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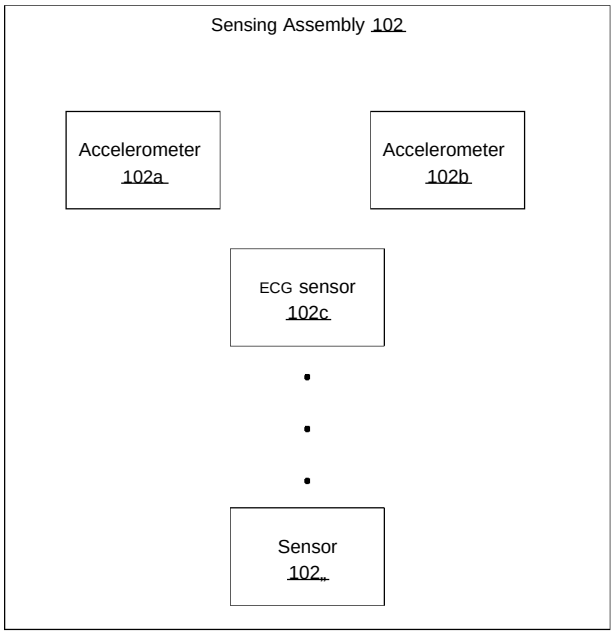

FIG. 3

(57) Abstract: A blood pressure and cardiac monitoring system includes a sensing assembly, which comprises a first sensor (102a) located at a first axis of a target generating a first time-dependent motion waveform (302) representative of one or more contractile properties of the target's heart and a second sensor (102b) located at a second axis of the target generating a second time dependent motion waveform (304). The processor is configured to determine a first time difference between a vital sign present in the first time dependent motion waveform and the second time dependent motion waveform. A third sensor (102c) located either at the first or the second axis of the target generates a third time dependent waveform (300) representative of the electrical potential due to the depolarization of heart muscle. At least one of the sensors may be configured to either remove motion artifacts (as a reference sensor) or detect attributes from the environment for providing context awareness information.

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Blood Pressure and Cardiac Monitoring System and Method Thereof

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/319,920, filed April 8, 2016, which is incorporated herein by reference.

FIELD

[0002] This disclosure is related to health monitoring devices, and more particularly, to a blood pressure and cardiac monitoring system and method for monitoring vital signs.

SUMMARY

[0003] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0004] Embodiments of the disclosure related to a blood pressure and cardiac monitoring system are described. For example, the system comprises a sensing assembly and a processor communicatively coupled to the sensing assembly. The sensing assembly comprises a first accelerometer located at a first axis of a target generating a first time-dependent motion waveform representative of one or more contractile properties of the target's heart and a second accelerometer located at a second axis of the target generating a second time dependent motion waveform representative of the target's blood flow. The processor configured to receive the first time dependent motion waveform and the second time dependent motion waveform,

and to determine a first time difference between a vital sign present in the first time dependent motion waveform and the second time dependent motion waveform.

[0005] In another embodiment, a third sensor located either along the first or the second axis of the target generating a third time dependent waveform representative of the electrical potential due to the depolarization of heart muscle is provided.

[0006] In yet another embodiment, a fourth sensor located along any axis of the target is provided.

[0007] In one or more embodiments, the fourth sensor is configured to either remove motion artifacts (as a reference sensor) or detect attributes from the environment for providing context awareness information.

[0008] Embodiments of another disclosure relates to a sensing assembly for monitoring vital signs includes a first sensor located at a first axis of a target generating a first time-dependent motion waveform representative of one or more contractile properties of the target's heart and a second sensor located at a second axis of the target generating a second time dependent motion waveform representative of the target's blood flow. A processor configured to receive the first time dependent motion waveform and the second time dependent motion waveform, and to determine a first time difference between a vital sign present in the first time dependent motion waveform and the second time dependent motion waveform.

[0009] In one or more embodiments, a housing is provided to encapsulate the processor and the sensing assembly.

[0010] In one or more embodiments, the processor is remotely located outside the sensing assembly and is communicatively coupled to the sensing assembly via a wireless network.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] These and other features, aspects, and advantages of this disclosure will become better understood when the following detailed description of certain exemplary embodiments is read with reference to the accompanying drawings in which like characters represent like arts throughout the drawings, wherein:

[0012] FIG. 1 illustrates a block diagram of a blood pressure monitoring system according to an exemplary embodiment of a disclosure;

[0013] FIG. 2 illustrates a target with a blood pressure monitoring system of FIG. 1 placed on a sternum of the target according to a described embodiment of the disclosure;

[0014] FIG. 3 illustrates a sensing assembly for the blood pressure monitoring system of FIG. 1 according to a described embodiment of the disclosure; and

[0015] FIG. 4 illustrates a graph of time-dependent waveforms according to an exemplary embodiment of the disclosure.

DETAILED DESCRIPTION

[0016] One or more specific embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the

developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0017] The following description is presented to enable any person skilled in the art to make and use the described embodiments, and is provided in the context of a particular application and its requirements. Various modifications to the described embodiments will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the described embodiments. Thus, the described embodiments are not limited to the embodiments shown, but are to be accorded the widest scope consistent with the principles and features disclosed herein.

