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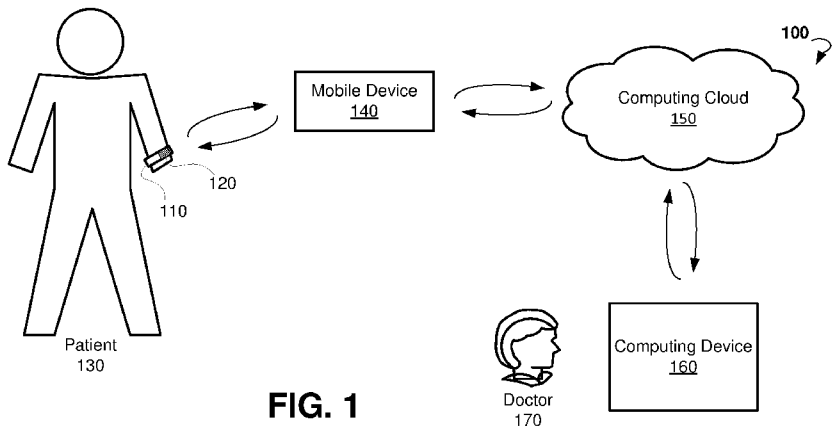

FIG. 1

(57) Abstract: A method and systems for monitoring health status of chronically ill people are provided. An example system includes a wearable device with sensors, with the wearable device being designed to be worn on a wrist of a patient. The wearable device is operable to continuously collect, via sensors, sensor data from a single place on body of the patient. The sensor data are processed to obtain electrocardiogram data and photoplethysmogram data. The electrocardiogram data and the photoplethysmogram data are analyzed to obtain medical parameters associated with a chronic disease. Based at least partially on the changes in the medical parameters over time, a progression of the at least one chronic disease can be determined. Based on the progression, messages regarding a current health condition are sent to the patient. The messages include advice to take medicine or contact a medical professional if a chronic condition is worsening.

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MONITORING HEALTH STATUS OF PEOPLE SUFFERING FROM CHRONIC DISEASES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is related to U.S. Patent Application No. 14/738,636, filed June 12, 2015 and titled "Wearable Device Electrocardiogram" and U.S. Patent Application No. 14/738,711, filed June 12, 2015 and titled "Pulse Oximetry." The subject matters of the aforementioned applications are incorporated herein by reference for all purposes.

FIELD

[0002] The present application relates to systems and methods for monitoring health status of people suffering from chronic diseases.

BACKGROUND

[0003] It should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

[0004] Monitoring chronic diseases, which includes measuring medical parameters, is central for providing appropriate and timely treatment to patients suffering from such chronic diseases as chronic heart failure, cardiac arrhythmia, chronic obstructive pulmonary disease, asthma, and diabetes. Traditionally, monitoring is carried out and measurements are taken while a patient is hospitalized or in other clinical settings. Appropriate treatment regimen can be based on these measurements, and thus it is highly beneficial to monitor medical parameters of the patient after the patient is released from the hospital. Therefore, the patient can be asked to visit the hospital or clinic periodically for monitoring, and adjustment of treatment, if necessary. However, most often, no measurements are carried out

between visits, usually due to the need for trained examiners and medical devices. This is unfortunate, because between visits the chronic disease from which the patient suffers can worsen and result in emergency treatment and hospitalization. Furthermore, after receiving repeated courses of emergency hospital treatment, the patient's health condition may degrade and never return to the pre-hospitalization level. Therefore, a technology that allows for at-home measurements can be essential to managing chronic diseases or even saving a patient's life. Early warnings of worsening conditions associated with chronic diseases may prevent unnecessary hospitalizations by providing a preventive treatment and, as a result, reduce financial and human costs of the hospitalization and treatment.

[0005] Currently there are no user-friendly devices for continuous non-intrusive measurements of medical parameters of patients at their home or working environment. In some cases, patients with severe symptoms can be monitored at home while staying in bed. However, devices for taking measurements of bedridden patients are generally not suitable for chronic patients which, with timely treatment, should be able to maintain a high quality normal life.

[0006] Some existing mobile devices can provide functionalities for tracking people's physical activity. Such devices can measure a pulse rate and the distance a person walks or runs, calculate burned calories, and so forth. Some of these existing devices are designed as or are part of a watch, a bracelet, and a wristband. However, these devices are primarily designed for healthy people for monitoring of their physical exercise and not for chronically ill people.

SUMMARY

[0007] This summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0008] According to one embodiment of the present disclosure, a system for monitoring health status of a patient is provided. The system can be embedded in a wearable device, and includes at least one sensor. The wearable device is configured to continuously collect, via the sensor or sensors, data from a single place on the body of a patient. The wearable device can store or transmit the sensor data for subsequent processing and analysis to obtain medical parameters. The sensor data can be processed to receive at least electrocardiogram (ECG) data and photoplethysmogram (PPG) data. The ECG data and PPG data can be analyzed to obtain the medical parameters. The medical parameters can be associated with at least one chronic disease. The medical parameters can be analyzed to track changes in the medical parameters over time. Based at least partially on the changes in the medical parameters, a dynamic profile of the chronic disease can be determined, which can be used to monitor disease progression or remission.

[0009] In some embodiments, the sensors include at least one of the following: an optical sensor, an electrical sensor, and a motion sensor. The wearable device includes a wristband operable to be placed around a wrist of the patient. The wristband can include sensors in a dedicated sensor area. The sensor area can be arranged to cover at least the radial artery of the patient. In other embodiments, the wearable device can be worn at a wrist, ankle, chest, neck, and positioned at other sites of a human body.

[0010] The medical parameters that are monitored include but are not limited to at least one of SpO2 oxygen saturation, tissue oxygen saturation, cardiac output, vascular resistance, pulse rate, blood pressure, respiration, and motion data.

[0011] In some embodiments, the chronic disease might be at least one of the following: congestive heart failure, hypertension, arrhythmia, asthma, chronic obstructive pulmonary disease, hypoglycemia, hyperglycemia, sleep apnea, and Parkinson's disease.

[0012] The determination of the progression or remission includes estimation of a deviation or divergence of at least one of the medical parameters from expected medical parameters. The expected medical parameters are based on individual historical medical parameters of the patient as well as on established or theoretical medical knowledge.

[0013] If the deviation of the at least one medical parameter is larger than a pre-determined deviation value, the wearable device may be further configured to alert at least one of the following: the patient, a doctor, a relative of the patient, and a caretaker of the patient. In certain embodiments, the wearable device is operable to advise the patient to contact a medical professional.

[0014] If the deviation of the at least one medical parameter is larger than a pre-determined value; the wearable device may be further configured to provide an alert message to the patient. The alert message can include an advisory to take medicine. In certain embodiments, the wearable device is further configured to determine, based on changes in the medical parameters, that the patient has taken the medicine.

[0015] In various embodiments, when the deviation of the medical parameter is less than a pre-determined value, the wearable device is configured to repeatedly message the patient to assure the patient of a normal health condition.

[0016] In certain embodiments, when the deviation of the medical parameter is less than a pre-determined value, the wearable device is configured to repeatedly

provide a sensory stimulus such as sound or vibration to the patient to assure that the patient of a normal health condition.

[0017] In further embodiments, the wearable device is communicatively coupled to a mobile device. The mobile device can be configured to receive the sensor data from the wearable device, analyze the sensor data to provide medical parameters, and process the medical parameters to provide to the patient at least one report regarding the health condition of the patient.

[0018] The mobile device may be communicatively coupled to a cloud-based computing resource. The cloud-based computing resource is configured to receive the sensor data and/or the medical parameters from the mobile device for further analysis and provide at least one application for generating, based on the sensor data and/or the medical parameters, at least one report regarding the health status of the patient.

[0019] According to another aspect of the present disclosure, a method for monitoring a patient's health status is provided. The method can include continuously collecting, via sensors, physiological data from a single place on the body of the patient. The method can allow processing the sensor data to obtain at least ECG data and PPG data. At least one of the ECG data and PPG data are analyzed to obtain medical parameters associated with at least one chronic disease. The method can include analyzing the medical parameters to track changes in the medical parameters over time. The method can include determining, based at least partially on the changes in the medical parameters, a dynamic profile of at least one chronic disease. In some embodiments, the sensors are associated with a wearable device. The wearable device can be placed around a wrist of the patient. The sensors can be arranged to cover at least a radial artery and/or nearby skin tissue of the patient.

