS DATA TO A MONITORING CENTER
1010
TRANSMIT PHYSIOLOGICAL DATA STORED IN MEMORY TO MONITORING CENTER FOR RETROSPECTIVE ANALYSIS
1012

FIG. 10

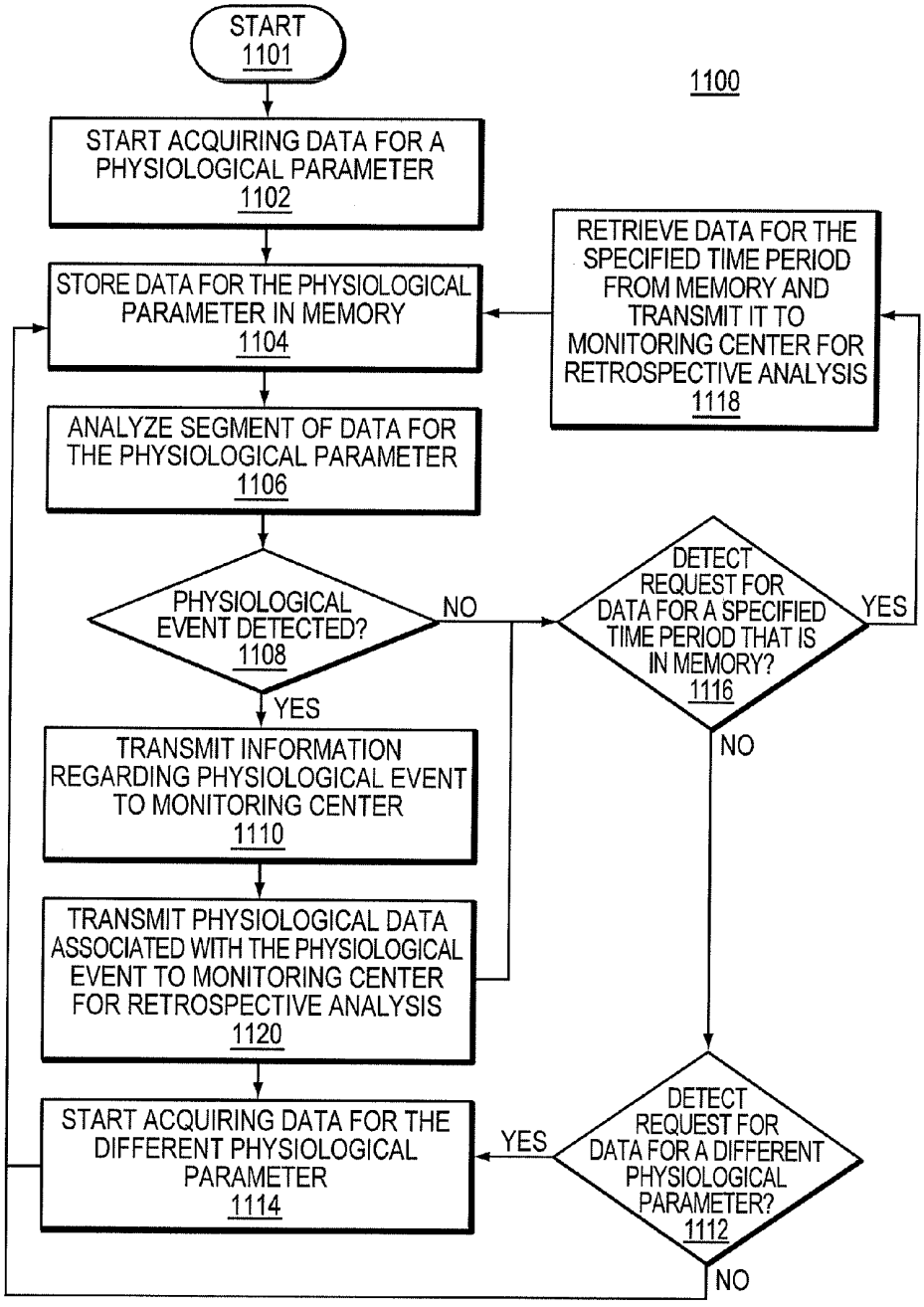

START
1101
1100
START ACQUIRING DATA FOR A PHYSIOLOGICAL PARAMETER
1102
STORE DATA FOR THE PHYSIOLOGICAL PARAMETER IN MEMORY
1104
RETRIEVE DATA FOR THE SPECIFIED TIME PERIOD FROM MEMORY AND TRANSMIT IT TO MONITORING CENTER FOR RETROSPECTIVE ANALYSIS
1118
ANALYZE SEGMENT OF DATA FOR THE PHYSIOLOGICAL PARAMETER
1106
PHYSIOLOGICAL EVENT DETECTED?
1108
NO
YES
DETECT REQUEST FOR DATA FOR A SPECIFIED TIME PERIOD THAT IS IN MEMORY?
1116
YES
NO
TRANSMIT INFORMATION REGARDING PHYSIOLOGICAL EVENT TO MONITORING CENTER
1110
TRANSMIT PHYSIOLOGICAL DATA ASSOCIATED WITH THE PHYSIOLOGICAL EVENT TO MONITORING CENTER FOR RETROSPECTIVE ANALYSIS
1120
START ACQUIRING DATA FOR THE DIFFERENT PHYSIOLOGICAL PARAMETER
1114
YES
DETECT REQUEST FOR DATA FOR A DIFFERENT PHYSIOLOGICAL PARAMETER?
1112
NO

FIG. 11

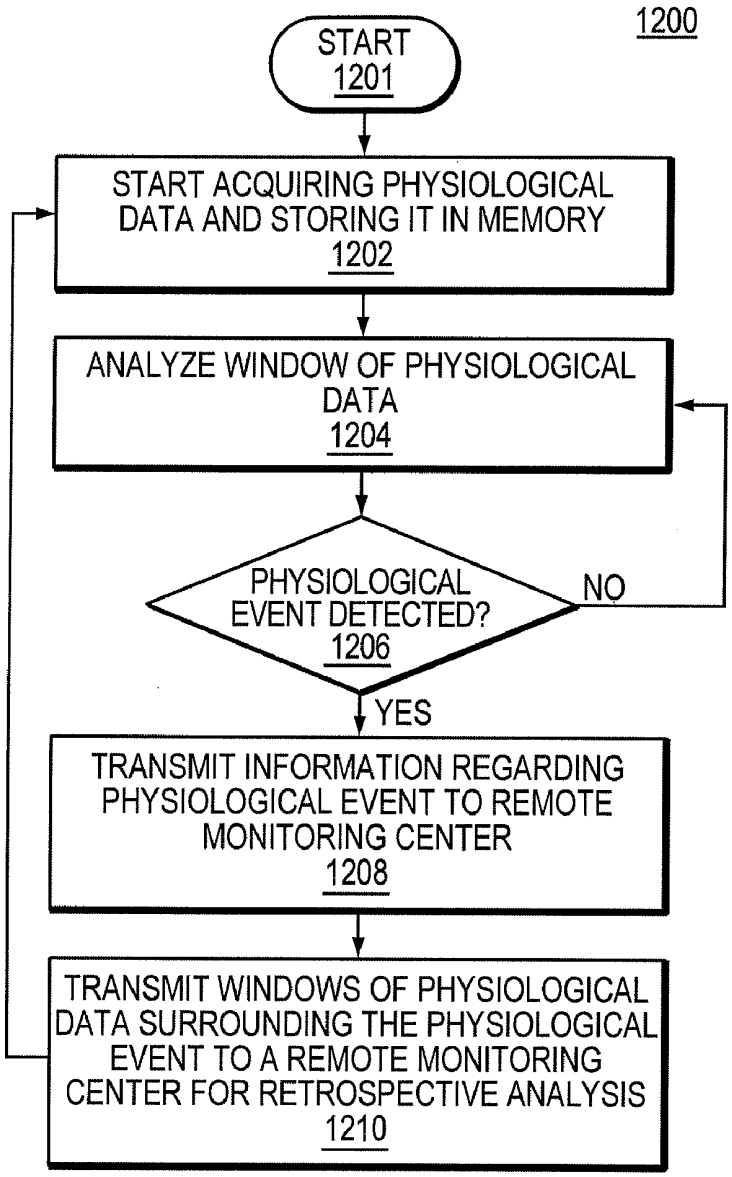

1200
START
1201
START ACQUIRING PHYSIOLOGICAL DATA AND STORING IT IN MEMORY
1202
ANALYZE WINDOW OF PHYSIOLOGICAL DATA
1204
PHYSIOLOGICAL EVENT DETECTED?
1206
NO
YES
TRANSMIT INFORMATION REGARDING PHYSIOLOGICAL EVENT TO REMOTE MONITORING CENTER
1208
TRANSMIT WINDOWS OF PHYSIOLOGICAL DATA SURROUNDING THE PHYSIOLOGICAL EVENT TO A REMOTE MONITORING CENTER FOR RETROSPECTIVE ANALYSIS
1210

