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(54) OPPOSING ACCELEROMETERS FOR A HEART RATE MONITOR

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A61B 5/11	(2006.01)
A61B 5/00	(2006.01)

(52) **U.S. Cl.**

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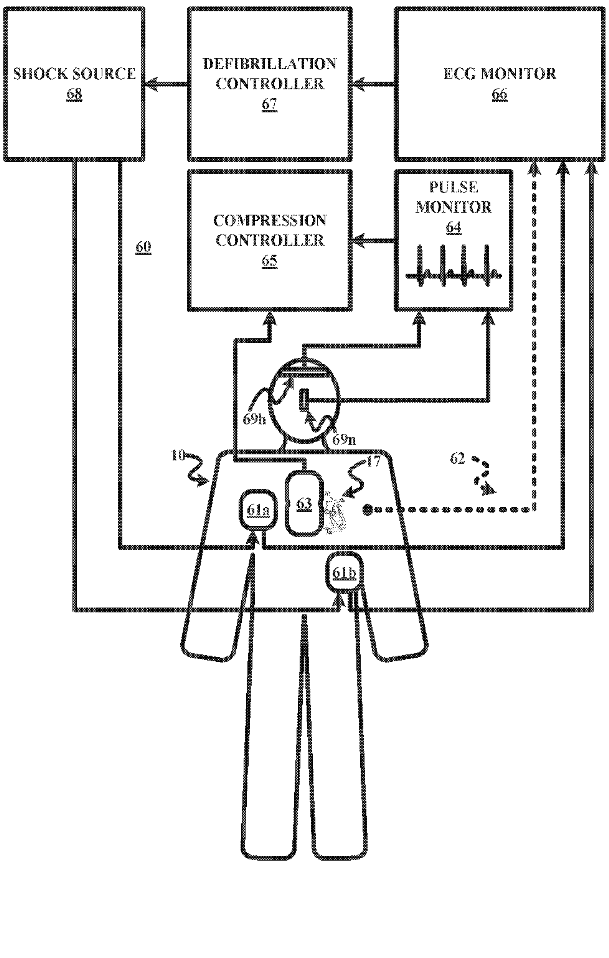
(57) **ABSTRACT**

A heart rate monitor (**40**) for detecting a pulse of a person (**10**) employs a platform (**43**), a plurality of multi-axis accelerometers (**41**R, **41**L) and a pulse detector (**44**). The multi-axis accelerometers (**41**R, **41**L) are adjoined to the platform (**43**) to generate differential mode signals (A_{ZR}, A_{ZL}) indicative of a sensing by the accelerometers (**41**) of physiological motion (**12**) of the person (**10**) relative to acceleration sensing axes (**42**R, **42**L) and to generate common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}) indicative of a sensing by the accelerometers (**41**R, **41**L) of extraneous motion by the person (**10**) relative to the acceleration sensing axes (**42**R, **42**L). The pulse detector (**44**) is operably connected to the multi-axis accelerometers (**41**R, **41**L) to generate a pulse signal (PS)as a function of a vertical alignment of the acceleration sensing axes (**42**R, **42**L) combining the differential mode signals (A_{ZR}, A_{ZL}) and cancelling the common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}).