[0018] As used herein, the term "electrocardiography (ECG)" refers to the changes of the electrical potential due to the depolarization of heart muscle. R-peak of the ECG signal can be used in the calculation of time intervals for monitoring blood pressure (e.g. RJ-time interval), R-peak or Q-peak of ECG signal for monitoring cardiac activity (e.g. pre-ejection period (PEP) and its influencing parameters such as hormones, preload, afterload, etc.) or as the trigger to start data measurement/analysis. The term "seismocardiography (SCG)" refers to the acceleration of the sternum caused by the cardiac activity of the heart while the term "ballistocardiography (BCG)" refers to the changes in the center of mass of the body due to blood flow or heart activity. The J-peak of the RJ-time interval comes from

the peak obtained from either SCG or BCG. In an example case where a tri-axis accelerometer is used for SCG measurement, the J-peak of the SCG is labelled as J_x-peak for acceleration in the X-axis (also referred as head-to-foot axis), Jy-peak in Y-axis (also referred as right-left axis) and J_z-peak for acceleration in the Z-axis (also referred as dorso-ventral axis). Accelerometer signal detected on Z-axis (also referred as dorso-ventral axis) measures the chest movement due to heart contraction. J_z-peak can be used with ECG signal (e.g. R-J_z or Q-J_z time interval) to investigate important cardiac activity such as the pre-ejection period (PEP) and its influencing parameters such as hormones, preload, afterload, etc. Accelerometer signal (detected on X-axis (also referred as head-to-foot axis) measures the body recoil movement due to blood flow. J_x-peak signifies the time where blood pumps out from the heart and reaches the arches of Aorta blood vessel. One example will be R-J_x time interval for blood pressure monitoring. In the measurement of the time intervals, R-peak of ECG or J_z-peak of accelerometer can be used to trigger the start of measurement.

[0019] The blood pressure monitoring can also be performed solely using SCG or accelerometers (e.g. J_z-J_x time interval). J_z-peak signifies the time where heart contracts while J_x-peak signifies the time where the blood rushes through the arches of the Aorta blood vessel. This time interval is inversely correlated to the blood pressure. J_z-peak can also be used as the trigger to start data measurement/analysis. Jx-peak can be used in the calculation of time intervals for monitoring blood pressure (e.g. R-Jx time interval, J_z-J_x time interval, or J_x with photoplethysmogram (PPG) signal time interval). The term "photoplethysmography (PPG)" refers to the changes in light adsorption in blood. Depending on the position where the PPG data is taken,

the time interval between R-peak with PPG, J_z-peak (from SCG) with PPG, J_x-peak (from SCG) with PPG, PPG in one location with PPG in another location, can be used to monitor blood pressure or blood flow velocity.

[0020] FIG. 1 illustrates an exemplary embodiment of a blood pressure monitoring system 100. The system 100 can be either removably worn by a target, i.e. a patient, applied to, or placed at a sternum of the target and configured to either continuously, semi-continuously, or synchronously detected at least one signal. In some embodiments, the system 100 can be implanted into the target. In another embodiment, the system 100 can be integrated into a client device either worn by the target, applied to, or positioned placed at the sternum of the target and configured to either continuously, semi-continuously, or synchronously detected at least one signal. As some examples, the client device may be a patch, a neckless, a chest strap, a pendant, or any suitable device. If the system 100 is implantable into the target, the system 100 may be a pacemaker, or any suitable implantable device. The system 100 includes a sensing assembly 102, a processor 104, a memory 106, a communication interface 108, and any suitable computer implemented modules communicatively coupled to each other via a bus. A housing may be provided to encapsulate at least one or more of the sensing assembly 102, the processor 104, the memory 106, and the communication interface 108. In one embodiment, the housing may be formed from a thin film material that allows the target to stretch, bend, twist, squeeze, fold, expand, or combination thereof either worn by the target, applied to, reapplied to, removed from, or positioned placed at the sternum of the target. The memory 106 communicatively coupled to the processor 104 stores computer-readable instructions

that, when executed by the processor 104 of the system 100, causes the system, and more particularly the processor 104, to perform or monitor vital signs and cardiac activity based on the detected signal transmitted by the sensing assembly 102. The memory 106 may include any transitory, non-transitory, volatile, non-volatile, magnetic, optical, or electrical media, such as a random access memory (RAM), read-only memory (ROM), non-volatile RAM (NVRAM), electrically-erasable programmable ROM (EEPROM), flash memory, or any other digital or analog media. The vital signs include body temperature, pulse rate, blood pressure, and respiratory rate.