FIG. 12

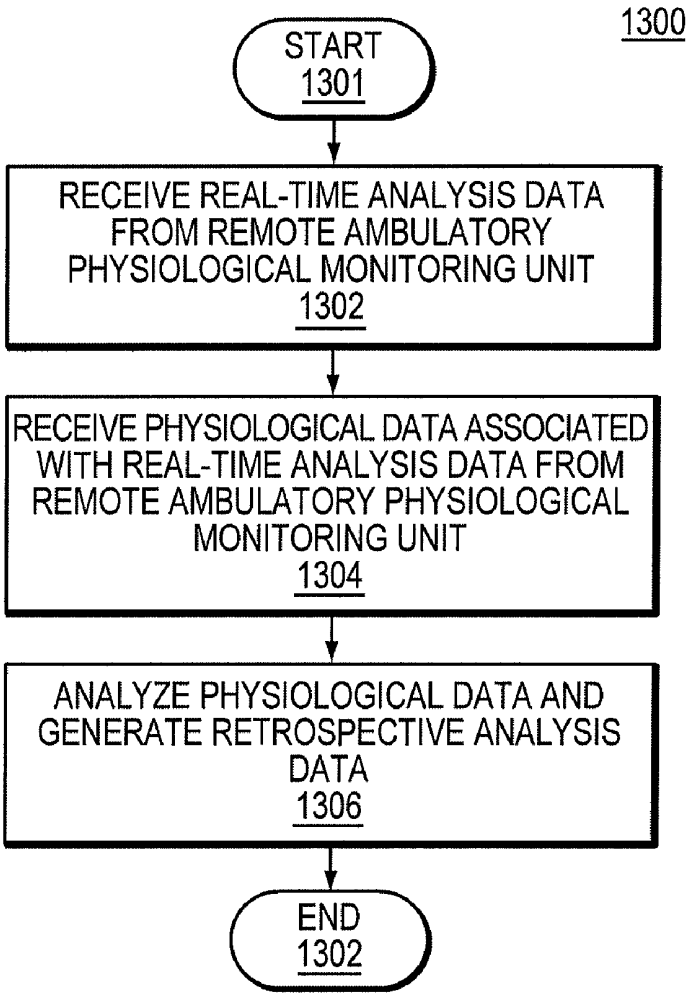

1300
START
1301
RECEIVE REAL-TIME ANALYSIS DATA FROM REMOTE AMBULATORY PHYSIOLOGICAL MONITORING UNIT
1302
RECEIVE PHYSIOLOGICAL DATA ASSOCIATED WITH REAL-TIME ANALYSIS DATA FROM REMOTE AMBULATORY PHYSIOLOGICAL MONITORING UNIT
1304
ANALYZE PHYSIOLOGICAL DATA AND GENERATE RETROSPECTIVE ANALYSIS DATA
1306
END
1302

FIG. 13

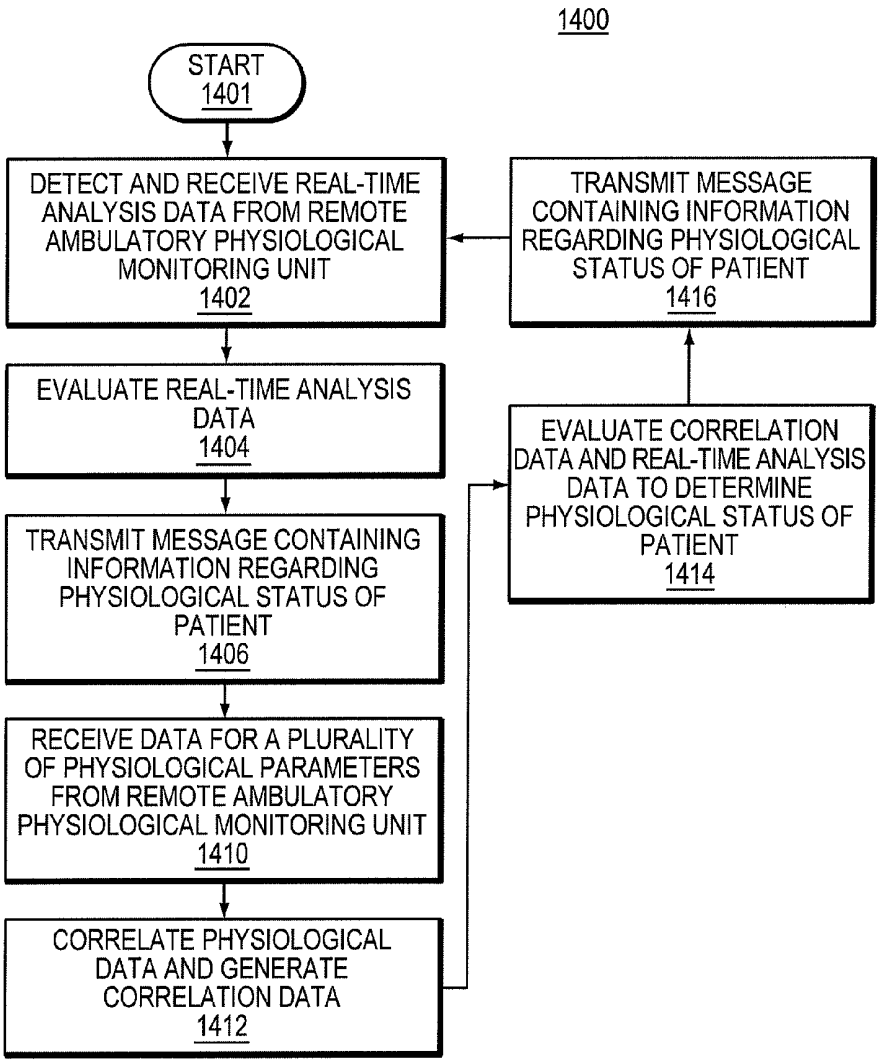

1400
START
1401
DETECT AND RECEIVE REAL-TIME ANALYSIS DATA FROM REMOTE AMBULATORY PHYSIOLOGICAL MONITORING UNIT
1402
EVALUATE REAL-TIME ANALYSIS DATA
1404
TRANSMIT MESSAGE CONTAINING INFORMATION REGARDING PHYSIOLOGICAL STATUS OF PATIENT
1406
RECEIVE DATA FOR A PLURALITY OF PHYSIOLOGICAL PARAMETERS FROM REMOTE AMBULATORY PHYSIOLOGICAL MONITORING UNIT
1410
CORRELATE PHYSIOLOGICAL DATA AND GENERATE CORRELATION DATA
1412
EVALUATE CORRELATION DATA AND REAL-TIME ANALYSIS DATA TO DETERMINE PHYSIOLOGICAL STATUS OF PATIENT
1414
TRANSMIT MESSAGE CONTAINING INFORMATION REGARDING PHYSIOLOGICAL STATUS OF PATIENT
1416