[0020] According to another example embodiment of the present disclosure, the steps of the method for monitoring a patient's health status are stored on a non-transitory machine-readable medium comprising instructions, which when implemented by one or more processors perform the recited steps.

[0021] Other example embodiments of the disclosure and aspects will become apparent from the following description taken in conjunction with the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] Embodiments are illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

[0023] FIG. 1 is a block diagram showing an example system for monitoring a health status of a chronically ill patient.

[0024] FIG. 2 is a block diagram showing components of an example device for monitoring a health status of a chronically ill patient.

[0025] FIG. 3 is a block diagram illustrating example sensors, example medical parameters, and example chronic diseases.

[0026] FIGs. 4A and 4B are block diagrams illustrating an example device for monitoring health status of a chronically ill patient.

[0027] FIG. 5 is a block diagram showing an example system for monitoring a chronically ill patient.

[0028] FIG. 6 is a flow chart showing steps of an example method for monitoring a chronically ill patient.

DETAILED DESCRIPTION

[0029] The following detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show illustrations in accordance with exemplary embodiments. These exemplary embodiments, which are also referred to herein as "examples," are described in enough detail to enable those skilled in the art to practice the present subject matter. The embodiments can be combined, other embodiments can be utilized, or structural, logical and electrical changes can be made without departing from the scope of what is claimed. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope is defined by the appended claims and their equivalents.

[0030] The present disclosure provides systems and methods for monitoring health status in people suffering from chronic diseases. Embodiments of the present disclosure can allow measuring medical parameters of a patient in a non-intrusive manner while, for example, the patient is at home, at work, outdoors, traveling, and at other stationary or mobile environments. Some example embodiments can provide for a wearable device (e.g., a wristband, a watch, or a bracelet) that includes sensors configured to measure medical parameters such as, for example, blood pressure, heart rate, blood oxygen saturation, respiration, and the like. The measurements can be taken during daytime and nighttime for days, weeks, months, and years. The medical parameters can be analyzed to determine trends in the medical parameters and to determine whether the severity of the patient's chronic disease (e.g., a heart disease, diabetes, lung disease, and so on) worsens or improves. Embodiments of the present technology may facilitate a rapid reaction to provide an appropriate and timely treatment for the patient. The early treatment may allow taking timely measures to avoid worsening of the patient's condition to the point of requiring an emergency hospitalization and associated expensive medical treatment.

[0031] According to various example embodiments, a method for monitoring health status of people suffering from chronic diseases includes continuously collecting sensor data from a single place on the body of a patient. The method can further include processing the sensor data to obtain at least electrocardiogram (ECG) data and photoplethysmogram (PPG) data. The method may include analyzing at least one of the ECG data and the PPG data to obtain medical parameters associated with at least one chronic disease. The method can allow detecting changes in the medical parameters over time. The method includes determining, based at least partially on the changes in the medical parameters, a dynamic profile of the at least one chronic disease. The method can allow, based at least on the progression or remission, providing at least one message to the patient.

[0032] Referring now to FIG. 1, an example system 100 for monitoring a patient's health status is shown. The system 100 includes at least a wearable device 110. The wearable device includes sensors 120. In some embodiments, the wearable device 110 is worn by a patient 130, for example on a wrist, for an extended period of time. The mobile device can be carried out as a watch, a bracelet, a wristband, and the like.

[0033] The wearable device 110 is operable to constantly collect, via sensors 120, sensor data from a patient 130. In some embodiments, based on the sensor data, the wearable device 110 is operable to obtain medical parameters associated with the patient 130. The medical parameters can be analyzed to obtain changes (trends) in medical parameters over time. Based on the changes, one or more conclusions regarding severity of one or more chronic disease can be obtained. The wearable device is operable to send messages regarding a current health status to the patient, a relative, a caretaker of the patient, or a doctor treating the patient. The patient can be advised to see a doctor and/or take medicine. In some embodiments, the wearable device 110 analyzes the medical parameters to determine whether the patient has taken the medicine and to provide further advice to the patient.

[0034] In various embodiments, the system 100 includes a mobile device 140. The mobile device 140 can be communicatively coupled to the wearable device 110. In various embodiments, the mobile device 140 is operable to communicate with the wearable device 110 via a wireless connection such as, for example, Wi-Fi, Bluetooth, Infrared (IR), and the like. The mobile device 140 can include a mobile phone, a smart phone, a phablet, a tablet computer, a notebook, and so forth. The mobile device 140 can be operable to receive the sensor data and medical parameters from the mobile device 110. In certain embodiments, the mobile device is operable to perform analysis of the received sensor data and medical parameters and to provide the patient with a report regarding current health status. In various embodiments, the mobile device 140 runs one or more applications that provide, via a graphical display system, charts and graphics concerning medical parameters of the patient.

[0035] In some embodiments, the mobile device 140 is operable to determine the severity of a health status resulting from the chronic disease from which the patient suffers and provide the patient with advice to see a medical professional or to take medicine. An alert message regarding health status of the patient can be sent to a doctor, a relative, or caretaker of the patient.

[0036] In further embodiments, the system 100 may include a cloud-based computing resource 150 (also referred to as a computing cloud). In some embodiments, the cloud-based computing resource 150 includes one or more server farms/clusters comprising a collection of computer servers and is co-located with network switches and/or routers. In certain embodiments, the mobile device 140 is communicatively coupled to the computing cloud 150. The mobile device 140 can be operable to send the sensor data and medical parameters to the computing cloud 150 for further analysis. The computing cloud 150 is operable to store historical data concerning patient health status including sensor data and medical parameters collected over days, weeks, months, and years. The computing cloud can be operable

to run one or more applications and to provide reports regarding health status of the patient. A doctor 170 treating the patient may access the reports, for example via computing device 160, using the Internet or a secure network. In some embodiments, the results of the analysis of the medical parameters can be sent back to the mobile device 140.

[0037] The severity of the health status resulting from a chronic disease can be estimated by computing a deviation or divergence from normal medical parameters of one or more medical parameters being measured at the moment. The normal medical parameters can be specific to the patient and can be derived based on historical data concerning the patient's health status recorded over an extended time period. If the deviation in the medical parameters becomes sufficiently large, the patient can be advised, via a message to the mobile device 140, to take medicine or contact a doctor. In some situations, when the deviation becomes substantial, an alert message can be sent by the mobile device 140 and/or the wearable device 110 to a relative, a doctor, or a caretaker of the patient.

[0038] It may be desirable for the patient to be assured that the current medical parameters are within an acceptable deviation of the normal medical parameters. For example, when the current medical parameters are normal, the wearable device 110 and/or mobile device 140 can be operable to periodically alert the patient using a pleasant sound. The signal can be provided, for example, every 30 minutes, once every hour, and the like. In certain embodiments, when the medical parameters are within normal values, the mobile device 140 may provide a text message assuring the patient of normal conditions. A haptic feedback component can be used to alert the patient to a health condition, to warn the patient about a specific event concerning treatment of a chronic disease, to remind the patient to take a medicine, if the patient has failed to take the medicine within a pre-determined period of time, and so forth. The wearable device 110 may include a haptic feedback functionality for providing

the patient with haptic feedback, for example, a tap-in device, to apply a force or vibration to skin of the patient. In further embodiments, the haptic alert can be provided by the mobile device 140. The mobile device can vibrate when the mobile device in a pocket of the patient or when the mobile device is located on a surface (e.g., a table).

[0039] FIG. 2 is a block diagram illustrating components of wearable device 110, according to an example embodiment. The example wearable device 110 includes sensors 120, a transmitter 210, processor 220, memory storage 230, and a battery 240. The wearable device 110 may comprise additional or different components to provide a particular operation or functionality. Similarly, in other embodiments, the wearable device 210 includes fewer components that perform similar or equivalent functions to those depicted in FIG. 2.

[0040] The transmitter 210 is configured to communicate with a network such as the Internet, a Wide Area Network (WAN), a Local Area Network (LAN), a cellular network, and so forth, to send a data stream, for example sensor data, medical parameters, and messages concerning the health condition of a patient.

[0041] The processor 220 can include hardware and/or software, which is operable to execute computer programs stored in memory 230. The processor 220 can use floating point operations, complex operations, and other operations, including processing and analyzing sensor data.