[0021] The processor 104 may be of any type, including but not limited to a microprocessor, a microcontroller, a digital signal processor, or any combination thereof. The processor 104 may include one or more levels of caching, such as a level cache memory, one or more processor cores, and registers. Depending on the desired configuration, the processor may be of any type, including but not limited to a microprocessor (μP), a microcontroller (μC), a digital signal processor (DSP), or any combination thereof. The processor may include one or more levels of caching, such as a level cache memory, one or more processor cores, and registers. The example processor cores may (each) include an arithmetic logic unit (ALU), a floating point unit (FPU), a digital signal processing core (DSP Core), or any combination thereof. An example memory controller may also be used with the processor, or in some implementations the memory controller may be an internal part of the processor. The communication interface 108 allows software and data to be transferred between a computer system external to the system 100 and the system in the form of signals

which may be, for example, electronic, electromagnetic, optical, or other signals capable of being received by the communication interface. The communication interface may be for example a modem, a network interface, a communication port, a PCM-CIA slot and card, or the like. The sensing assembly 102 is configured to detect at least one or more of electrocardiogram (ECG) signal, a first motion signal, a second motion signal, a photoplethysmorgram (PPG) signal, seismocardiogram signal (SCG) and ballistocardiogram (BCG) signal. In one embodiment, the sensing assembly 102 is a single-axis sensing assembly. In another embodiment, the sensing assembly 102 is a double-axis sensing assembly. In yet another embodiment, the sensing assembly 102 is a multi-axis assembly. As an example, the sensing assembly 102 includes at least one sensor device. The sensor device may be an accelerometer, a motion sensor, an optical sensor, a transducer, a Doppler ultrasonic transducer, an acoustic sensor, an electrode, an ECG sensor, a target orientation sensor, a sonar sensor, a thermal sensor, an environmental sensor, and any suitable sensor or transducer. As an example, a first sensor device located at a first axis of the target for detecting a first time-dependent motion waveform representative of one or more contractile properties of the target's heart and a second sensor device located at a second axis of the target for detecting a second time dependent motion waveform representative of the target's blood flow. Additional sensors provided at a location along any axis of the target to either remove motion artifacts (as a reference sensor) or detect attributes from the environment for providing context awareness information.

[0022] The system 100 may be a wired computing system or a wireless computing system. In one embodiment, the system 100 is a cloud computing device which may be communicated with via the Internet, and which may be co-located or geographically distributed, wherein shared resources, software, and information are provided to computers and other devices on demand for example, as will be appreciated by those skilled in the art. In another embodiment, the cloud blood pressure system 100 may be implemented as one or more servers which may be communicated with via the Internet. The system 100 may communicatively couple to a computing device 122, a server 124, or a network 126 via one or more links. The link may be wired, wireless, or combination thereof. The wireless communication link may include cellular protocol, data packet protocol, radio frequency protocol, satellite band, infrared channel, or any other protocol able to transmit data among client machines. The wired communication link may include any wired line link.

[0023] Depending on the application, one or more servers may be communicatively coupled to the computing device 122 to and the system 100. The server 124 may be an application server, a certificate server, a mobile information server, an e-commerce server, a FTP server, a directory server, CMS server, a printer server, a management server, a mail server, a public/private access server, a real-time communication server, a database server, a proxy server, a streaming media server, or the like. The client machine 122 may be a personal computer or desktop computer, a laptop, a cellular or smart phone, a tablet, a personal digital assistant (PDA), a gaming console, an audio device, a video device, an entertainment device such as a television, a vehicle infotainment, a wearable device, a thin client system, a thick client system,

or the like. The client machine 122 can in some embodiment be referred to as a single client machine or a single group of client machines, while the server 124 may be referred to as a single server or a single group of servers. In one embodiment a single client machine communicates with more than one server, while in another embodiment a single server communicates with more than one client machine. In yet another embodiment, a single client machine communicates with a single server. The network 126 can comprise one or more sub-networks, and can be installed between any combination of the client machines 122 and the server 124. In some embodiments, the network 126 can be for example a local-area network (LAN), a metropolitan area network (MAN), a wide area network (WAN), a primary network 126 comprised of multiple sub-networks located between the client machines 122 and the server 124. Still further embodiments include the network 126 that can be any network types such as a point to point network, a broadcast network, a telecommunication network, a data communication network, a computer network, an ATM (Asynchronous Transfer Mode) network, a SONET (Synchronous Optical Network) network, a SDH (Synchronous Digital Hierarchy) network, a wireless network, a wireline network, and the like. Depending on the application, other networks may be used so that data exchanged between the client machine and the server can be transmitted over the network. Network topology of the network 124 can differ within different embodiments which may include a bus network topology, a star network topology, a ring network topology, a repeater-based network topology, or a tiered-star network topology. Additional embodiments may include a network of mobile telephone networks that use a protocol to communicate among mobile

devices, where the protocol can be for example AMPS, TDMA, CDMA, GSM, GPRS, UMTS, LTE or any other protocol able to transmit data among mobile devices.

[0024] FIG. 2 illustrates a target 202, such as a user or a patient, with a blood pressure monitoring system 200 according to a described embodiment of the disclosure. The system 200 identical to the system 100 depicted in FIG. 1 is placed on a sternum of the target and configured to continuously, semi-continuously, or synchronously detect or monitor at least one or more of electrocardiogram (ECG) signal, a first motion signal, a second motion signal, a photoplethysmorgram (PPG) signal, a seismocardiogram (SCG) signal, a ballistocardiogram (BCG) signal or environmental signal. In some embodiments, the system 200 is placed on the sternum of the target for sensing movement of the chest wall. Since bones can transfer the body movement due to cardiac activities with less damping effects than muscles, the system 200 is able to detect the signal that is less affected by motion artifacts. In another embodiment, the system 100 may be placed on any location of the body proximal to the sternum of the target. In yet another embodiment, the system 200 is configured to detect the time interval between heart contraction and blood flow. As illustrated, X-axis 204, Y-axis 206, and Z-axis 208 are provided. A first sensor device of the system 100 located at a first axis of the target for continuously detecting a first time-dependent motion waveform representative of one or more contractile properties of the target's heart and a second sensor device located at a second axis of the target for continuously detecting a second time dependent motion waveform representative of the target's blood flow. The first axis is the