FIG. 14

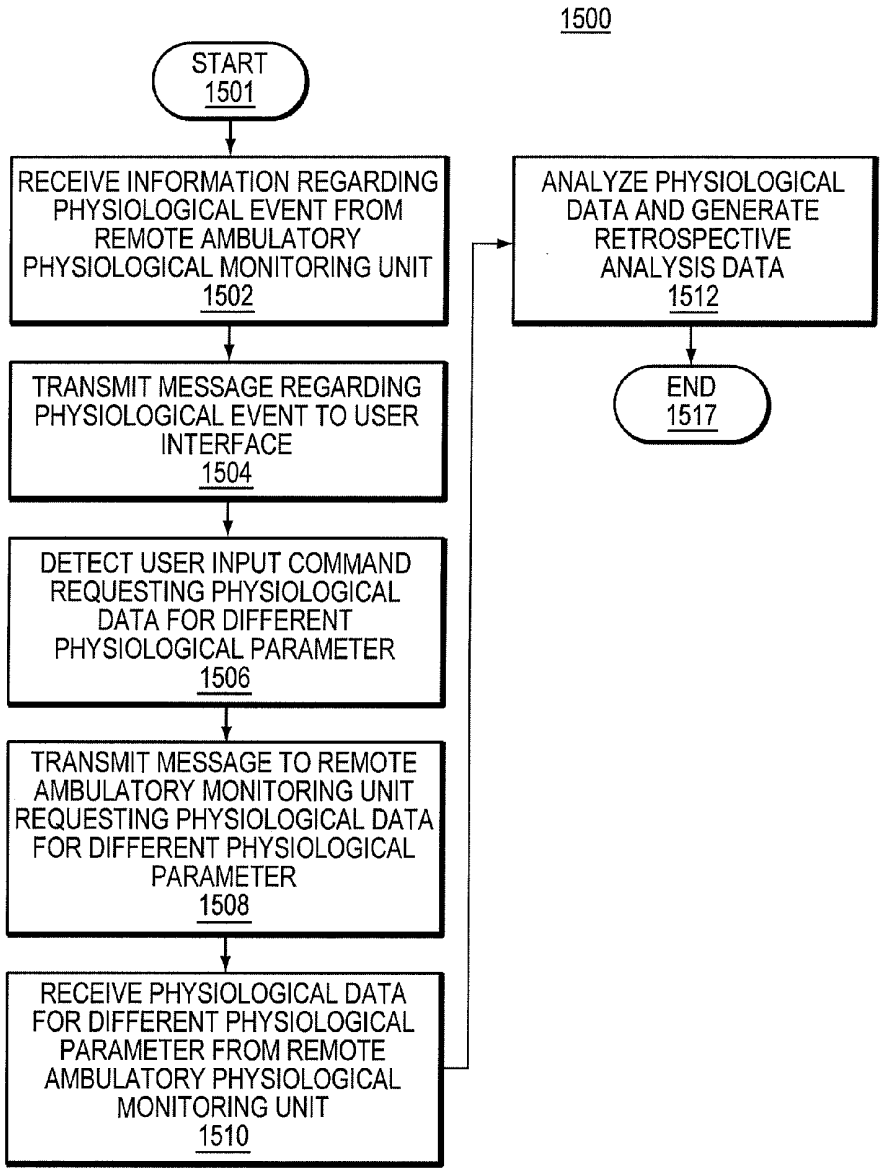

1500
START
1501
RECEIVE INFORMATION REGARDING PHYSIOLOGICAL EVENT FROM REMOTE AMBULATORY PHYSIOLOGICAL MONITORING UNIT
1502
TRANSMIT MESSAGE REGARDING PHYSIOLOGICAL EVENT TO USER INTERFACE
1504
DETECT USER INPUT COMMAND REQUESTING PHYSIOLOGICAL DATA FOR DIFFERENT PHYSIOLOGICAL PARAMETER
1506
TRANSMIT MESSAGE TO REMOTE AMBULATORY MONITORING UNIT REQUESTING PHYSIOLOGICAL DATA FOR DIFFERENT PHYSIOLOGICAL PARAMETER
1508
RECEIVE PHYSIOLOGICAL DATA FOR DIFFERENT PHYSIOLOGICAL PARAMETER FROM REMOTE AMBULATORY PHYSIOLOGICAL MONITORING UNIT
1510
ANALYZE PHYSIOLOGICAL DATA AND GENERATE RETROSPECTIVE ANALYSIS DATA
1512
END
1517

FIG. 15

METHODS AND APPARATUS FOR PROCESSING PHYSIOLOGICAL DATA ACQUIRED FROM AN AMBULATORY PHYSIOLOGICAL MONITORING UNIT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of U.S. Provisional Patent Application Ser. No. 61/164,318, entitled "Methods and Apparatus for Processing Physiological Data Acquired from an Ambulatory Physiological Monitoring Unit," and filed on Mar. 27, 2009, the entire contents of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention pertains to methods and apparatus for accurately monitoring and evaluating the health of a person using an ambulatory physiological monitoring unit and a monitoring center, which communicate with each other across a network.

BACKGROUND OF THE INVENTION

[0003] Many ambulatory health monitors have been developed by medical technology companies and used by medical professionals to monitor and diagnose the health of their patients. Many of these ambulatory health monitors are used to record electrocardiography (ECG) data. A patient wears an ambulatory ECG monitor for long periods of time ranging from many hours to many days. After this long period of time, the monitor is returned to the medical professional for detailed analysis of the ECG data, such as a Holter analysis of the ECG data. The medical professional uploads the ECG data to a computer, which executes software for performing a detailed analysis of the ECG data and displays the results on a screen that can be reviewed by a medical professional. Although the results of the Holter analysis are detailed and accurate, by the time the medical professional diagnoses the patient, the patient may have already suffered from a severe heart-related injury.

[0004] Advances in wireless, networking, and electronics technologies have allowed medical technology companies to develop and deploy wireless ambulatory physiological monitoring units so that information regarding a physiologic parameter can be transmitted to a remote monitoring center. Some wireless ambulatory physiological monitoring units acquire ECG data and transmit a small portion or a representation of this data to a remote monitoring center via a cellular network. This information may be current and helpful, but it may be insufficient to arrive at an accurate and conclusive diagnosis of the patient's physiological condition.

SUMMARY OF THE INVENTION

[0005] More timely and accurate information regarding the physiological condition of a patient can be obtained by combining real-time analysis of physiological data in an ambulatory physiological monitoring unit with the detailed retrospective analysis of the physiological data at a remote monitoring center. The invention in one aspect features a method for monitoring the patient, which includes the steps of acquiring physiological data, analyzing segments of physiological data and generating real-time analysis data for each segment, transmitting real-time analysis data to a remote monitoring center, and transmitting physiological data that is associated with the real-time analysis data to the remote monitoring center.

[0006] Analyzing segments of physiological data includes monitoring for a physiological condition or event. If the physiological condition or event is detected, real-time analysis data is generated to include information regarding the physiological condition or event. Detecting a physiological condition or event can include determining whether the physiological data or processed physiological data reaches a predetermined level.

[0007] In some embodiments, the physiological data includes data for any number of physiologic parameters of any body system, such as electrocardiography or pulse-oximetry data. The real-time analysis data can be transmitted to the remote monitoring center at predetermined intervals, or in response to input from a human user, an algorithm, or both. The physiological data can be transmitted to the remote monitoring center by storing the physiological data in a memory module of an ambulatory physiological monitoring unit and by uploading the physiological data from the memory module to the remote monitoring center. In some embodiments, the data acquisition module is in wireless communications with the real-time analysis module and the memory module.

[0008] In some embodiments, the method may further include detecting a message requesting physiological data or real-time analysis data for at least one physiologic parameter, and executing the data acquisition module and real-time analysis module to acquire and to analyze physiological data for at least one physiologic parameter. A user interface associated with the ambulatory physiological monitoring unit can generate and transmit the message.

[0009] Another aspect of the invention features a method for monitoring the patient, which includes the steps of receiving real-time analysis data, which is based on an analysis of segments of physiological data, from a remote ambulatory physiological monitoring unit, receiving physiological data associated with the real-time analysis data from the remote ambulatory physiological monitoring unit, and invoking an analysis module to generate detailed retrospective analysis based on the physiological data.

[0010] In some embodiments, the real-time analysis data is information regarding a physiological event or condition detected by the remote ambulatory physiological monitoring unit. The physiological data can include data for a plurality of physiologic parameters associated with the same and/or different body systems. In some embodiments, the retrospective analysis module correlates physiological data for the plurality of physiologic parameters.

[0011] The real-time analysis data can be received via a wireless communications link and the physiological data can be uploaded from a memory module on the remote ambulatory physiological monitoring unit to the monitoring center via a wired communications link.

[0012] In some embodiments, an evaluation module evaluates the real-time analysis data or retrospective analysis data to determine the physiological status of the patient. The evaluation module can include a user interface module for allowing a user (e.g., a medical professional) to interact with the real-time analysis data and retrospective analysis data. For example, if the user interface module detects a user input command requesting physiological data or real-time analysis data, a message requesting physiological data or real-time analysis data can be transmitted to the remote ambulatory

monitoring unit. The evaluation module can also automatically determine whether the physiological data and real-time analysis data is sufficient to generate conclusive diagnostic information.

[0013] The messages transmitted to the ambulatory physiological monitoring unit can include a request for additional physiological data or a request for physiological data for a different physiologic parameter. These messages can also include information regarding the physiological status of the patient.

[0014] Another aspect of the invention features an ambulatory physiological monitoring unit. In some embodiments that ambulatory physiological monitoring unit includes a physiological data acquisition module for acquiring physiological data; a real-time analysis module, which analyzes segments of the physiological data and generates real-time analysis data; a storage module for storing the physiological data; and a transceiver for transmitting the real-time analysis data to a remote monitoring center via a communications network at predetermined intervals or in response to at least one event or physiological condition detected by the real-time analysis module. The transceiver can also transmit physiological data associated with the real-time analysis data to the remote monitoring center for retrospective analysis of the physiological data.

[0015] In some embodiments, the ambulatory physiological monitoring unit can include a user interface module, which accepts input from a user regarding at least one event or physiological condition and generates a message containing information regarding the event or physiological condition. The transceiver can then transmit the message to the remote monitoring center.