[0042] In some embodiments, the battery 240 is operable to provide electrical power for operation of other components of the wearable device 110. In some embodiments, the battery 240 is a rechargeable battery. In certain embodiments, the battery 240 is recharged using inductive charging technology.

[0043] FIG. 3 is a block diagram showing a list of example sensors 120, a list of example medical parameters 310, and a list of example chronic diseases 320. In various embodiments, the sensors 120 include optical sensors 222, electrical sensors

224, and motion sensors 226. The medical parameters 310, determined based on the sensor data, include, but are not limited to, SpO2 oxygen saturation, tissue oxygen saturation, cardiac output, vascular resistance, pulse rate, blood pressure, respiration, electrocardiogram (ECG) data, and motion data. The chronic diseases 320, the progression of which can be tracked based on changes of the medical parameters, include but are not limited to congestive heart failure (CHF), hypertension, arrhythmia, asthma, chronic obstructive pulmonary disease (COPD), hypoglycemia, sleep apnea, and Parkinson's disease.

[0044] The optical sensors 222 are operable to measure medical parameters associated with blood flow in an artery (for example, radial artery) using changing absorbance of light at different wavelengths in arterial blood and skin. The optical sensor can determine multiple medical parameters, including but not limited to: SpO2 oxygen saturation, cardiac output, vascular resistance, pulse rate, and respiration. Based on the measurements obtained from optical sensors, abnormal cardiac rhythms (for example, atrial fibrillation, rapid rhythms and slow rhythms) can be detected.

[0045] In some embodiments, respiration can be derived from a sinus arrhythmia waveform. The sinus arrhythmia waveform can be obtained based on intervals between subsequent heart beats (RR intervals) measured by the optical sensors using the fact that the rhythm of the heart beats is modulated by human breathing.

[0046] The electrical sensors 224 can be operable to obtain electrocardiographic (ECG) activity data of the patient. The ECG activity data includes a characteristic electrically-derived waveform of a heart activity. The ECG data can include a number of components, whose characteristics (timing, amplitude, width, and so forth), alone or in combination, can provide a picture of cardiac and overall health. The ECG data is typically derived by measurements from one or more sets of leads (groups of electrodes comprising grounded circuits), such that the exact

characteristics of the resulting waveforms is a function of the electrical and spatial vectors of the electrode positions relative to the heart. While the details of interpretation of the ECG data are too involved to describe succinctly in this disclosure, consideration of each of the component parameters can indicate health status, physical or psychological stress, or trends of disease conditions. Various cardiovascular parameters can be extracted from the ECG alone (such as a heart rate for example), or in combination with other physiological measurements.

[0047] ECG-like components can also be obtained, or re-constructed, through other methods of physiological measurements, such as mechano-cardiography, for example.

[0048] According to example embodiments of present disclosure, ECG of the patient can be measured via the electrical sensors 224. Since measurements are taken from a wrist of the patient, electrodes of the electrical sensors 224 should be located very close to each other on a wearable device. Therefore the ECG data may contain noise. Averaging of several subsequent intervals of the ECG data between heart beats can be used to cancel out noise in ECG data. To determine intervals between two subsequent heart beats, the pulse wave as measured by optical sensors 222 can be used as a reference. In some embodiments, an arrhythmia analysis can be carried out using the ECG data and data concerning cardiac output and pulse rate.

[0049] In some embodiments, motion sensors 226 include an accelerometer, gyroscope, and Inertial Measurement Unit (IMU). The motion data obtained via motion sensors 226 can provide parameters of body movement and tremor. The motion data can allow tracking the progression or remission of a motor disease, Parkinson's disease, and physical condition of the patient. In some embodiments, the motion data can be analyzed to determine whether the patient is likely to fall. In some embodiments, the motion data can be analyzed in time domain and frequency domain. By tracking amplitudes of movement of the patient it can be determined if

the patient's movements become slower (i.e., the patient becomes sluggish) or the patient is not moving at all.

[0050] FIG. 4A is a block diagram illustrating an example wearable device 110. The wearable device 110 can be carried out as a watch or, a bracelet, or a wristband. The wearable device 110 can include sensors 120. The wearable device 110 can be placed around a wrist of patient's hand 410 in such a way that sensors 120 are located above and as close as possible to the radial artery 420. The radial artery is located right beneath the skin, thereby allowing measurements of oxygen saturation, heart rate, cardiac output, and other parameters by optical sensors using pulse oximetry methods.

[0051] Oxygen saturation is the relative proportion (typically expressed as percentage) of oxygen dissolved in blood, as bound to hemoglobin, relative to non-oxygen-bound hemoglobin. Oxygen saturation is important in clinical monitoring of surgical anesthesia, and in monitoring and assessment of various clinical conditions such as the COPD and asthma. In healthy individuals, oxygen saturation is over 95%. Direct measurement can be made from arterial blood sample, but drawing blood is an invasive procedure, and, except for a few controlled environments (e.g. during a surgery) cannot be easily performed continuously. Pulse oximetry can yield a quantity called SpO2 (saturation of peripheral oxygen), an accepted estimate of arterial oxygen saturation, derived from optical characteristics of blood using transmission of light through a thin part of a human body, for example, a fingertip or an earlobe (in the most common transmissive application mode). Reflectance pulse oximetry can be used to estimate SpO2 using other body sites. The reflectance pulse oximetry does not require a thin section of the person's body and is therefore can be suited to more universal application such as the feet, forehead and chest, but it has some serious issues due to the light reflected from non-pulsating tissues.

[0052] In some embodiments, the wearable device 110 includes self-adjusting mechanical catches to allow positioning the sensors 120 above the radial artery 420 by using the wrist bones as a physical reference and support.

[0053] In other embodiments, as shown in FIG. 4B, the sensors 120 include multiple light sensors 440 (photoelectric cells), to measure the reflected light, and multiple light transmitters 450 (for example, Light Emission Diodes (LEDs)). The number and location of the light sensors and light transmitters can be chosen such that in case of an accidental displacement of the wearable device, at least one of the light sensors is still located sufficiently close to the radial artery. In some embodiments, when measuring the light reflected from the skin and radial artery, a signal from those photoelectric cells that provides the strongest or otherwise determined best output can be selected for further processing in order to obtain medical parameters using methods of pulse (reflectance) oximetry. In certain embodiments, the wearable device 110 is configured to apply a pre-determined amount of pressure to the wrist each time the user wears the wearable device to allow the same conditions for the reflection of the light from the skin.

[0054] In other embodiments, when oxygen saturation cannot be measured directly from arterial blood, an indirect measurement can be performed by tracking tissue oxygen saturation. The measurement of oxygen saturation is commonly used to track progression of heart diseases or lung disease. When heart or lungs are not functioning properly, the saturation of oxygen drops in both arterial blood and tissue around the artery. Therefore, tissue oxygen saturation can be measured by sensing the skin color near the radial artery. For example, if the wearable device 110 moves so that sensors 120 are not covering the radial artery, measurements of tissue saturation near the radial artery can be used as a backup to provide values for oxygen saturation. In certain embodiments, the oxygen saturation and tissue

saturation can be measured simultaneously. In some embodiments, the oxygen saturation and tissue saturation can be measured using the same optical sensor.

[0055] In some embodiments, a combination of ECG and pulse oximetry can be used to determine cardiac output. Cardiac Output (CO, Q, or Qc) is a volume of blood pumped by the ventricles of the heart per unit time, typically expressed as milliliters per minute (ml/min). The cardiac output can be directly derived from other cardiac parameters, namely as the product of stroke volume (SV, the blood volume output of the heart with each beat), and the heart rate (HR), that is, CO = SV * HR. Clinically, the cardiac output is an indicator of the sufficiency of blood supply. In healthy individuals at rest, CO is about 5 or 6 liters of blood per minute. During strenuous activity, CO can increase to levels more than five times the resting level. In conditions such as hypertension, valvular heart disease, congenital heart disease, arrhythmias, CO is typically reduced.

[0056] In some embodiments, a combination of ECG and pulse oximetry can be used to estimate CO directly using the equation CO = SV * HR, by least squares regression modeling of stroke volume (based either on individual direct calibration to a specific patient, or calibration to physical and clinical patient characteristics), and replacing SV by the appropriate regression expression. Specifically, pulse wave transit time, the interval between the ECG R wave peak and the pulse oximeter pulse wave foot, transformed by an appropriate regression expression, replaces SV. The CO estimate can be determined using individual heartbeat raw ECG and pulse oximetry waveform parameters, or may be a time-averaged estimate, derived from synchronized reconstructed one-handed ECG and averaged pulse oximeter readings over a specified time period. Simple changes in CO, useful in tracking individualized patient trends, can be obtained by similar means, without the necessity for absolute calibration.