dorso-ventral axis and the second axis is the head-to-foot axis. The axis can be interchangeable between x, y, and z depending on position arrangement of the system 200. If the system 200 is pointing at X-axis 204, as illustrated in FIG. 2 the first axis is the Z-axis 208 and the second axis is the X-axis 204. In another embodiment, the system 200 is pointing at Y-axis 206, the first axis is the Z-axis 208 and the second axis is the Y-axis 206. The sensor devices may be a single-axis sensor device or a double-axis sensor device. In another embodiment, the sensor device is a multi-axis sensor device configured to map the resulting vector along the axis of interest, e.g. if the multi-axis sensor device is rotated and not completed aligned with for example the head-to-foot axis. As illustrated, the first and second sensor devices are accelerometers.

[0025] FIG. 3 illustrates a sensing assembly 102 for the blood pressure monitoring system 100. The sensing assembly 102 is configured to detect at least one or more of electrocardiogram (ECG) signal, a first motion signal, a second motion signal, a photoplethysmorgram (PPG) signal, seismocardiogram (SCG) signal and ballistocardiogram (BCG) signal. In one embodiment, the sensing assembly 102 is a single-axis sensing assembly. In another embodiment, the sensing assembly 102 is a double-axis sensing assembly. In yet another embodiment, the sensing assembly 102 is a multi-axis assembly. As an example, the sensing assembly 102 includes at least one sensor device. The sensor device may be an accelerometer, a motion sensor, an optical sensor, a transducer, a Doppler ultrasonic transducer, an acoustic sensor, an electrode, an ECG sensor, a target orientation sensor, a sonar sensor, a thermal sensor, an environmental sensor, and any suitable sensor or transducer. As an example, a

first sensor device located at a first axis of the target generates a first time-dependent motion waveform representative of one or more contractile properties of the target's heart and a second sensor device located at a second axis of the target generates a second time dependent motion waveform representative of the target's blood flow. As another example, a third sensor device located at either the first or the second axis of the target generates a third time dependent waveform representative of the electrical potential due to the depolarization of heart muscle. In one embodiment, the first and second sensor devices are accelerometers 102a, 102b and the third sensor device 102c is either an electrode or a ECG sensor. In another embodiment, a fourth sensor located along any axis of the target is provided and is configured to either detect attributes from the environment for providing context awareness information or remove motion artifacts (as reference sensor).

[0026] FIG. 4 illustrates time-dependent waveforms, ECG waveform 300, a first motion waveform 302, and a second motion waveform 304 continuously monitored by the blood pressure system to determine the target's vital sign, i.e. blood pressure and cardiac activity (e.g. PEP and its influencing parameters). The ECG waveform 300, generated by the ECG sensor 102c of the sensing assembly 102 placed on the target represents the electrical excitation of the heart, features a peak 310. The first motion waveform 302 generated by the first accelerometer 102a of the sensing assembly 102 represents the chest movement due to the heart contraction or the cardiac activity of the heart. In one embodiment, the first motion waveform 302 is a SCG waveform in the Z-axis. In another embodiment, the first motion waveform 302 is a BCG waveform in the Z-axis. The second motion waveform 304, generated by

the second accelerometer 102b of the sensing assembly 102 represents the body recoil movement due to the blood flow, features a peak 306. In one embodiment, the second motion waveform 304 is a SCG waveform in the X-axis. In another embodiment, the second motion waveform 304 is a BCG waveform in the X-axis. The peak 310 also referred as R-peak of ECG waveform 300 may be used either in the calculation of time intervals for monitoring blood pressure, vital signs and cardiac activity or to trigger a start of blood pressure measurement. The peak 312 also referred as Q-peak of ECG waveform 300 may also be used in the calculation of time intervals for monitoring blood pressure, vital signs and cardiac activity or to trigger a start of blood pressure measurement. Any points along the first motion waveform 302 may be used in calculation of time intervals for monitoring blood pressure, vital signs and cardiac activity or to trigger a start of blood pressure measurement. As an example, the peak 314 may be used in calculation of time intervals for monitoring blood pressure, vital signs and cardiac activity or to trigger a start of blood pressure measurement. As another example, the peak 316 may be used in calculation of time intervals for monitoring blood pressure, vital signs and cardiac activity or to trigger a start of blood pressure measurement. Any points along second motion waveform 304 may be used in the calculation of time intervals for monitoring blood pressure, vital signs and cardiac activity. As one example, the peak 306 may be used in the calculation of time intervals for monitoring blood pressure, vital signs and cardiac activity. In one embodiment, the time difference between the peaks 306, 310 is pulse arrival time (PAT). In another embodiment, the time difference between any points 312 located along the ECG waveform 300 and the peak 306 of the second motion