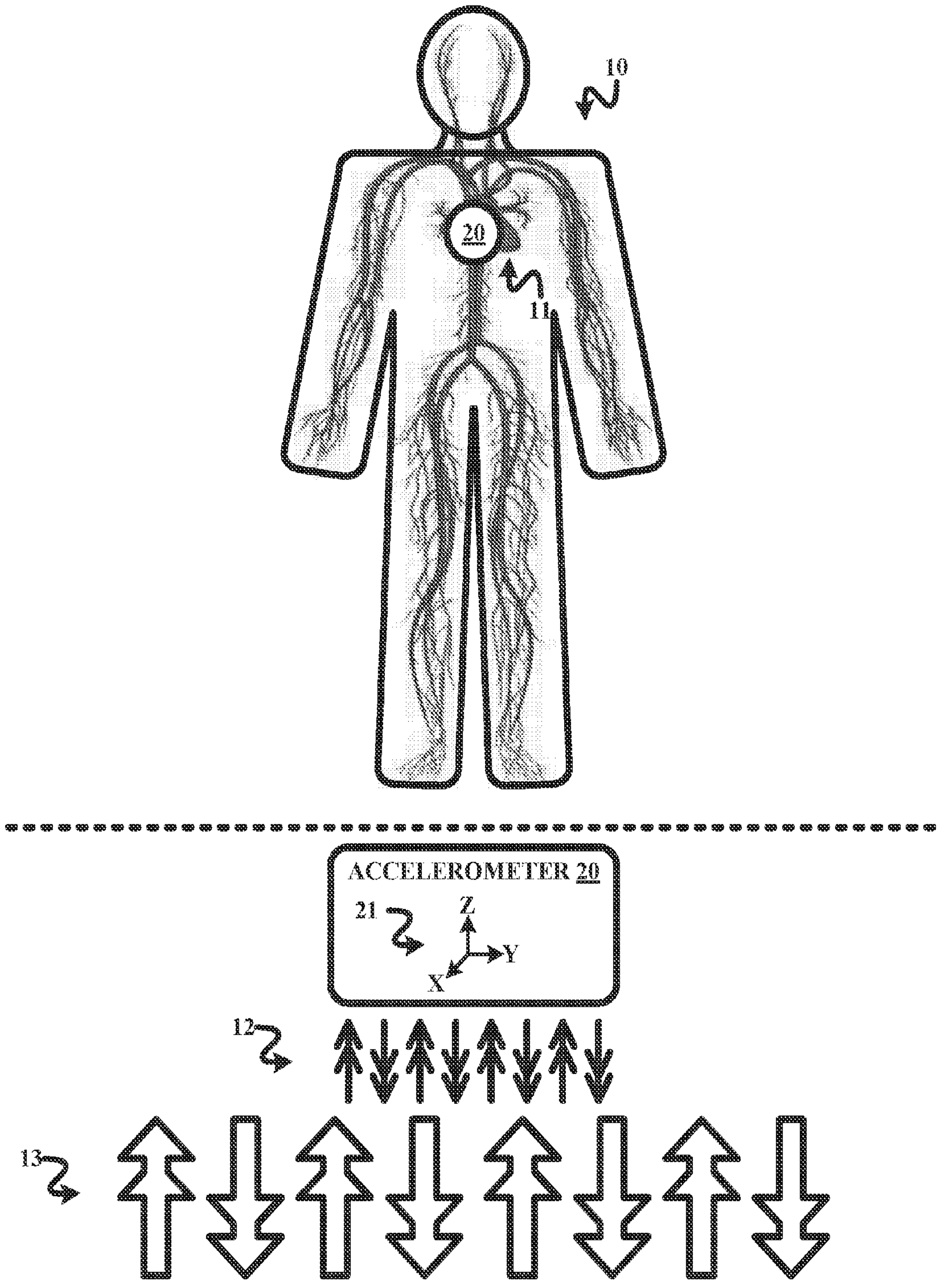


FIG. 1 (PRIOR ART)