[0057] In some embodiments, the wearable device 110 is operable to determine a pulse rate. The pulse rate is an indicator of a heart rate, as determined at a peripheral body site (arteries of a wrist, arm, leg, or neck). Considered as one of the vital signs, the pulse rate can be an indicator of a general health and physiological state. The pulse rate can be derived directly from any pulse-oximeter. Normal resting values can vary widely, but typically, remain within 60-100 pulsations per minute. Fluctuations in the heart rate (Heart rate variability or HRV) are normal, with higher degrees generally associated with better heart reactivity and health.

[0058] In some embodiments, the wearable device 110 is operable to determine a blood pressure (BP). The BP, another vital sign, generally refers to the intra-arterial pressure of blood at two specific stages of the heartbeat, the maximum pressure at systole (ventricular contraction) and the minimum pressure at diastole (relaxation and filling of ventricles), expressed as a delimited pair of numbers for systolic and diastolic BP respectively, in mmHg, e.g. 150/80 mmHg. The BP can be measured continuously by an invasive arterial catheter, non-invasive measurement at the arm by a stethoscope and a sphygmomanometer, or an automated cuff. A healthy adult resting BP can vary around 120/80 mmHg. High or low BPs are associated with many disease states, with long-term changes being associated with changes in the health status. Extreme short-term changes can be associated with acute disease episodes, particularly in chronically ill patients. A risk of developing a number of diseases, such as cardiovascular disease, can be associated with extreme BPs. Short-term changes in the BP can be associated with changes in physical or mental state.

[0059] According to some embodiments of present disclosure, a combination of ECG and pulse oximetry can be used to estimate systolic BP changes. The systolic BP changes can be estimated using a pulse wave transit time, the interval between the ECG R wave peak and the pulse oximeter pulse wave foot.

[0060] In certain embodiments, with a suitable calibration and individualized adjustment based on various patient characteristics, absolute estimates of the BP can be determined. The BP changes or absolute estimates can be determined using individual heartbeat raw ECG and pulse oximetry waveform parameters, or may be a time-averaged estimate, derived from synchronized reconstructed one-handed ECG and averaged pulse oximeter readings over some specified time period.

[0061] In some embodiments, the wearable device 110 is operable to determine vascular resistance. Vascular resistance is the force which opposes the flow of blood through the circulation. Typically, the systemic vascular resistance (SVR), which is the resistance of the peripheral circulation, is considered. Measurements can be expressed in several different unit systems; clinically the units are often mmHg/L/min, as SVR is a function of both blood pressure and cardiac output, that is, SVR=BP / CO. Normal values are typically within 10 – 20 mmHg/L/min. SVR can change as a result of various physiological stresses on the body, such as with exercise where the vascular resistance decreases, resulting in increased blood flow, or with drug or disease-related challenges.

[0062] Using measurements of ECG and pulse oximetry, the SVR can be derived as either a change or tracking score, or an absolute estimate, based on instantaneous (single heartbeat) or average BP and CO estimates.

[0063] In some embodiments, the wearable device 110 is operable to determine respiratory rate using a pulse oximetry and ECG. The respiratory rate, which is another vital sign, is typically expressed as the number of breaths per minute. Typical adult resting respiratory rate is about 16-20 breaths per minute. Extreme variations can result from physical or psychological stress. The respiratory rate is often affected in chronic disease states, particularly in pulmonary and cardiovascular disease. Extreme short-term changes may be associated with acute disease episodes, particularly in chronically ill patients.

[0064] In further embodiments, the mobile device 110 can be operable to track levels of one or more medicine in the blood of the patient 130 for a desired period of time. The level of medicine can be analyzed in combination with other blood parameters to see trends in progression or regression of chronical diseases. Based on the trends, the patient can be provided with advice to modify times for taking the medicine and/or amounts of the medicine. The patient can be warned if the level of the medicine in the blood is too high or too low. The doctor 170 view reports on the medicine levels to ensure that the medication level is within a proper range for providing effective treatment of the chronic diseases.

[0065] In some embodiments, the wearable device 110 can facilitate monitoring trends of medical parameters of the patient during a treatment. The information concerning the trends can be further used to predict a reaction of the patient to various medicines.

[0066] In some embodiments, an analysis of trends of the medical parameters can be used to predict susceptibility of the patient to local environment condition. For example, based on a weather forecast, a reaction of patient to a weather condition, pollen count, air pollution indices can be predicted. The patient can be given an advice, for example, to take a medicine in order to avoid worsening the health conditions.

[0067] In some embodiments, changes in monitored medical parameters can be correlated to certain social events, like news, or other external stimuli. The correlation can be used for determining psychological characteristics of the patient.

[0068] In some embodiments, the monitoring of medical parameters can be combined with monitoring particular habits of the patient. The habits can be determined based on movement activity. For example the following can be monitored: a number of steps during a day, times of waking up and going to sleep, daily time periods of performing physical exercises, and so forth. Based on the

changes in medical parameters, the user can be advised, for example to change quantity and/or quality of certain activities.

[0069] FIG. 5 is a block diagram showing components of system 500 for monitoring health status of people suffering from chronic diseases, according to an example embodiment. The system 500 can include a sensor data acquisition module 510, a data processing module 520, and output module 530. In some embodiments, the modules 510-530 are implemented as chipsets included in the wearable device 110. In other embodiments, the modules 520 and 530 can be stored as instructions in memory of the wearable device 110, mobile device 140, or computing cloud 150, and executed by a processor.

[0070] In some embodiments, the sensor acquisition module 510 is configured to receive and digitalize the sensor data. The sensor acquisition module 510 can include one or more analog-to-digital converters to transform the electrical signals from sensors to digits.

[0071] In some embodiments, the data processing module 520 is configured to analyze the sensor data to obtain medical parameters associated with chronic diseases and analyze trends in medical parameters to track progression or remission of the chronic diseases.

[0072] In some embodiments, the output module 530 is configured to provide reports and alert messages regarding health status of the patient.

[0073] FIG. 6 is a flow chart diagram showing example method 600 for monitoring health conditions of people suffering from chronic diseases. In block 610, the method 600 incudes continuously collecting sensor data from a single place on a body of a patient. In block 620, the method 600 includes processing the sensor data to obtain at least ECG data and PPG data. In block 630, the method 600 includes analyzing at least on of the ECG data and PPG data to obtain medical parameters associated with at least one chronic disease. In block 640, the method 600 includes

detecting changes in the medical parameters over time. In block 650, the method 600 includes determining, based partially on the changes and the medical parameters, a progression or a remission of the at least one chronic disease. In block 660, the method 600 includes providing, based on the progression or the remission, one or more messages to the patient.

Example 1. Asthma severity assessment

[0074] In some embodiments, the wearable device 110 is operable to perform assessment of asthma severity. The wearable device can be used to monitor blood SpO2 oxygen saturation, heart rate, and respiration. Measurements showing that SpO2 oxygen saturation has dropped may be indicative of an acute asthma flare-up. If an analysis of a heart rate indicates presence of tachycardia, the flare-up severity can be substantiated. Measurements of respiration can show presence of tachypnea. Tachypnea can limit speech and imply flare-up severity.

Example 2. COPD severity diagnostics

[0075] In some embodiments, the wearable device 110 is operable to provide COPD severity diagnostics by measuring SpO2 blood oxygen saturation, respiration, and a heart rate.

[0076] A drop in blood oxygen saturation may indicate episodic worsening of COPD. If respiration shows presence of tachypnea, it substantiates worsening of COPD. If heart rate measurements show presence of tachycardia, severe worsening of COPD can be diagnosed.

Practical considerations

[0077] One of the important considerations is how to conserve the battery power of the wearable device 110. In some embodiments, the system 100 for

monitoring health conditions of people suffering from chronic diseases includes at least one additional wearable device. The additional wearable device can be identical to the wearable device 110. In some embodiments, patient 130 may wear one of the devices throughout the day and another device at nighttime. The device that is not in use at the moment can be recharged. In some embodiments, the device can be recharged using induction charging technology. In some embodiments, since both the devices are in communication with mobile device 140, the replaced device can at least partially transmit recorded information to the replacing wearable device. The information can be downloaded to the mobile device 140, and the mobile device 140 can be operable to send the information to the replacing device.