waveform 304 features the PAT. As an example, the point 312 is located at Q. As described previously, pre-ejection period (PEP) is defined between two points located along waveforms 300, 302. In one embodiment, J_{z1}-peak 314 located along the waveform 302 can be used with point Q 312 along the ECG waveform 300 to investigate important cardiac activity such as the pre-ejection period (PEP) and its influencing parameters such as hormones, preload, afterload, etc. In yet another embodiment, J_{Z2}-peak 316 located along the waveform 302 can be used with point Q 312 along the ECG waveform 300 to investigate important cardiac activity such as the pre-ejection period (PEP) and its influencing parameters such as hormones, preload, afterload, etc. In yet another embodiment, J_{z1}-peak 314 located along the waveform 302 can be used with peak R 310 along the ECG waveform 300 to investigate important cardiac activity such as the pre-ejection period (PEP) and its influencing parameters such as hormones, preload, afterload, etc. In further yet another embodiment, J_{z2}-peak 316 located along the waveform 302 can be used with peak R 310 along the ECG waveform 300 to investigate important cardiac activity such as the pre-ejection period (PEP) and its influencing parameters such as hormones, preload, afterload, etc. As one embodiment, the time difference between J_{z1}-peak 314 of the waveform 302 and the peak 306 of the waveform 304 features pulse transit time (PTT).

[0027] The time interval between the J_z-peak of the dorso-ventral axis to the J_x-peak of the head-to-foot axis signifies the time it takes for the heart to start contracting till the time the blood flow reaches the arches of the aorta. This J_z-J_x time interval can be used to monitor blood pressure or relative blood pressure. The time

interval can also be used to monitor other cardiovascular parameters such as arterial stiffness, as one example.

[0028] As described above, blood pressure can be monitored by measuring the blood flow velocity profile of two PPG signals at two different locations at the time intervals. Alternatively, the blood flow velocity can be measured using a Doppler ultrasonic transducer. This method uses reflection of ultrasonic irradiation of frequency f_0 from the blood in any arteries, e.g. the Aorta, with additional ultrasonic frequencies appearing in the reflected wave spectrum as sidebands at spectral position f_0 +/- Af, with Af being a time-dependent function of blood velocity v(t):

$$\Delta f(t) = \Delta f(v) = \Delta f(v(t))$$

[0029] The peak reading of Δf or its amplitude Δf_A corresponds to the peak velocity v_A of the blood ejected from the heart into the aorta, and has a correlation to blood pressure. Δf_A or v_A corresponds to the systolic blood pressure.

[0030] The minimum reading of Af in between 2 maxima Δf_A, namely Δf_{min} has a correlation to the minimum blood velocity v_{min} and to blood pressure as well. Δf_{min} or V_{min} corresponds to the diastolic blood pressure.

[0031] The measurement of Af can be done by synchronous demodulation of the reflected ultrasonic signal spectrum with the center frequency f_0 into the base-band, by a combination of mixing stage and low-pass filter, or any suitable FM-demodulation technique. Phase-locked loop demodulators, ratio-detectors, and any suitable active components, depending on the applications, may be used.

[0032] In yet another embodiment, the sensor device may be any suitable piezoelectric or electrostatic/capacitive bending actuator or bimorph configured to

convert an electrical carrier frequency signal at fo into an ultrasonic wave, and an incoming ultrasonic wave spectrum is converted back to an electrical signal spectrum for further analysis. In addition, at least one accelerometer signal can be used, depending on the application, to trigger the ultrasonic irradiation and evaluation loop, for cross-correlating data, and for providing context-awareness information. More than one accelerometer of the system 200 can also be used to detect if the user is moving or the kind of activity the user is doing, to add additional information to the user. The additional accelerometer can also be utilized to reduce/filter motion artifacts from the J_x or J_z data.

[0033] The embodiments described above have been shown by way of example, and it should be understood that these embodiments may be susceptible to various modifications and alternative forms. It should be further understood that the claims are not intended to be limited to the particular forms disclosed, but rather to cover all modifications, equivalents, and alternatives falling with the sprit and scope of this disclosure.

[0034] While the patent has been described with reference to various embodiments, it will be understood that these embodiments are illustrative and that the scope of the disclosure is not limited to them. Many variations, modifications, additions, and improvements are possible. More generally, embodiments in accordance with the patent have been described in the context or particular embodiments. Functionality may be separated or combined in blocks differently in various embodiments of the disclosure or described with different terminology. These

and other variations, modifications, additions, and improvements may fall within the scope of the disclosure as defined in the claims that follow.

What is claimed is:

1. A blood pressure and cardiac monitoring system comprising:

a sensing assembly comprising:

a first accelerometer located at a first axis of a target generating a first time-dependent motion waveform representative of one or more contractile properties of the target's heart; and

a second accelerometer located at a second axis of the target generating a second time dependent motion waveform representative of the target's blood flow; and

a processor configured to receive the first time dependent motion waveform and the second time dependent motion waveform, and to determine:

a first time difference between a vital sign present in the first time dependent motion waveform and the second time dependent motion waveform.

2. The blood pressure and cardiac monitoring system of claim 1 further comprising at least one of a memory and a communication interface.