[0016] Another aspect of the invention features a system for monitoring a patient. The system can include an ambulatory physiological monitoring unit and a remote monitoring center, which is in communication with the ambulatory physiological monitoring unit via a network. The ambulatory physiological monitoring unit can include a physiological data acquisition module for acquiring physiological data; a real-time analysis module for analyzing segments of the physiological data and for generating real-time analysis data for each segment of physiological data; a storage module for storing the physiological data; and a transceiver for transmitting the real-time analysis data and physiological data associated with the real-time analysis data via a communications network. The remote monitoring center can further include a transceiver for receiving the real-time analysis data and the physiological data from the ambulatory physiological monitoring unit and for transmitting messages requesting physiological data to the ambulatory physiological monitoring unit via the communications network; a retrospective analysis module for performing a retrospective analysis based on the physiological data and for generating retrospective analysis data; and an evaluation module for evaluating the physiological condition of the patient based on the real-time analysis data or the retrospective analysis data.

[0017] The foregoing and other objects, aspects, features, and advantages of the invention will become more apparent from the following description and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The foregoing and other objects, features, and advantages of the invention, as well as the invention itself, will be more fully understood from the following illustrative description, when read together with the accompanying drawings which are not necessarily to scale.

[0019] FIG. **1** is a block diagram of a physiological monitoring system according to embodiments of the present invention.

[0020] FIG. **2** is a dataflow diagram of a physiological monitoring system according to an embodiment of the present invention.

[0021] FIG. **3**A is a block diagram of an ambulatory physiological monitoring unit according to embodiments of the present invention.

[0022] FIG. **3**B is a block diagram of a remote monitoring center according to embodiments of the present invention.

[0023] FIG. **4** is a block diagram of an ambulatory physiological monitoring unit, that comprises a sensor module and a monitor according to embodiments of the present invention.

[0024] FIGS. **5**A and **5**B are functional block diagrams of a physiological monitoring system that includes an ambulatory physiological monitoring unit having a sensor module and a monitor, a web service computer, and a clinical system computer in accordance with embodiments of the present invention.

[0025] FIG. **6** is a diagram of an ambulatory physiological monitoring system that includes an ambulatory health monitoring unit in accordance with embodiments of the present invention.

[0026] FIG. **7** is a block diagram of an ambulatory physiological monitoring unit in accordance with embodiments of the present invention.

[0027] FIG. **8** is a data flow diagram showing the acquisition, storage, and real-time analysis of physiological data in accordance with an embodiment of the present invention.

[0028] FIG. **9** is a data flow diagram showing the retrospective analysis of the physiological data that has been received from an ambulatory physiological monitoring unit in accordance with an embodiment of the present invention.

[0029] FIGS. **10-12** are flowcharts of processes which can be executed on an ambulatory physiological monitoring unit in accordance with embodiments of the present invention.

[0030] FIGS. **13-15** are flowcharts of processes which can be executed on a remote monitoring center in accordance with embodiments of the present invention.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0031] FIG. **1** shows a diagram of a physiological monitoring system **100** according to embodiments of the present invention. An ambulatory physiological monitoring unit **110** (e.g., an ambulatory cardiac monitor) connects to a patient **105** through sensors **102** (e.g., electrodes), which measure a physiologic parameter of a body system. The ambulatory physiological monitoring unit **110** may communicate with a remote monitoring center **120** via a cellular network system **130** and a communications network **140**, such as a public switched telephone network (PSTN), ISBN, LAN, WAN, Internet, or intranet. The remote monitoring center **120** may be located at an independent call center, hospital, or doctor's office, where a medical professional(s) may be notified of an abnormal physiological condition (e.g., an abnormal arrhythmia) that is detected by the ambulatory physiological monitoring unit **110**. The remote monitoring center **120** may itself communicate via a communications network with other electronic devices such as a personal digital assistant or Black-

Berry® device to provide information on the physiological status of the patient **105** to interested individuals, such as a medical professional(s).

[0032] FIG. **2** is a diagram that illustrates the different electronic devices and computers that interact in the ambulatory physiological monitoring system **100** of FIG. **1**, according to embodiments of the present invention. As illustrated in FIG. **2**, a ambulatory physiological monitoring unit **210** includes a physiological sensor module **212** (e.g., a cardiac sensor), which may also be referred to as a sensor module or a physiological data acquisition module, and an ambulatory physiological monitor **214** (e.g., an ambulatory cardiac monitor). The physiological sensor module **212** transmits physiological data **213** (e.g., electrocardiography data) to the ambulatory physiological monitor **214**. The ambulatory physiological monitor **214** processes the physiological data and transmits a message containing a portion of the physiological data **213** and/or information regarding the processed physiological data to a database or other Web service **222**, which stores and maintains the messages.

[0033] A computer located at a call center **224** may execute a web application, which allows an attendant, technician, or clinician to access or receive notifications of the messages. Like the computer at the call center **224**, a computer at a physician's office **254** may also access or receive notifications of the messages through a Web reporting application **252**. The computer at the physician's office **254** can also communicate with the ambulatory physiological monitoring unit **210**. For example, a physician using the computer **254** can send a message to the ambulatory physiological monitor **210** giving instructions or information to the user of the ambulatory physiological monitoring unit **210**. A physician using the computer **254** can also remotely program or change parameters in the sensor module **212** or the ambulatory physiological monitor **214**.

[0034] FIG. **3**A illustrates an ambulatory physiological monitoring unit **110** according to an embodiment of the present invention. The ambulatory physiological monitoring unit **110** may include a sensor module **311**, radio circuitry **312**, a processor **315**, and memory **316**. The sensor module **311** may include a series of ports to which a series of sensors **102** may connect. The sensor module **311** acquires physiological data from the series of sensors **102**, converts the data into digital form, and provides a digital physiological data stream to the processor **315**. The processor **315** executes a real-time analysis module **313**, which analyzes segments of the digital physiological data stream in real time or in near real-time. The processor **315** also stores the digital physiological data in the memory **316**. The radio circuitry **312** can transmit real-time analysis data (e.g., information on the results of the real-time analysis of the digital physiological data stream, including whether a physiological event has been detected) and a portion of the digital physiological data stream associated with the real-time analysis data.

[0035] A user interface **308**, which may include an LCD screen and/or a keyboard, allows a user to interact with the ambulatory physiological monitoring unit **110**. For example, the patient may start the real-time analysis when the patient experiences a particular symptom associated with an abnormal physiological condition (e.g., by selecting on option on a touch screen). The patient may also send a message to the remote monitoring system indicating that the patient has sensed a physiological event or that the patient has experienced a symptom associated with an abnormal physiological condition. Although the block depicting the user interface is shown as separate from the block depicting the ambulatory physiological monitoring unit, the user interface may be physically integrated into the ambulatory physiological monitoring unit.

[0036] The ambulatory physiological monitoring unit **110** can monitor a variety of physiologic parameters including blood pH, glucose, dissolved oxygen, carbon dioxide, breathing activity, heartbeat, ECG, and other parameters known in the art. The ambulatory physiological monitoring unit **110** can also monitor other ambulatory medical devices including an insulin pump or a pacemaker.

[0037] FIG. **3**B is a block diagram of a remote monitoring center **120** according to embodiments of the present invention, which is configured to communicate with the ambulatory physiological monitoring unit **110** via a network. As shown in FIG. **3**B, the remote monitoring center **120** can connect to a network through a wired connection **330**. The remote monitoring center **120** can also connect to the network through a wireless connection (not shown). The remote monitoring center **120** includes a processor **325**, a retrospective analysis module **327**, and an evaluation module **329**. The remote monitoring center **120** includes a receiver **323** that receives real-time analysis data through the wired connection **330**. The remote monitoring center **120** can also be designed to receive raw physiological data through the wired connection **300** via a communications network. The ambulatory physiological monitoring unit **110** or removable memory of the ambulatory physiological monitoring unit **110** can also be mailed to the location where the remote monitoring center **120** is located so that raw physiological data can be uploaded to the remote monitoring center **120** through the wired connection **330**.

[0038] After the remote monitoring center **120** receives the raw physiological data, the processor **325** executes a retrospective analysis module **327**, which retrospectively analyzes the raw physiological data in detail. The retrospective analysis module **327** can analyze a portion of physiological data associated with a physiological event or all the physiological data that has been acquired during a monitoring session lasting a few minutes to several days. The retrospective analysis module **327** provides retrospective analysis data (e.g., information on the results of the retrospective analysis) to the evaluation module **329**.