[0078] The present technology is described above with reference to example embodiments. Therefore, other variations upon the example embodiments are intended to be covered by the present disclosure.

CLAIMS

What is claimed is:

1. A system for monitoring health status of a patient, the system comprising:

a wearable device including at least one sensor and configured to:

continuously collect, via the at least one sensor, sensor data from a single place on a body of a patient;

process the sensor data to obtain at least electrocardiogram (ECG) data and photoplethysmogram (PPG) data;

analyze at least one of the ECG data and the PPG data to obtain medical parameters associated with at least one chronic disease;

detect changes in the medical parameters over time; and

determine, based at least partially on the changes in the medical parameters, a progression or a remission of the at least one chronic disease.

2. The system of claim 1, wherein the sensors include at least one of the following: a motion sensor, an optical sensor, and an electrical sensor.

3. The system of claim 1, wherein the wearable device includes a wristband operable to be placed around a wrist of the patient, the wristband including a sensor area, the sensor area including the at least one sensor and being arranged to cover at least a radial artery of the patient.

4. The system of claim 1, wherein the medical parameters include at least one of the following: an oxygen saturation, a tissue oxygen saturation, a cardiac output, a vascular resistance, a pulse rate, a blood pressure, a respiration, and motion data.

5. The system of claim 1, wherein the at least one chronic disease includes at least one of the following: a congestive heart failure, a hypertension, an arrhythmia, an asthma, a chronic obstructive pulmonary disease, a hypoglycemia, a sleep apnea, and a Parkinson's disease.

6. The system of claim 1, wherein the determination of the progression includes estimation of a deviation of at least one of the medical parameters from expected medical parameters, the expected medical parameters being based on individual historical medical parameters of the patient.

7. The system of claim 6, wherein if the deviation of the at least one of the medical parameter is larger than a pre-determined deviation value, the wearable device is further configured to:

alert at least one of the following: the patient, a doctor, a relative of the patient, and a caretaker of the patient; and

advise the patient to contact a medical professional.

8. The system of claim 6, wherein if the deviation of the at least one of the medical parameter is larger than a pre-determined value, the wearable device is further configured to provide an alert message to the patient, the alert message including an advisory to take medicine.

9. The system of claim 8, wherein the wearable device is further configured to determine, based on changes in the medical parameters, that the patient took the medicine.

10. The system of claim 6, wherein when the deviation of the medical parameters is less than a pre-determined value, the wearable device is configured to repeatedly message the patient to assure the patient of a normal health status.

11. The system of claim 6, wherein when the deviation of the medical parameters is less than a pre-determined value, the wearable device is configured to repeatedly provide a sound signal to the patient to assure that the patient of a normal health status.

12. The system of claim 1, wherein the wearable device is communicatively coupled to a mobile device, the mobile device being configured to:

receive the medical parameters from the wearable device; and

process the medical parameters to provide to the patient at least one report regarding the health status of the patient.

13. The system of claim 12, wherein the mobile device is communicatively coupled to a cloud-based computing resource, the cloud-based computing resource being configured to:

receive the medical parameters from the mobile device for further analysis; and

provide at least one application for generating, based on the medical parameters, at least one report regarding a health status of the patient.

14. A method for monitoring health status of a patient, the method comprising:

continuously collecting, via sensors, sensor data from a single place on a body of a patient;

processing the sensor data to obtain at least electrocardiogram (ECG) data and photoplethysmogram (PPG) data;

analyzing at least one of the ECG data and the PPG data to obtain medical parameters associated with at least one chronic disease;

detecting changes in the medical parameters over time; and

determining, based at least partially on the changes in the medical parameters, a progression or a remission of the at least one chronic disease.

15. The method of claim 14, wherein:

the sensors include at least one of the following: a motion sensor, an optical sensor, and an electrical sensor; and

the sensors are associated with a wearable device, the wearable device is placed around a wrist of the patient, and the sensors are arranged to cover at least a radial artery of the patient.

16. The method of claim 14, wherein:

the medical parameters include at least one of the following: an SpO2 oxygen saturation, a tissue oxygen saturation, a cardiac output, a vascular resistance, a pulse rate, a blood pressure, a respiration, and motion data; and

wherein the at least one chronic disease includes at least one of the following: a congestive heart failure; a hypertension, an arrhythmia, an asthma, a chronic obstructive pulmonary disease, a hypoglycemia, a sleep apnea, and a Parkinson's disease.

17. The method of claim 1, wherein determining the progression includes estimation of deviation of at least one of the medical parameters from normal medical parameters, the normal medical parameters derived based on previously collected individual medical parameters of the patient.

18. The method of claim 17, further comprising: if the deviation of at least one of the medical parameters is larger than a pre-determined value:

providing an alert message to at least one of the following: the patient, a doctor, a relative of the patient, and a caretaker of the patient; and

providing at least one of the following:

advice to the patient to contact a medical professional;

an alert message to the patient advising the patent to take medicine.

19. The method of claim 17, further comprising, when the deviation in the medical parameters is less than a pre-determined deviation value, providing repeatedly at least one of the following to the patient to assure the patient of a normal health status: a message and a sound signal.

20. A non-transitory computer-readable storage medium having embodied thereon instructions, which when executed by a processor, perform steps of a method, the method comprising:

continuously collecting sensor data from a single place on a body of a patient;

processing the sensor data to obtain at least electrocardiogram (ECG) data and photoplethysmogram (PPG) data;

analyzing at least one of the ECG data and the PPG data to obtain medical parameters associated with at least one chronic disease;

detecting changes of the medical parameters over time;

determining, based partially on the changes in the medical parameters, a progression or a remission of the at least one chronic disease; and

providing, based on the progression or the remission, at least one message to the patient.