3. The blood pressure and cardiac monitoring system of claim 1 further comprising a third sensor located either at the first or the second axis of the target generating a third time dependent waveform representative of the electrical potential due to the depolarization of heart muscle.

4. The blood pressure and cardiac monitoring system of claim 1 wherein the system is integrated into a client device and the processor is disposed in the client device.

5. The blood pressure and cardiac monitoring system of claim 1 wherein the system is integrated into a client device and the processor is disposed in the system.

6. The blood pressure and cardiac monitoring system of claim 1 wherein the system is a cloud computing device.

7. The blood pressure and cardiac monitoring system of claim 1 wherein the system is communicatively coupled to at least one of a client device, a server, and a network.

8. The blood pressure and cardiac monitoring system of claim 3 wherein the third sensor is selected from a group consisting of an accelerometer, a motion sensor, an optical sensor, a transducer, a Doppler ultrasonic transducer, an acoustic sensor, an electrode, an ECG sensor, a sonar sensor, a thermal sensor, an environmental sensor, and a target orientation sensor.

9. A sensing assembly for monitoring vital signs comprising:

a first sensor located at a first axis of a target generating a first time-dependent motion waveform representative of one or more contractile properties of the target's heart; and

a second sensor located at a second axis of the target generating a second time dependent motion waveform representative of the target's blood flow; and

a processor configured to receive the first time dependent motion waveform and the second time dependent motion waveform, and to determine:

a first time difference between a vital sign present in the first time dependent motion waveform and the second time dependent motion waveform.

10. The sensing assembly of claim 9 further comprising a third sensor located either at the first or the second axis of the target generating a third time dependent waveform representative of the electrical potential due to the depolarization of heart muscle.

11. The sensing assembly of claim 9 wherein the assembly is integrated into a client device and the processor is disposed in the client device.

12. The sensing assembly of claim 9 wherein the assembly is a cloud computing device.

13. The sensing assembly of claim 9 wherein the assembly is communicatively coupled to at least one of a client device, a server, and a network.

14. The sensing assembly of claim 10 wherein the sensor is selected from a group consisting of an accelerometer, a motion sensor, an optical sensor, a transducer, a Doppler ultrasonic transducer, an acoustic sensor, an electrode, an ECG sensor, a sonar sensor, a thermal sensor, an environmental sensor, and a target orientation sensor.

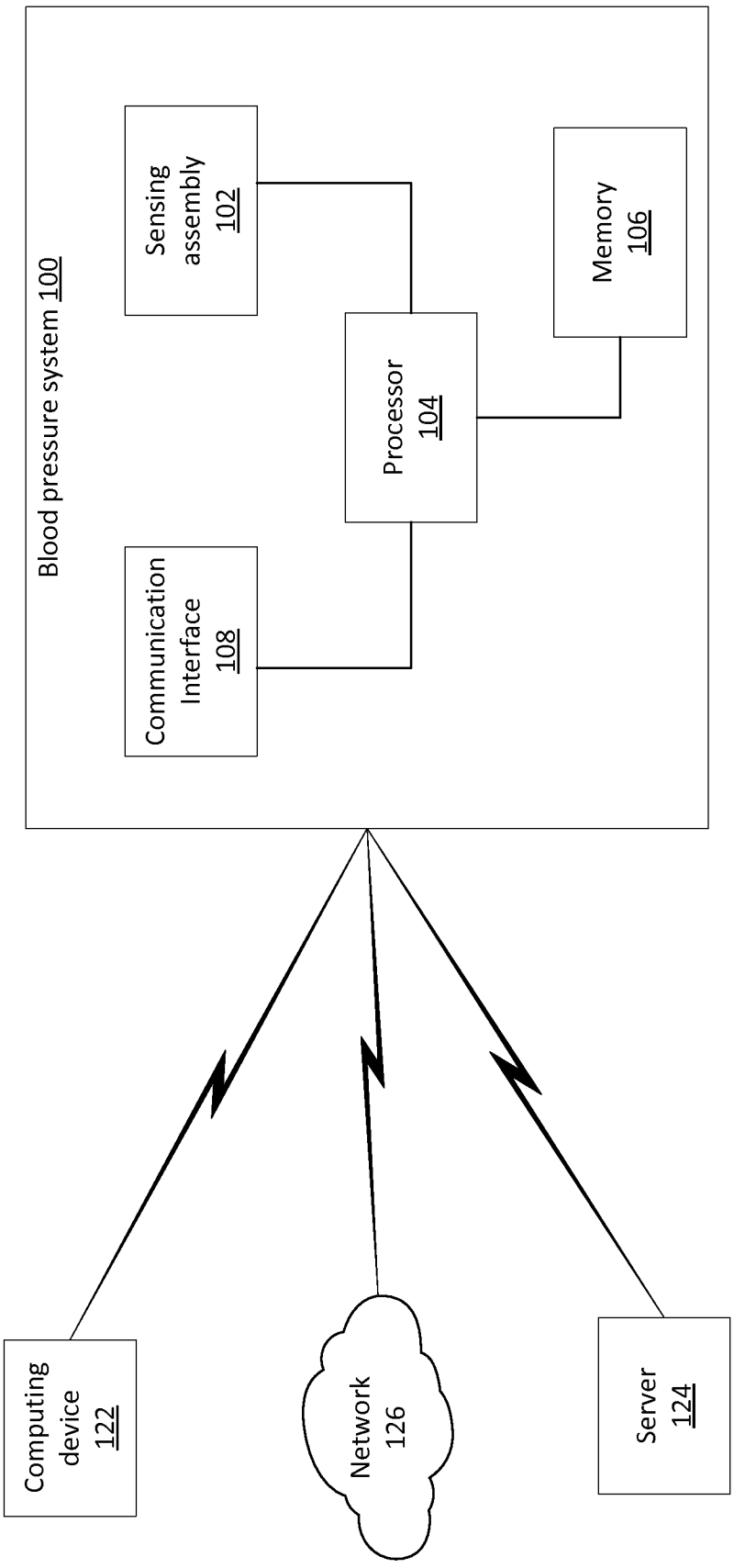
Blood pressure system 100
Sensing assembly 102
Memory 106
Processor 104
Communication Interface 108
Computing device 122
Network 126
Server 124