[0039] The evaluation module **329** evaluates the retrospective analysis data to determine the condition or status (physiological or non-physiological) of a patient. The evaluation module **329** can evaluate the retrospective analysis data against a set of predetermined rules to determine the physiological status of a patient. The evaluation module **329** can also transmit the retrospective analysis data or a summary or representation of the retrospective analysis data to a display of a user interface **320** so that a medical professional can review the retrospective analysis data, determine the status of the patient, and take appropriate action. The user interface **320** can be designed to accept commands or input from the medical professional. For example, the user interface **320** can include a menu of possible patient status levels that the medical professional can select based on her review of the retrospective analysis data. The user interface **320** can also include a menu of possible commands that the medical professional can select, such as a command to request additional physiological data or data regarding a different physiologic parameter from the ambulatory physiological monitoring unit **110**.

[0040] FIG. **4** is a block diagram of an embodiment in which a ambulatory physiological monitoring unit **310** is divided into two modules: a sensor module **311** and a monitor **420**. The sensor module **311** includes electronic components that interface with and process the analog data acquired by the sensors **102**. In particular, the sensor module **311** includes sensor interface circuitry **410**, a multiplexer **411**, and a radio frequency (RF) transmitter **412** (e.g., a Bluetooth® transmitter). The sensor interface circuitry **410** acquires analog physiological data from the sensors **102** and converts it into digital form. The multiplexer **411** takes the digital physiological data for each of the sensors **102** and combines it into a stream of digital physiological data. The RF transmitter **412** modulates a carrier signal with the stream of digital physiological data and transmits it to an associated RF receiver **414** (e.g., a Bluetooth® receiver) in the monitor **420**.

[0041] The monitor **420** includes circuitry for analyzing, in real-time or near real-time, the digital physiological data transmitted from the sensor module **311**. The monitor **420** can be any portable electronic device that is capable of wireless network communications, including a smartphone (e.g., a BlackBerry® device or an iPhone® device). The monitor **420** includes the RF receiver **414**, a demultiplexer **413**, radio circuitry **312**, a processor **315** that executes the real-time analysis module **313**, memory **316**, and a user interface **314**. The RF receiver **414** receives and demodulates the physiological data signal to obtain the digital physiological data and the demultiplexer **413** provides digital physiological data for each of the sensors **102** to the processor **315**. The processor **315** executes the real-time analysis module **313**, which, in one embodiment, analyzes a sliding window of digital data in a digital physiological data stream. The real-time analysis module **313** can include any known algorithms for interpreting digital physiological data, such as digital ECG data. The real-time analysis module **313** can generate real-time analysis data and transmit it to a display of the user interface **314**. The processor **315** can also store the digital physiological data in memory **316**.

[0042] The radio circuitry **312** can transmit real-time analysis data (e.g., information on the results of the real-time analysis of the digital physiological data stream, including whether a physiological event has been detected) and a portion of the digital physiological data stream associated with the real-time analysis data.

[0043] FIG. **5**A is a functional block diagram of the ambulatory physiological monitoring unit **210**, including the sensor module **212** and the monitor **214**, and the web service computer **222** of FIG. **2**. The sensor module **212** includes an analog front end **511** for acquiring analog ECG signals **107**, a signal preprocessor **512** for converting the ECG signals into digital form, temporal storage **513**, a signal transmission module **412**, and a remote control module **514**. The monitor **214** includes a signal reception module **414**, a real-time analysis module **313**, an events transmission module **515**, a device control module **516**, a removable storage module **316**, and a mobile phone application **517**.

[0044] The temporal storage module **513** of the sensor module **212** temporarily stores digital ECG data from the signal preprocessor **512** for subsequent transmission to the monitor **214**. The signal transmission module **412** of the sensor module **212** transmits digital physiological data to the signal reception module **414** of the monitor **214** via an RF wireless network connection **215**, (e.g., a Bluetooth® network connection). In this embodiment, the real-time analysis module **313** determines whether an event has occurred based on an analysis of the digital physiological data. If the real-time analysis module **313** determines that a predetermined event has occurred, the events transmission module **515** will transmit information regarding the event to the mobile phone application **517**. The mobile phone application **517** then transmits the information regarding the event to a Web service **222**, which, in turn, stores and distributes the information to appropriate computers or portable electronic devices connected to the Web service **222** via a network connection.

[0045] The mobile phone application **517** can also be configured to receive instructions or commands from the monitoring center **120** using generic communication protocols such as the hyper text transfer protocol (http) implemented on the Web service **222**. The device control module **516** of the monitor **214** can interpret those instructions or commands and control the sensor module **212** accordingly. The device control module **516** can control the sensor module **212** by communicating with the remote control module **514** via the RF wireless network **215**. For example, the mobile phone application **517** may receive a command from the monitoring center **120** via the Web service **222** to retransmit ECG data for a specified time period, to acquire and transmit data for a different physiologic parameter, or to reprogram or to change the parameters of the sensor module **212** or the monitor **214**. In the case where the monitoring center **120** requests that the monitor **214** retransmit ECG data for a specified time period, the device control module **516** can initiate a process to resend the ECG data stored in the removable storage module **316**. In the case where the monitoring center requests that the sensor module **212** acquire and transmit data for different physiologic parameters (e.g., pulse-oximetry data), the device control module **516** automatically configures the sensor module **212** to acquire data for the different physiologic parameters through the remote control **514**. The device control module **516** can also request through the remote control module **514** that the signal transmission module **412** retransmit physiological data stored in temporal storage **513** to the monitor **214**.

[0046] As shown in FIG. **5**A, the monitor **214** of the ambulatory physiological monitoring unit **210** communicates with the web service computer **222** via a wireless communications link **525**. FIG. **5**B is a functional block diagram of the web service computer **222** and a clinical system computer **575** that is configured to communicate with the web service computer **222** over a communications network **574**, **576**. In some embodiments, the web service computer **222** serves as a communications interface between the monitor **214** and the clinical system computer **575**. The web service computer **222** executes an inbound communications module **560** when it detects a transmission, such as a packet or series of packets, from the monitor **214**. The inbound communications module **560** accepts the transmission **561** and converts the data contained in the transmission into a device-independent format **563**. After the data has been converted, the patient associated with the monitoring unit **210** or other portable device is identified **565**. Then, the transmission type is identified **567**. The inbound communications module **560** then populates the clinical system computer **569** with the data contained in the received transmission. If the data contained in the received transmission is Holter data **542** or any other type of physiological data, this data is stored in a database **544** residing in the clinical system computer **575**.

[0047] After Holter data is received and stored, the Holter analysis module **550** determines whether Holter analysis is required **552**. In some instances, Holter analysis would not be required because the real-time analysis data is sufficient to conclusively determine the status of the patient. If Holter analysis is required, a Holter file is created for the period during which Holter data was collected **554**. Next, a Holter analysis is performed on the Holter file **555**. The results of the Holter analysis then undergo a quality assurance subroutine **556**, which can include displaying the results of the Holter analysis on a computer screen so that a medical professional can review it. The quality assurance subroutine **556** can also include executing a test program, which performs an analysis of the results of the Holter analysis.

[0048] If the Holter analysis quality assurance routine determines that the results of the Holter analysis are accurate, a Holter report is generated **557** and published **558**. The Holter report can include a summary of the Holter analysis results. The Holter report can also indicate the physiological status of the patient and suggest possible courses of action.

[0049] When the clinical system computer **575** receives event data, the event analysis module **530** performs an initial review of the event data **532** and executes a quality assurance subroutine **534** on the event data. If the event analysis module **530** determines that more data is needed **536** or that data for a different or additional physiologic parameter, an outbound communications module **520** identifies the device associated with the event data **522** (e.g., an ambulatory health monitor), converts a message requesting physiological data into a format that can be read by the identified device **524**, and sends the message to the device **526**. If no further data is needed, an event report is published **538**.

[0050] FIG. **6** is a diagram of an ambulatory health monitoring unit **610** that is configured to communicate **600** via a wireless network (e.g., a Bluetooth® network) with other medical components such as a pulse-oximetry measurement device **602** and a blood pressure and glucose meter **604**. In this embodiment, physiological data from the pulse-oximetry measurement device **602** and a blood pressure and glucose meter **604** can be incorporated into real-time analysis of ECG data by the ambulatory physiological monitoring unit **610**, which can act as a medical components communication hub.