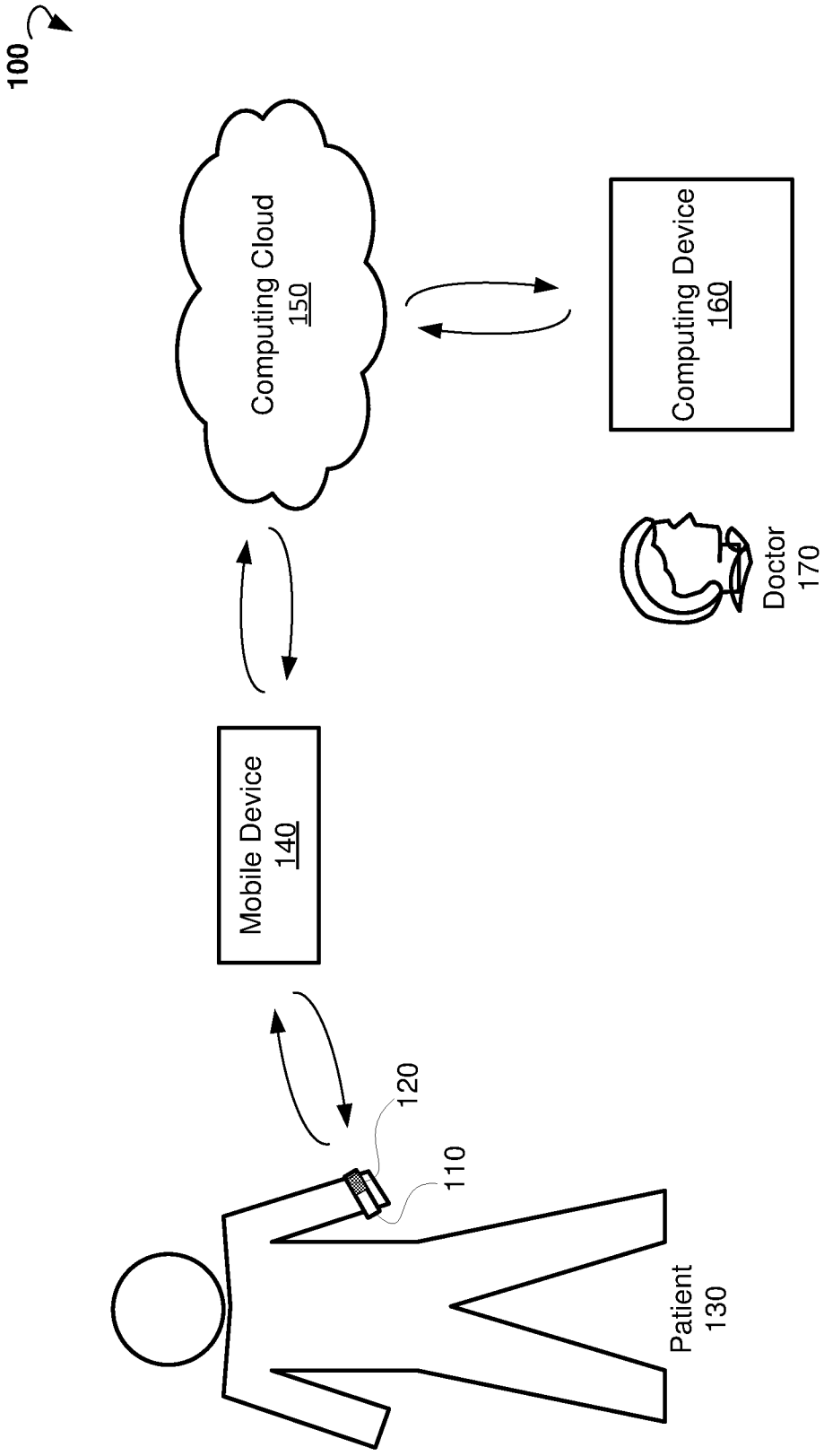

100
Computing Cloud
150
Computing Device
160
Doctor
170
Mobile Device
140
120
110
Patient
130

FIG. 1

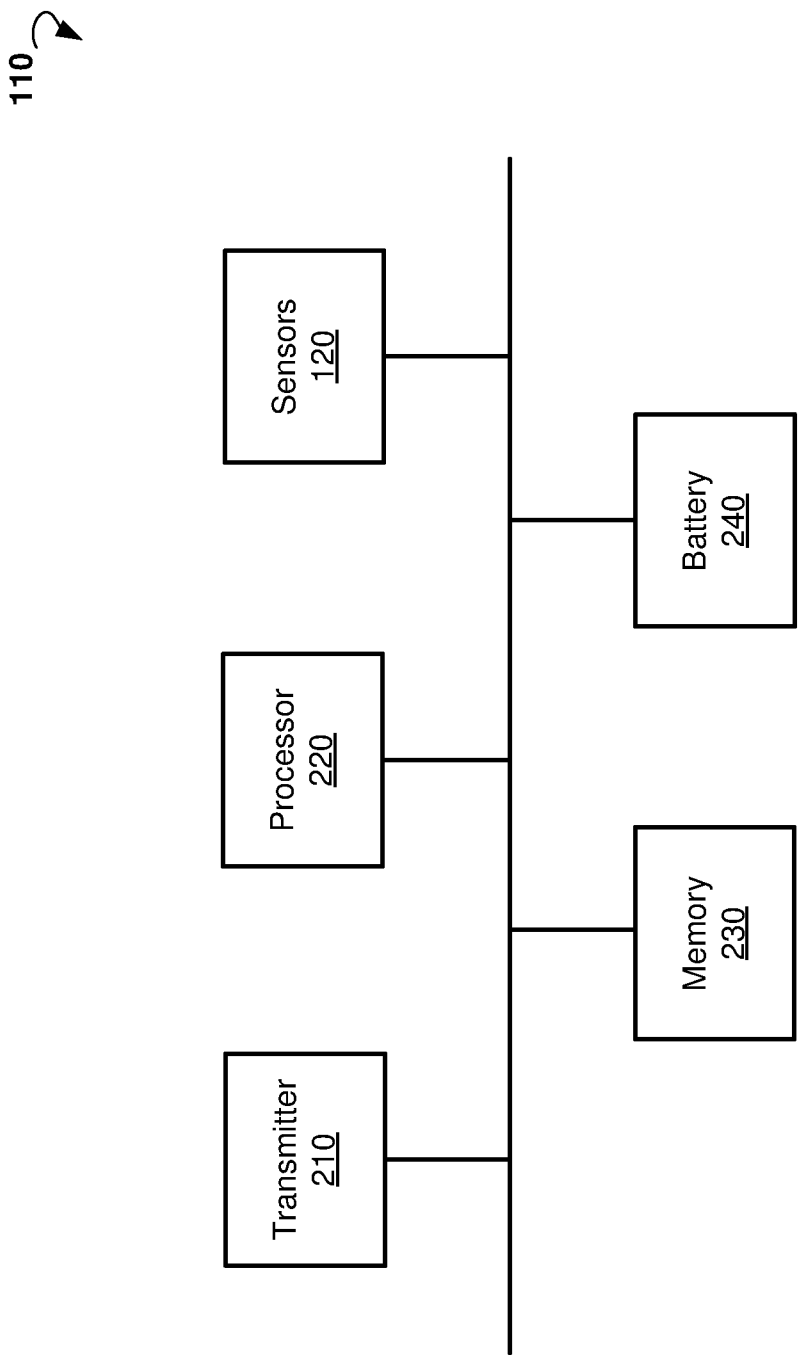
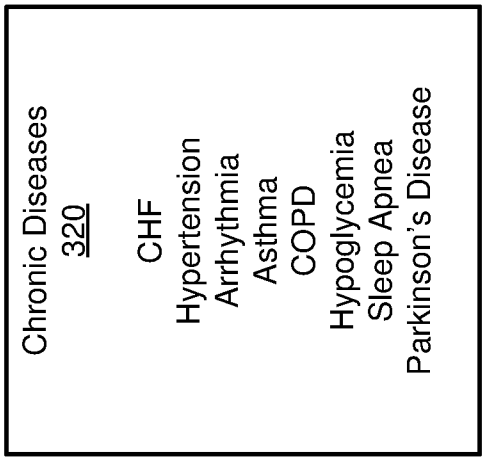
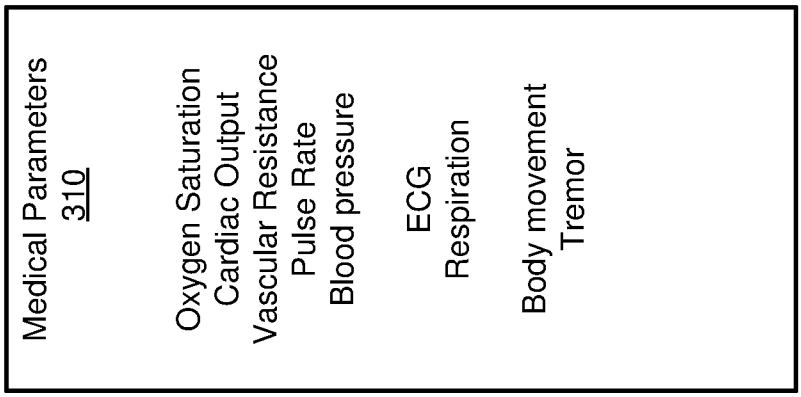

110
Sensors
120
Battery
240
Processor
220
Memory
230
Transmitter
210

FIG. 2


Chronic Diseases
320
CHF
Hypertension
Arrhythmia
Asthma
COPD
Hypoglycemia
Sleep Apnea
Parkinson's Disease


Medical Parameters
310
Oxygen Saturation
Cardiac Output
Vascular Resistance
Pulse Rate
Blood pressure
ECG
Respiration
Body movement
Tremor