FIG. 1

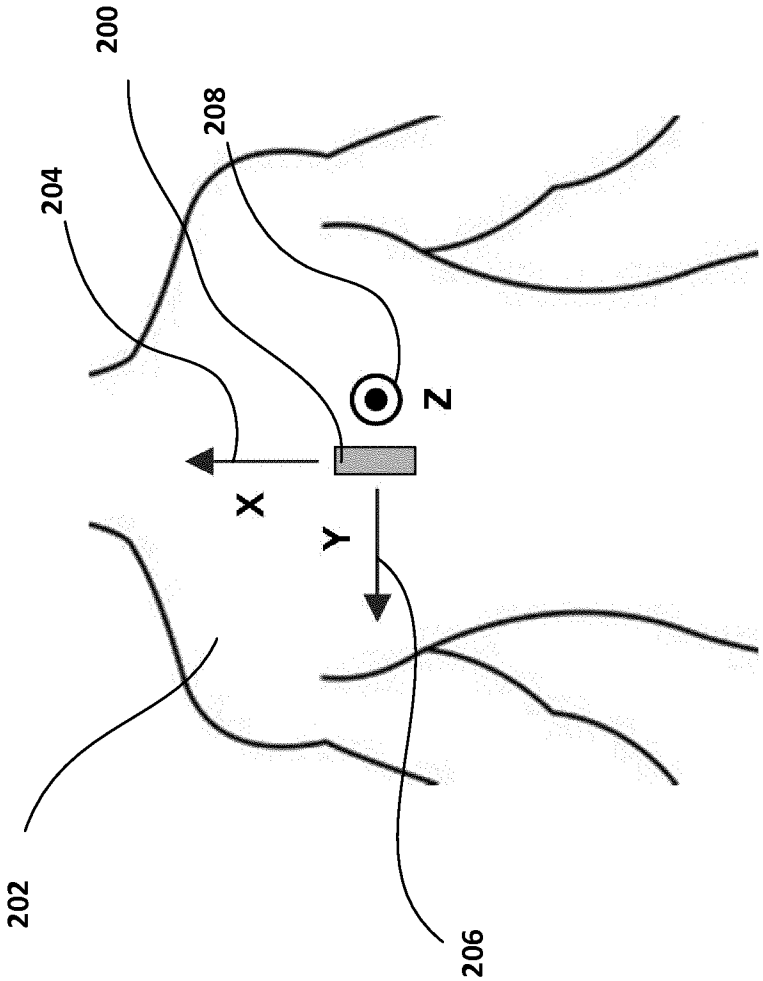

FIG. 2

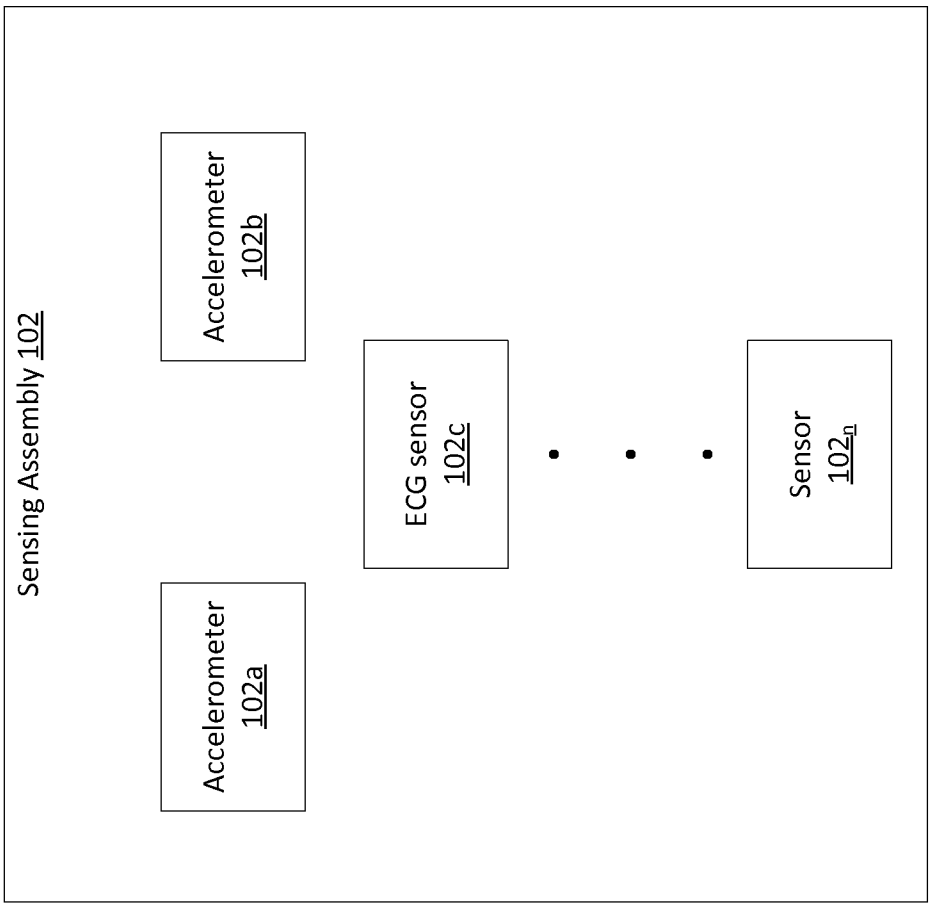
Sensing Assembly 102
Accelerometer 102a
Accelerometer 102b
ECG sensor 102c
Sensor 102n