[0051] FIG. **7** is a block diagram of another embodiment of an ambulatory physiological monitoring unit **810**. In this embodiment, many of the components of the sensor module **212** shown in FIG. **5** are incorporated into the ambulatory physiological monitoring unit **810** in the form of an ECG module **705**. The ECG module **705**, like the sensor module **212**, includes an analog front end **511** that receives signals from ECG leads **510**, a signal preprocessor **512**, and real-time analysis module **313**, an events transmission module **515**, and a device control module **516**. In some embodiments, the real-time analysis module **313** is a software module that performs an analysis of the physiological data and determines whether a physiological event has occurred. The ambulatory physiological monitoring unit **810** also includes various modules, which interact with the ECG module **705**. These various modules can include a user interface module **750**, a supplementary sensing module **710**, a cellular module **517** for connecting with a communications network **140**, a localization and orientation module **720**, and a power module **730**.

[0052] The user interface module **750** includes an LCD screen **752**, a keyboard **754**, and a voice reply module **756**. The voice reply module can include an audio speaker, circuitry, and software, which generate voice prompts to the user. The user interface module **750** can also include a visual alert, such as a blinking LED, which can prompt the user of a problem or other event. The LCD screen **752** can allow the user to view information regarding the user's physiological condition and environment. The keyboard **754** allows the user to control some of the components and operation of the ambulatory physiological monitoring unit **810**.

[0053] The ambulatory physiological monitoring unit **810** also includes a supplementary sensing module **710**, which can sense non-physiologic parameters. For example, in this embodiment, the supplementary sensing module **710** includes a falling detector **712**, which detects whether the patient has fallen down from a standing position, a pedometer **714**, and a temperature & humidity sensor **716**. The real-time analysis module can use data from these sensors to determine, for example, the probability that a physiological event has occurred.

[0054] The ambulatory physiological monitoring unit **810** also includes a localization and orientation module **720**. The localization and orientation module can include an RFID tag **722** for identifying the ambulatory physiological monitoring unit or a person associated with it. The localization and orientation module **720** can also include a GPS **724** and a compass **726** for locating the patient. If a GPS signal is available, the localization and orientation module **720** can determine the location of the user using the GPS **724**. If a GPS signal is unavailable (e.g., when the user enters a building), the localization and orientation module **720** can determine the user's location based on the last known location of the user stored in the GPS **724**, the orientation of the user from the compass **726**, and the position information from the pedometer **714**.

[0055] The ambulatory physiological monitoring unit **810** also includes a USB port **742** and an RF transceiver **744** (e.g., a Bluetooth® transceiver) for wired and wireless communications with nearby electronic devices. The power module **730** includes a rechargeable battery **734** and a secondary backup battery **732** in case power supplied by the rechargeable battery **734** is disrupted.

[0056] In some embodiments, when the real-time analysis module **313** detects an event from a segment of physiologic data, the ambulatory physiological monitoring unit **810** transmits information about the event and the physiological data that surrounds the event to the remote monitoring center for detailed retrospective analysis. FIG. **8** is a flow diagram illustrating this process. Sensor module **311** acquires analog physiological signals from multiple sensors **102** and provides a stream of digital physiological data **801***a-m* corresponding to each sensor **102** to the processor **315**, which stores the digital physiological data **802***a-m* in memory **316** and executes a real-time analysis module **313**, which analyzes the stream of digital physiological data **802***a-m*. The digital physiological data stored in memory **316** can be organized by sensor. For example, all physiological data corresponding to sensor **1** (**802***a*) are aggregated in one location in memory **316** and all physiological data corresponding to sensor j (**802***m*) are aggregated in a different location in memory **316**.

[0057] The digital data stream **802** is also analyzed by the real-time analysis module **313**. In one embodiment, the real-time analysis module **313** analyzes segments of the physiological data stream **801**, **802** using a sliding window technique. According to the sliding window technique, the real-time analysis module **313** analyzes overlapping or adjacent segments or windows of the physiological data stream **802**.

For example, at time n−1, the real-time analysis module analyzes physiological data that has been acquired at both times n−1 and n−2 (i.e., the data in the window indicated by the bracket labeled n−1). At time n, the real-time analysis module analyzes physiological data that has been acquired at the current time n and the previous time n−1 (i.e., the data in the window indicated by the bracket labeled n).

[0058] After the real-time analysis module **313** completes its analysis, the processor generates and transmits a message **803**. For example, at time n+p, the processor generates and transmits a message **803**, which can contain real-time analysis data (e.g., information regarding the occurrence of an event) generated based on an analysis of physiological data acquired from at least one sensor at times n and n−1 (i.e., the data in the window at time n). At time n+p+1, the message **803** is transmitted to the monitoring center **120**. At the same time, physiological data acquired at times n+p and n−q (**804***a-m*) (i.e., the data segments coming before and after the segment of data acquired at time n), which is stored in memory **316**, is transmitted to the monitoring center **120**. The monitoring center **120** can analyze the physiological data acquired at times n+p and n−q to better understand an event detected at time n. The ambulatory physiological monitoring unit **110** can also transmit a large segment of raw physiological data that includes the data acquired at time n. For example, the ambulatory physiological monitoring unit **110** can transmit the raw physiological data acquired starting at time n−q and ending at time n+p.

[0059] The real-time analysis module **313** can perform any analysis on the physiological data that is known in the art. For example, the real-time analysis module **313** may be configured to analyze electrocardiography data. Also, the real-time analysis module **313** may be configured to analyze all types of physiological data, including electrocardiography data, pulse-oximetry data, blood pressure data, and temperature data.

[0060] At any particular time, physiological data associated with the real-time analysis data can be transmitted to the monitoring center. For example, the monitoring center **120** may request physiological data acquired by the sensor module **311** at times n and n−1. In other words, the monitoring center **120** may request the physiological data associated with the real-time analysis performed at time n. In response to this request, the physiological data acquired by the sensor module **311** at times n and n−1 is transmitted to the monitoring center **120**.

[0061] As illustrated in FIG. **9**, the message **803** generated by the real-time analysis module **313** of the ambulatory physiological monitoring unit **110**, which can contain information regarding an event that has been detected, is evaluated by an evaluation module **910** of the monitoring center **120**. The evaluation module **910** can format and display the event information so that it can be reviewed and evaluated by a medical professional. If the medical professional needs more detailed and specific information to diagnose the patient and determine an appropriate course of treatment, the medical professional can quickly request and receive detailed retrospective analysis data. The medical professional does not have to wait to receive the physiological data at the end of a monitoring session.

[0062] The evaluation module **910** can also automatically evaluate the information contained in the message **803** and determine a course of action based on the information contained in the message **803**. For example, the evaluation module **910** can include a series of rules, which automatically determines a diagnosis and takes appropriate action. If the information in the message **803** indicates a life-threatening event, the evaluation module can automatically generate and transmit a message (e.g., the notification/action request message **912**) to paramedics or a care-giver requesting that they immediately go to the patient's location. If the information in the message **803** is insufficient to determine an accurate and/or conclusive diagnosis for the patient, the evaluation module can evaluate the more detailed retrospective analysis data to determine a diagnosis.

[0063] The retrospective analysis module **327** in the monitoring center **120** may then analyze the physiological data to determine, among other things, whether the information contained in the real-time analysis data message **803** reconciles with the physiological data. The retrospective analysis module **327** can also correlate physiological data acquired from different sensors **102**.

[0064] In some instances, the physiological data transmitted to the monitoring center **120** may include gaps or other anomalies. For example, the physiological data may include a gap because the user removes the sensors from his body to take a shower or the ambulatory physiological monitoring unit turns off (e.g., because the rechargeable battery fails). If the ambulatory physiological monitoring unit is turned on, the retrospective analysis module **327** can determine whether the sensors are connected to the user's body or to the ambulatory physiological monitoring unit **110** by monitoring for a signal pattern transmitted from the ambulatory physiological monitoring unit **110**, which indicates that the sensors are disconnected. The ambulatory physiological monitoring unit **110** can determine whether the sensors are properly connected by performing an impedance check.

[0065] If the retrospective analysis module **327** finds gaps or anomalies in the physiological data, it can compensate for the gaps or anomalies and re-construct the time line using known techniques in the art. For example, the retrospective analysis module **327** can use other physiological or non-physiological data that corresponds to a time period within the gap. The monitoring center **120** can also request that the ambulatory physiological monitoring unit **110** acquire and analyze additional physiological data from the ambulatory physiological monitoring unit **110** so that the retrospective analysis module **327** has sufficient physiological data to perform an accurate and complete retrospective analysis.

[0066] The retrospective analysis module **327** can generate a notification/action request message **914** based on the results of the retrospective analysis module and transmit it to an appropriate device or network-connected computer associated with a medical professional or another appropriate person. For example, if the retrospective analysis module **327** determines that its analysis does not reconcile with the information contained in real-time analysis data message **803**, it can generate a message **914** notifying a medical professional that the retrospective analysis data does not reconcile with the information contained in real-time analysis data message **803**.