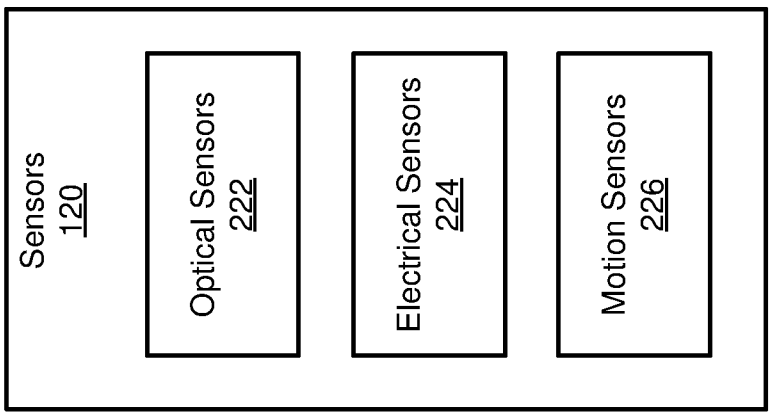

Sensors
120
Optical Sensors
222
Electrical Sensors
224
Motion Sensors
226

FIG. 3

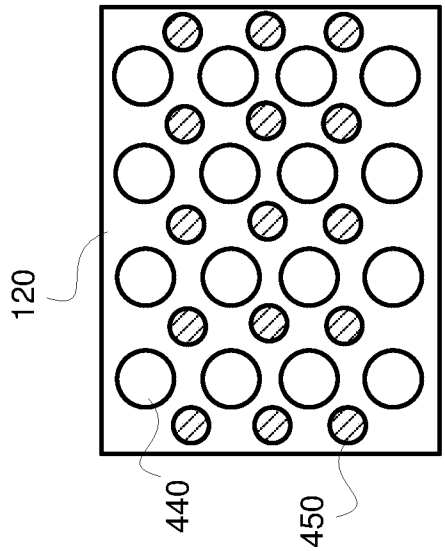


FIG. 4B

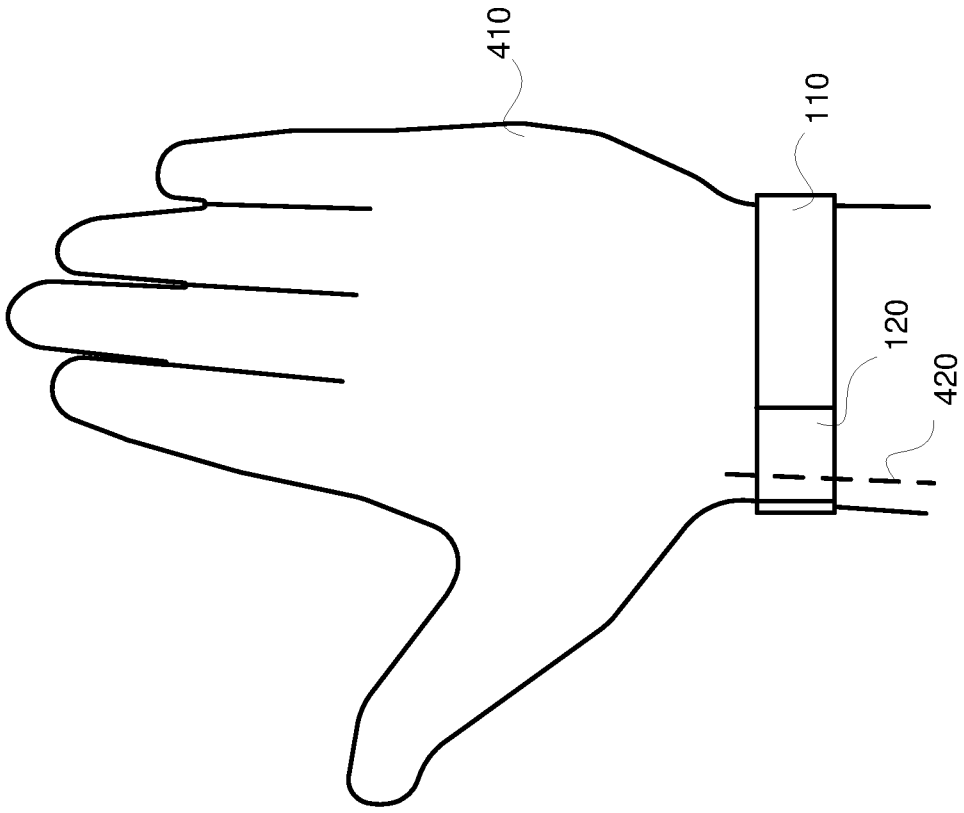


FIG. 4A

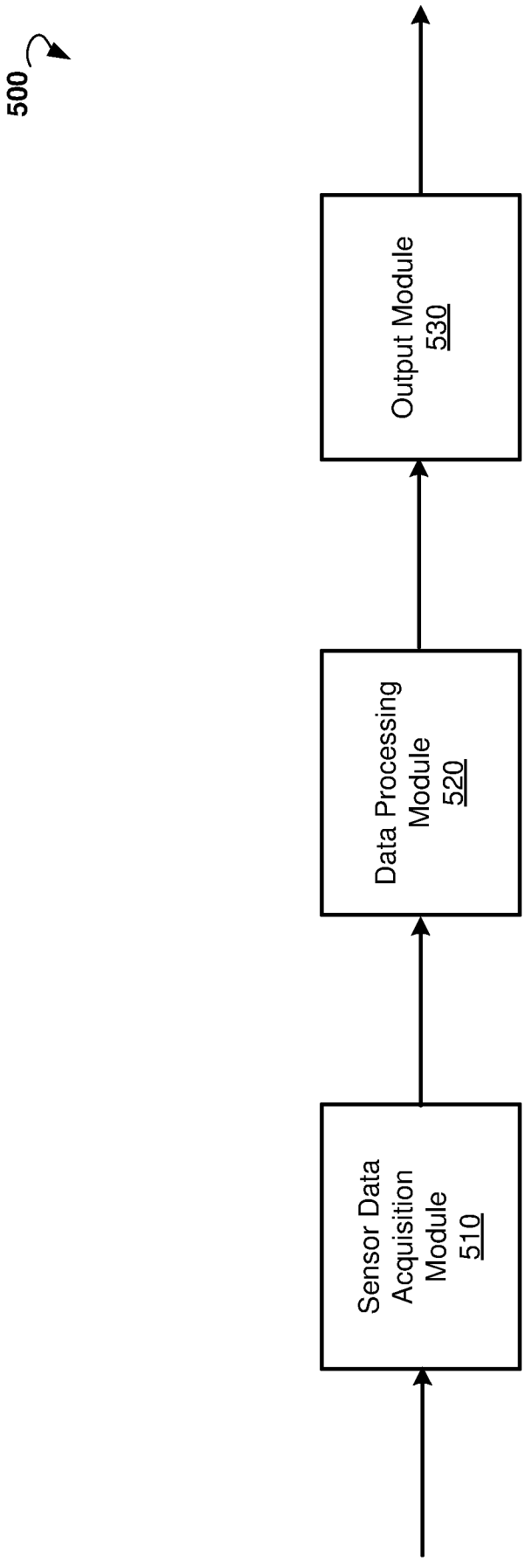

500
Sensor Data Acquisition Module 510
Data Processing Module 520
Output Module 530

FIG. 5

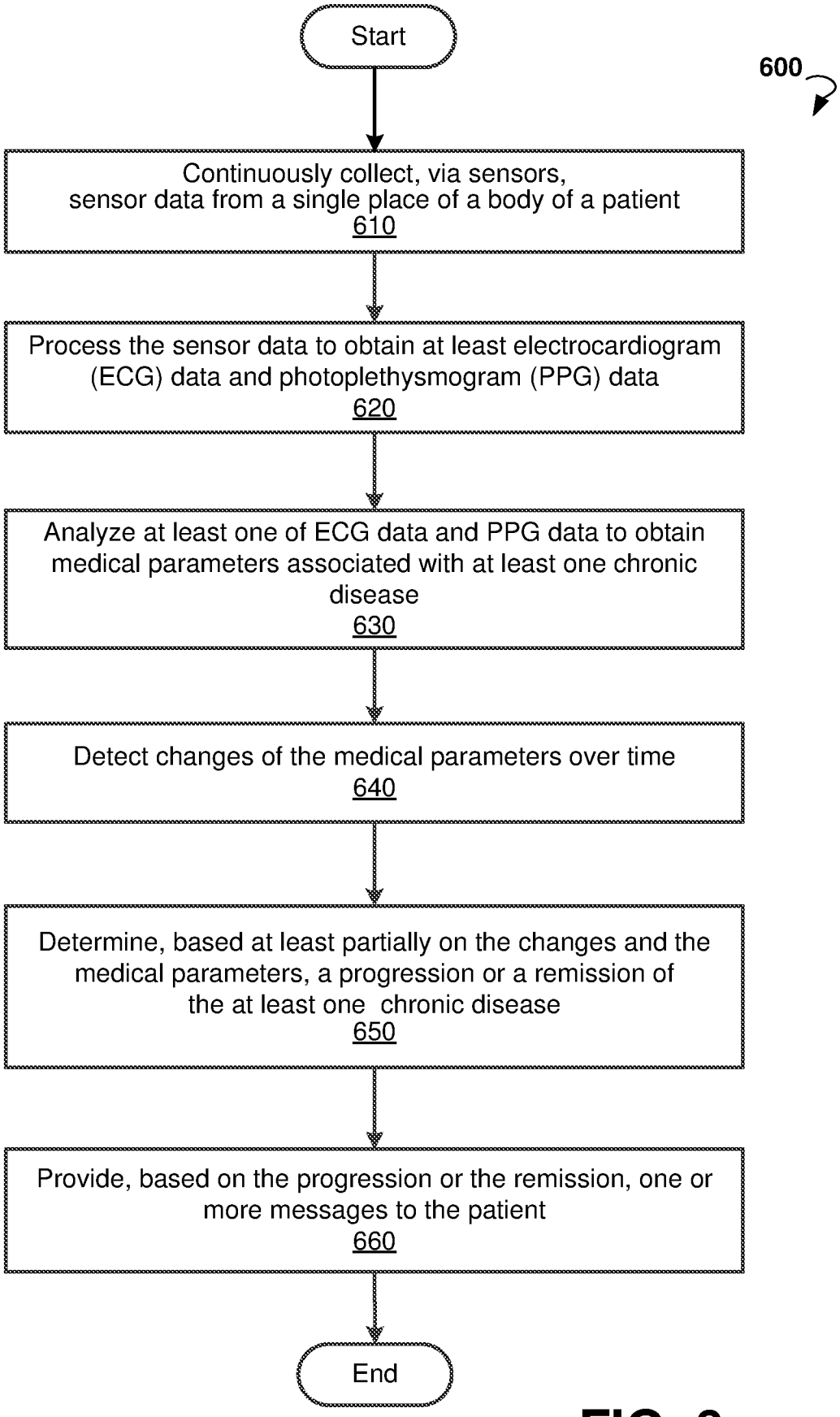

Start
600
Continuously collect, via sensors, sensor data from a single place of a body of a patient
610
Process the sensor data to obtain at least electrocardiogram (ECG) data and photoplethysmogram (PPG) data
620
Analyze at least one of ECG data and PPG data to obtain medical parameters associated with at least one chronic disease
630
Detect changes of the medical parameters over time
640
Determine, based at least partially on the changes and the medical parameters, a progression or a remission of the at least one chronic disease
650
Provide, based on the progression or the remission, one or more messages to the patient
660
End

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2016/050511

A. CLASSIFICATION OF SUBJECT MATTER

IPC (2016.01) A61B 5/020500, A61B 5/00, A61B 5/02, A61B 5/040800, A61B 5/021

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC (2016.01) A61B 5/020500, A61B 5/00, A61B 5/02, A61B 5/040800, A61B 5/021

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases consulted: THOMSON INNOVATION, Esp@cenet, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014275888 A1 Wegerich et al. 18 Sep 2014 (2014/09/18) (The whole document especially abstract, Figs. 1, 2A, 2B, 3-7, paragraphs 6-8, 10, 12-14, 29, 30-32, 42-48, 50-51, 60, 61, 70).	1-20
Y	US 2011224564 A1 MOON et al. 15 Sep 2011 (2011/09/15) (The whole document especially abstract, Figs. 1, 2A, 2B, 4, 5, 7, 9, 11, 12, 20, 26-28).	1-20
Y	US 2011066051 A1 MOON et al 17 Mar 2011 (2011/03/17) (The whole document especially abstract, Figs. 1, 2, 4A, 4B, 14).	1-20
Y	US 2013338460 A1 He et al. 19 Dec 2013 (2013/12/19) (The whole document especially abstract, Figs. 1a, 1b, 3a-3c, 4a, 4b, 5, 6a-6d).	1-20
Y	WO 2014022906 A1 Harris. 13 Feb 2014 (2014/02/13) (The whole document especially abstract, Figs. 1, 4 , 7-10, Claims 1, 10, paragraphs 79, 80).	1-20

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 Jul 2016	11 Jul 2016
Name and mailing address of the ISA: Israel Patent Office Technology Park, Bldg.5, Malcha, Jerusalem, 9695101, Israel Facsimile No. 972-2-5651616	Authorized officer NIMER Emad Telephone No. 972-2-5657801

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL2016/050511

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010298656 A1 McCombie et al. 25 Nov 2010 (2010/11/25) (The whole document especially abstract, Figs. 1-4, 8, 11A, 11B, 20A, 20B).	1-20