FIG. 3

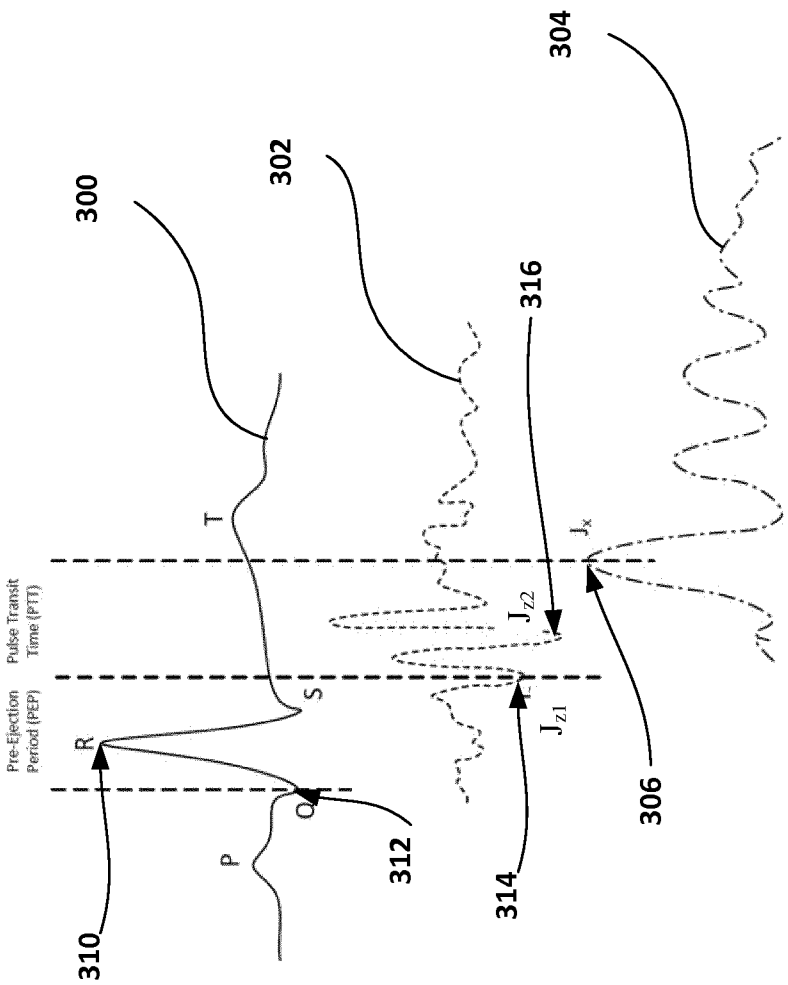
300
302
304
316
T
S
R
Q
P
Pre-Ejection Period (PEP)
Pulse Transit Time (PTT)
J_{Z2}
J_{Z1}
J_x
310
312
314
306

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/058487

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/021
ADD. A61B5/0285 A61B5/0456 A61B5/00 A61B5/11 A61B5/024

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)
A61B

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)
EPO-Internal , WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	US 2015/196213 Al (PANDIA KEYA R [US] ET AL) 16 July 2015 (2015-07-16) paragraphs [0183] - [0184] , [0198] , [0200] - [0203] , [0214] ; figures 2,30-32	1-14
A	US 2014/257056 Al (MOON JIM [US] ET AL) 11 September 2014 (2014-09-11) paragraphs [0051] - [0071] , [0078] - [0082] ; figures 1-3	1,9
A	W0 2015/120330 Al (S0TERA WI RELESS INC [US]) 13 August 2015 (2015-08-13) paragraphs [0051] - [0100]	1,9
A	US 2016/081563 Al (WIARD RICHARD M [US] ET AL) 24 March 2016 (2016-03-24) paragraphs [0045] - [0051] ; figure lb	1,9

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[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

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"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
4 July 2017	18/07/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Kronberger, Raphael

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/058487

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No
PCT/EP2017/058487

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