[0067] FIG. **10** is a flow diagram illustrating a process **1000** that can be executed in the ambulatory physiological monitoring unit **110**. After starting the process **1001**, physiological data is acquired from sensors attached to a patient's body **1002**. The physiological data is then stored in memory **1004** and analyzed **1006**. Based on an analysis of the physiological data, real-time analysis data is generated **1008** and transmit-

ted to a monitoring center **1010**. After real-time analysis data is transmitted to the monitoring center, physiological data associated with the real-time analysis data and stored in memory is transmitted to the monitoring center for detailed retrospective analysis **1012** and the process **1000** returns to step **1002**.

[0068] The ambulatory physiological monitoring unit **110** can acquire different types of physiological data or can retrieve physiological data stored in memory in response to a request from the monitoring center **120**. As illustrated in FIG. **11**, the ambulatory physiological monitoring unit can start **1101***a* process **1100** that continuously acquires data for a physiologic parameter **1102** and stores that data in memory **1104**. In step **1106**, windows or segments of data for the physiologic parameter are analyzed. A module in the ambulatory physiological monitoring unit **110** then determines whether a physiological event has been detected based on the analysis **1108**. If a physiological event has been detected, information regarding the physiological event and physiological data associated with the physiological event are transmitted to the monitoring center **1110**, **1120**.

[0069] If a physiological event has not been detected or after physiological data associated with the physiological event is transmitted to the monitoring center, a module in the ambulatory physiological monitoring unit **110** determines whether a request for data for a specified time period that is stored in memory has been requested by the monitoring center **120** (step **1116**). If such a request is detected, the ambulatory physiological monitoring unit **110** retrieves the data for the specified time period from memory and transmits it to the monitoring center for retrospective analysis **1118**. If a request for data a for a specified time period is not detected, a module in the ambulatory physiological monitoring unit **110** determines whether a request for data for a different physiologic parameter has been received from the monitoring center **120** (step **1112**). If a request for data for a different physiologic parameter is detected, the ambulatory physiological monitoring unit starts acquiring this data **1114** and the process **1100** returns to step **1104**. Otherwise, the process **1100** returns to step **1104**.

[0070] FIG. **12** is a flowchart illustrating process steps that are executed by the processor of the ambulatory physiological monitoring unit according to another embodiment of the invention. After starting **1201**, physiological data (e.g., ECG data) is acquired and stored in memory **1202**. In step **1204**, a window of physiological data is analyzed. If, as a result of the analysis of the physiological data, a physiological event is detected **1206**, information regarding the event and windows of physiological data surrounding the event are transmitted to a remote monitoring center **1208**, **1210**. If a physiological event is not detected, the process **1200** returns to step **1204** and process steps **1204**-**1210** are repeated for another window of physiological data.

[0071] FIG. **13** is a flowchart illustrating the steps performed by the monitoring center **120**. After starting **1301**, real-time analysis data is received from an ambulatory physiological monitoring unit **1302**. At this point, the real-time analysis data can be evaluated to determine the physiological status of the patient and a message notifying a medical professional of the patient's physiological status can be generated and sent to the appropriate portable electronic device or computer. In step **1304**, physiological data associated with the real-time analysis data is received, and, in step **1306**, the physiological data is analyzed to generate retrospective analysis data. In some embodiments, the physiological data associated with the real-time data is received in response to a request for the physiological data from the monitoring center **120**.

[0072] The remote monitoring center can automatically evaluate the real-time analysis data and the retrospective analysis data and notify a medical professional of the physiological status of the patient or provide a medical professional with a summary of the retrospective analysis data. FIG. **14** is a flowchart illustrating such a process. After the process **1400** starts **1401**, real-time analysis data or physiological data is detected and received from an ambulatory physiological monitoring unit **110** (**1402**). In step **1404**, the real-time analysis data is evaluated. Based on the evaluation, a message containing information regarding the physiological status of the patient can be generated and transmitted to an appropriate computer or portable electronic device **1406** (e.g., a medical professional's BlackBerry® device or personal computer). In some embodiments, evaluating the real-time analysis data **1404** and transmitting a message **1406** can include displaying the real-time analysis data (e.g., information regarding the occurrence of an event) on a computer screen.

[0073] Next, data for a plurality of physiologic parameters is then received from the remote ambulatory physiological monitoring unit **1410**. The data for a plurality of physiologic parameters is correlated and correlation data is generated **1412**. In step **1414**, the correlation data and the real-time analysis data are evaluated to determine the physiological status of the patient. A message containing information regarding the physiological status of the patient can then be transmitted to a networked device that is accessible by a medical professional or other relevant care-giver **1416** and the monitoring center can continue to detect and receive real-time analysis data.

[0074] In some instances, a medical professional may determine that the physiological data may be insufficient (e.g., because it contains gaps or invalid data) for an accurate and specific retrospective analysis. The remote monitoring center **120** can allow a medical professional to request real-time analysis data or physiological data from the ambulatory physiological monitoring unit **110**. FIG. **15** is a flowchart illustrating a process that allows a medical professional to request additional physiological data or data for a different physiologic parameter. After the process starts **1501**, information regarding a physiological event is received from a remote ambulatory physiological monitoring unit **1502**. A message regarding that physiological event is transmitted to a user interface **1504** at the remote center **120** so that a medical professional can determine an appropriate course of action. If the medical professional determines that data for a different physiologic parameter is needed, she can input an appropriate command to the user interface requesting data for a different physiologic parameter. In step **1506**, a user input command requesting data for a different physiologic parameter is detected and, in step **1508**, a message requesting data for a different physiologic parameter is generated and transmitted to the ambulatory physiological monitoring unit **110**. In step **1510**, physiological data for different physiological parameter is received from an ambulatory physiological monitoring unit **110**. Before ending **1517**, the physiological data is analyzed and retrospective analysis data is generated **1512**.

[0075] The above-described systems, modules, and methods can be implemented in digital electronic circuitry, in computer hardware, firmware, and/or software. The imple-

mentation can be a computer program product. For example, the implementation can be in a machine-readable storage device, for execution by, or to control the operation of, data processing apparatus. The implementation can, for example, be a programmable processor, a computer, and/or multiple computers.

[0076] A computer program can be written in any form of programming language, including compiled and/or interpreted languages, and the computer program can be deployed in any form, including as a stand-alone program or as a subroutine, element, and/or other unit suitable for use in a computing environment. A computer program can be deployed to be executed on one computer or on multiple computers at one site.

[0077] Method steps can be performed by one or more programmable processors executing a computer program to perform functions of the invention by operating on input data and generating output. Method steps can also be performed by and an apparatus can be implemented as special purpose logic circuitry. The circuitry can, for example, be a FPGA (field programmable gate array) and/or an ASIC (application specific integrated circuit). Modules, subroutines, and software agents can refer to portions of the computer program, the processor, the special circuitry, software, and/or hardware that implement that functionality.

[0078] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer. Generally, a processor receives instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for executing instructions and one or more memory devices for storing instructions and data. Generally, a computer can include, can be operatively coupled to receive data from, and/or can transfer data to one or more storage devices for storing data (e.g., magnetic, magneto-optical disks, or optical disks).

[0079] Data transmission and instructions can also occur over a communications network. Information carriers suitable for embodying computer program instructions and data include all forms of non-volatile memory, including by way of example semiconductor memory devices. The information carriers can, for example, be EPROM, EEPROM, flash memory devices, magnetic disks, internal hard disks, removable disks, magneto-optical disks, CD-ROM, and/or DVD-ROM disks. The processor and the memory can be supplemented by, and/or incorporated in special purpose logic circuitry.

[0080] To provide for interaction with a user, the above described techniques can be implemented on a computer having a display device. The display device can, for example, be a cathode ray tube (CRT) and/or a liquid crystal display (LCD) monitor. The interaction with a user can, for example, be a display of information to the user and a keyboard and a pointing device (e.g., a mouse or a trackball) by which the user can provide input to the computer (e.g., interact with a user interface element). Other kinds of devices can be used to provide for interaction with a user. Other devices can, for example, be feedback provided to the user in any form of sensory feedback (e.g., visual feedback, auditory feedback, or tactile feedback). Input from the user can, for example, be received in any form, including acoustic, speech, and/or tactile input.

[0081] The above described techniques can be implemented in a distributed computing system that includes a back-end component. The back-end component can, for example, be a data server, a middleware component, and/or an application server. The above described techniques can be implemented in a distributed computing system that includes a front-end component. The front-end component can, for example, be a client computer having a graphical user interface, a Web browser through which a user can interact with an example implementation, and/or other graphical user interfaces for a transmitting device. The components of the system can be interconnected by any form or medium of digital data communication (e.g., a communications network). Examples of communications networks include a local area network (LAN), a wide area network (WAN), the Internet, wired networks, and/or wireless networks.