Y	US 6047203 A Sackner et al. 04 Apr 2000 (2000/04/04) (The whole document especially abstract, Figs. 1-3).	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2016/050511

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
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US 2011224564 A1	15 Sep 2011	US 2011224564 A1	15 Sep 2011
		EP 2544584 A1	16 Jan 2013
		EP 2544584 A4	15 Jul 2015
		SG 183973 A1	30 Oct 2012
		SG 10201502467U A	28 May 2015
		US 2011224507 A1	15 Sep 2011
		US 8591411 B2	26 Nov 2013
		US 2011224557 A1	15 Sep 2011
		US 8727977 B2	20 May 2014
		US 2011224498 A1	15 Sep 2011
		US 2011224499 A1	15 Sep 2011
		US 2011224500 A1	15 Sep 2011
		US 2011224506 A1	15 Sep 2011
		US 2011224508 A1	15 Sep 2011
		US 2011224556 A1	15 Sep 2011
		WO 2011112782 A1	15 Sep 2011
US 2011066051 A1	17 Mar 2011	US 2011066051 A1	17 Mar 2011
		US 8364250 B2	29 Jan 2013
		EP 2470067 A1	04 Jul 2012
		EP 2470067 A4	02 Oct 2013
		SG 179149 A1	27 Apr 2012
		SG 10201405704Q A	30 Oct 2014
		US 2011066050 A1	17 Mar 2011
		US 8321004 B2	27 Nov 2012
		US 2011066009 A1	17 Mar 2011
		US 8527038 B2	03 Sep 2013
		US 2011066010 A1	17 Mar 2011
		US 2011066044 A1	17 Mar 2011

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2016/050511

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		US 2011066045 A1	17 Mar 2011
		WO 2011034881 A1	24 Mar 2011
US 2013338460 A1	19 Dec 2013	US 2013338460 A1	19 Dec 2013
		CA 2877282 A1	27 Dec 2013
		CN 104602592 A	06 May 2015
		EP 2861133 A1	22 Apr 2015
		IL 236329 D0	26 Feb 2015
		JP 2015519999 A	16 Jul 2015
		KR 20150023795 A	05 Mar 2015
		WO 2013192166 A1	27 Dec 2013
WO 2014022906 A1	13 Feb 2014	WO 2014022906 A1	13 Feb 2014
		CA 2912358 A1	13 Feb 2014
		US 2015182132 A1	02 Jul 2015
US 2010298656 A1	25 Nov 2010	US 2010298656 A1	25 Nov 2010
		US 8180440 B2	15 May 2012
		EP 2432380 A1	28 Mar 2012
		EP 2432380 A4	06 Mar 2013
		SG 176190 A1	29 Dec 2011
		SG 10201403428U A	26 Sep 2014
		US 2012190949 A1	26 Jul 2012
		US 8594776 B2	26 Nov 2013
		US 2010298660 A1	25 Nov 2010
		US 8909330 B2	09 Dec 2014
		US 2010298658 A1	25 Nov 2010
		US 8956293 B2	17 Feb 2015
		US 2010298659 A1	25 Nov 2010
		US 8956294 B2	17 Feb 2015
		US 2014163393 A1	12 Jun 2014

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IL2016/050511

Patent document cited search report	Publication date	Patent family member(s)	Publication Date
		US 9055928 B2	16 Jun 2015
		US 2010298657 A1	25 Nov 2010
		US 2010298661 A1	25 Nov 2010
		US 2015164437 A1	18 Jun 2015
		US 2015282717 A1	08 Oct 2015
		WO 2010135518 A1	25 Nov 2010
US 6047203 A	04 Apr 2000	US 6047203 A	04 Apr 2000
		AT 477746 T	15 Sep 2010
		DE 69841846 D1	30 Sep 2010
		EP 0969897 A1	12 Jan 2000
		EP 0969897 A4	18 Jul 2007
		EP 0969897 B1	18 Aug 2010
		EP 2305110 A1	06 Apr 2011
		IL 131592 D0	28 Jan 2001
		JP 2002507131 A	05 Mar 2002
		JP 4555919 B2	06 Oct 2010
		WO 9841279 A1	24 Sep 1998