[0082] The system can include clients and servers. A client and a server are generally remote from each other and typically interact through a communications network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[0083] Packet-based networks can include, for example, the Internet, a carrier internet protocol (IP) network (e.g., local area network (LAN), wide area network (WAN), campus area network (CAN), metropolitan area network (MAN), home area network (HAN)), a private IP network, an IP private branch exchange (IPBX), a wireless network (e.g., radio access network (RAN), 802.11 network, 802.16 network, general packet radio service (GPRS) network, HiperLAN, evolution-data optimized (EVDO) network, long term evolution (LTE) network), and/or other packet-based networks. Circuit-based networks can include, for example, the public switched telephone network (PSTN), a private branch exchange (PBX), a wireless network (e.g., RAN, Bluetooth® (Personal Area Network (PAN)), code-division multiple access (CDMA) network, time division multiple access (TDMA) network, global system for mobile communications (GSM) network), and/or other circuit-based networks.

[0084] The transmitting device can include, for example, a computer, a computer with a browser device, a telephone, an IP phone, a mobile device (e.g., cellular phone, personal digital assistant (PDA) device, laptop computer, electronic mail device), and/or other communication devices. The browser device includes, for example, a computer (e.g., desktop computer, laptop computer) with a world wide web browser (e.g., Microsoft® Internet Explorer® available from Microsoft Corporation, Mozilla® Firefox available from Mozilla Corporation). The mobile computing device includes, for example, a BlackBerry® device.

[0085] Certain embodiments of the present invention were described above. It is, however, expressly noted that the present invention is not limited to those embodiments, but rather the intention is that additions and modifications to what was expressly described herein are also included within the scope of the invention. Moreover, it is to be understood that the features of the various embodiments described herein were not mutually exclusive and can exist in various combinations and permutations, even if such combinations or permutations were not made express herein, without departing from the spirit and scope of the invention. In fact, variations, modifications, and other implementations of what was described herein will occur to those of ordinary skill in the art without departing from the spirit and the scope of the inven-

tion. As such, the invention is not to be defined only by the preceding illustrative description.

What is claimed is:

1. A method for monitoring a patient, the method comprising:

executing at least one data acquisition module in an ambulatory physiological monitoring unit to acquire physiological data;

executing a real-time analysis module in the ambulatory physiological monitoring unit, the real-time analysis module analyzing segments of physiological data and generating real-time analysis data for each segment;

transmitting the real-time analysis data to a remote monitoring center; and

transmitting physiological data associated with the real-time analysis data to the remote monitoring center for further analysis.

2. The method of claim **1**, wherein analyzing segments of physiological data comprises monitoring for a physiological condition or event and the real-time analysis data comprises information regarding the physiological condition or event, which is generated in response to detecting the physiological condition or event.

3. The method of claim **2**, wherein monitoring for a physiological condition or event comprises determining whether the physiological data or processed physiological data reaches at least one predetermined level.

4. The method of claim **1**, wherein the physiological data is electrocardiography data.

5. The method of claim **1**, wherein the physiological data comprises physiological data for a plurality of physiologic parameters of at least one body system.

6. The method of claim **5**, wherein the physiological data for the plurality of physiologic parameters of at least one body system comprises pulse-oximetry data.

7. The method of claim **1**, wherein the ambulatory physiological monitoring unit transmits the real-time analysis data to the remote monitoring center at predetermined intervals.

8. The method of claim **1**, wherein transmitting the physiological data to the remote monitoring center comprises storing the physiological data in a memory module of the ambulatory physiological monitoring unit and uploading the physiological data from the memory module to the remote monitoring center.

9. The method of claim **8**, wherein the data acquisition module is in wireless communications with the real-time analysis module and the memory module.

10. The method of claim **1**, further comprising:

detecting a message requesting physiological data or real-time analysis data for at least one physiologic parameter; and

executing the data acquisition module and real-time analysis module to acquire and to analyze physiological data for the at least one physiologic parameter.

11. The method of claim **10**, wherein the message is generated and transmitted automatically by the ambulatory physiological monitoring unit, generated and transmitted by a user interface associated with the ambulatory physiological monitoring unit, or both.

12. The method of claim **10**, wherein the message is generated and transmitted by the remote monitoring center, generated and transmitted by a service in communication with ambulatory physiological monitoring unit, or both.

13. A method for monitoring a patient, the method comprising:

receiving real-time analysis data from a remote ambulatory physiological monitoring unit, the real-time analysis data being based on an analysis of segments of physiological data acquired by the remote ambulatory physiological unit;

receiving physiological data associated with the real-time analysis data from the remote ambulatory physiological monitoring unit;

executing a retrospective analysis module to generate retrospective analysis data based on the physiological data.

14. The method of claim **13**, wherein the real-time analysis data is information regarding a physiological event or condition detected by the remote ambulatory physiological monitoring unit.

15. The method of claim **13**, wherein the physiological data comprises a plurality of physiologic parameters associated with the same and/or different body systems, and wherein executing the retrospective analysis module comprises correlating physiological data for the plurality of physiologic parameters.

16. The method of claim **13**, wherein receiving real-time analysis data and physiological data from a remote ambulatory physiological monitoring unit comprises receiving the real-time analysis data via a wireless communications link and uploading the physiological data from a memory module on the remote ambulatory physiological monitoring unit via a wired communications link

17. The method of claim **13**, further comprising executing an evaluation module for evaluating the real-time analysis data or retrospective analysis data to determine the physiological status of the patient.

18. The method of claim **17**, wherein executing an evaluation module comprises executing a user interface module for allowing user interaction with the real-time analysis data and retrospective analysis data.

19. The method of claim **18**, further comprising transmitting a message to the remote ambulatory monitoring unit requesting physiological data or real-time analysis data in response to the user interface module detecting a user input command requesting physiological data or real-time analysis data.

20. The method of claim **17**, wherein evaluating the real-time analysis data or retrospective analysis data comprises determining whether the physiological data or real-time analysis data is sufficient to generate conclusive diagnostic information.

21. The method of claim **17**, wherein the message comprises a request for additional physiological data.

22. The method of claim **17**, wherein the message comprises a request for physiological data for a different physiologic parameter.

23. The method of claim **17**, further comprising transmitting a message containing information regarding the physiological status of the patient.

24. An ambulatory physiological monitoring unit, comprising:

a physiological data acquisition module for acquiring physiological data;

a real-time analysis module for analyzing segments of the physiological data and generating real-time analysis data;

a storage module for storing the physiological data; and

a transceiver configured to transmit the real-time analysis data to a remote monitoring center via a communications network in response to at least one event or physiological condition detected by the real-time analysis module, the transceiver further configured to transmit physiological data associated with the at least one event or physiological condition to the remote monitoring center for retrospective analysis of the physiological data.

25. The ambulatory physiological monitoring unit of claim **24**, further comprising:

a user interface module configured to accept input from a user regarding at least one event or physiological condition, the user interface module further configured to generate a message containing information regarding the event or physiological condition, the transceiver further configured to transmit the message to the remote monitoring center.

26. A system for monitoring a patient, the system comprising:

an ambulatory physiological monitoring unit, comprising:

a physiological data acquisition module for acquiring physiological data;

a real-time analysis module for analyzing segments of the physiological data and for generating real-time analysis data for each segment of physiological data;

a storage module for storing the physiological data; and

a transceiver for transmitting the real-time analysis data and physiological data associated with the real-time analysis data via a communications network; and

a remote monitoring center in network communications with the ambulatory physiological monitoring unit, the remote monitoring center comprising:

a transceiver for receiving the real-time analysis data and the physiological data from the ambulatory physiological monitoring unit and for transmitting messages requesting physiological data to the ambulatory physiological monitoring unit via the communications network;

a retrospective analysis module for performing a retrospective analysis based on the physiological data and generating retrospective analysis data; and

an evaluation module for evaluating the physiological status of the patient based on the real-time analysis data or the retrospective analysis data.

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专利名称(译)	处理从动态生理监测单元获得的生理数据的方法和装置		
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摘要(译)

生理监测系统和相应的方法提供对一个或多个生理参数的数据的快速和详细分析，以实现快速和准确的医学诊断。移动生理监测单元获取生理数据，自动分析其以检测事件，并且将关于事件的信息和通过通信网络与事件相关联的生理数据发送到监控中心，在监控中心分析和分类事件信息。监控中心还可以基于与事件相关联的生理数据执行回顾性分析，以提供对检测到的事件的深入分析和准确的诊断。监测中心还可以请求额外的或不同的生理数据来改进分析。结果，生理监测系统和相应的方法可以确保采取及时和适当的干预以减少患者的不适，疼痛，损伤或死亡风险。