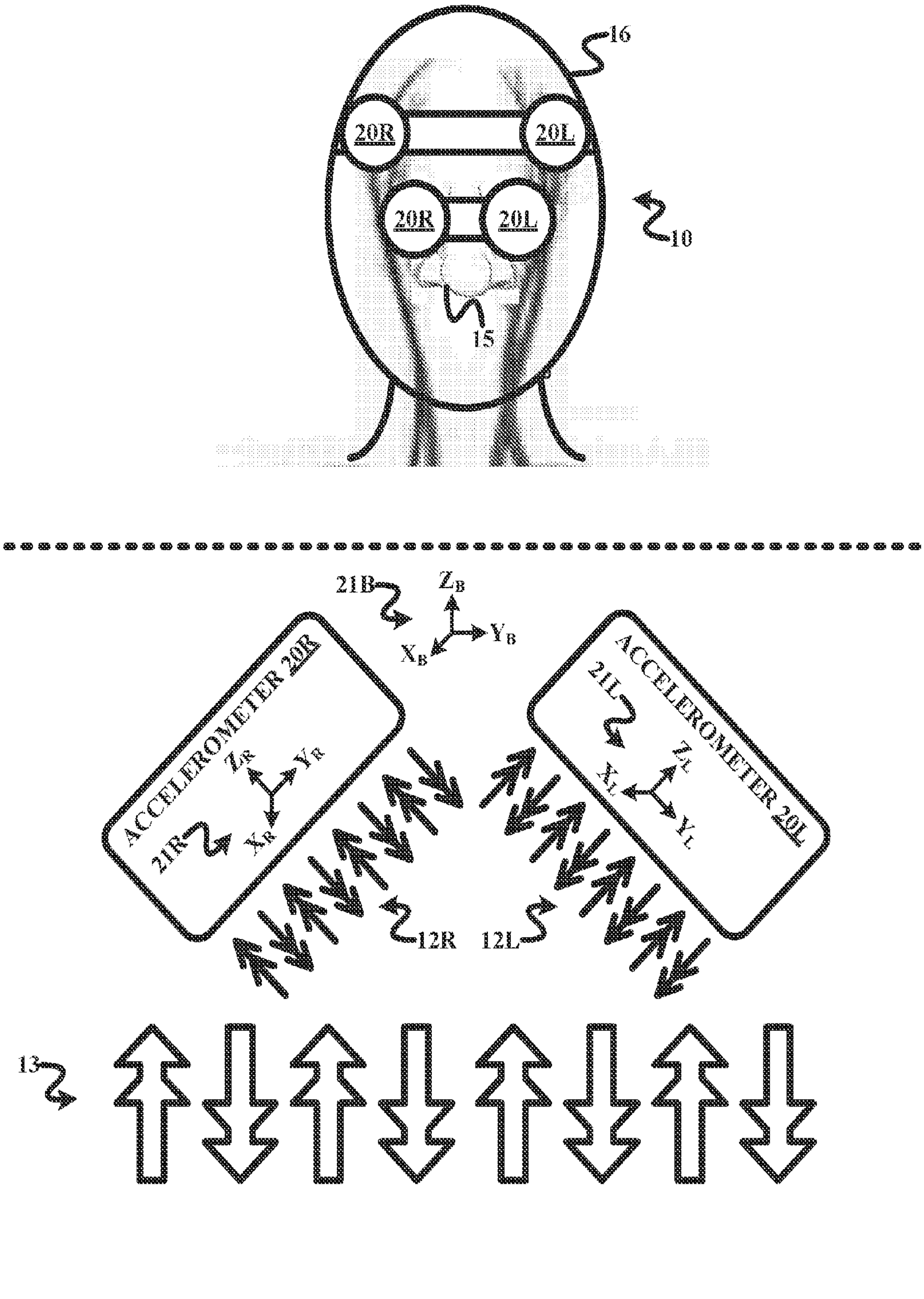

16
20R
20L
20R
20L
10
15
21B
Z_B
Y_B
X_B
ACCELEROMETER 20R
Z_R
Y_R
X_R
21R
ACCELEROMETER 20L
21L
Z_L
X_L
Y_L
12R
12L
13

FIG. 2

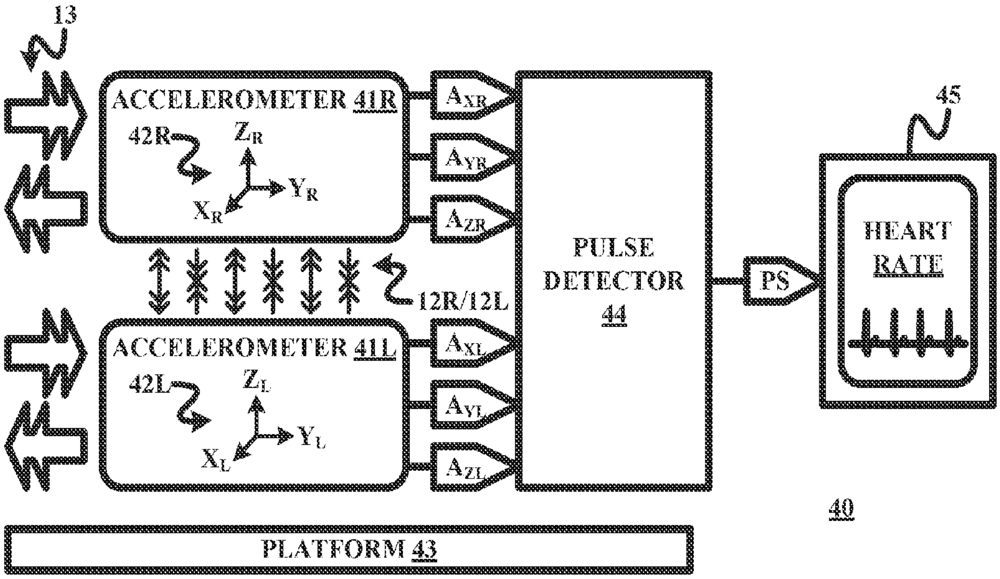

13
ACCELEROMETER 41R
42R
Z_R
Y_R
X_R
A_{XR}
A_{YR}
A_{ZR}
12R/12L
ACCELEROMETER 41L
42L
Z_L
Y_L
X_L
A_{XL}
A_{YL}
A_{ZL}
PULSE DETECTOR 44
PS
45
HEART RATE
40
PLATFORM 43

FIG. 3

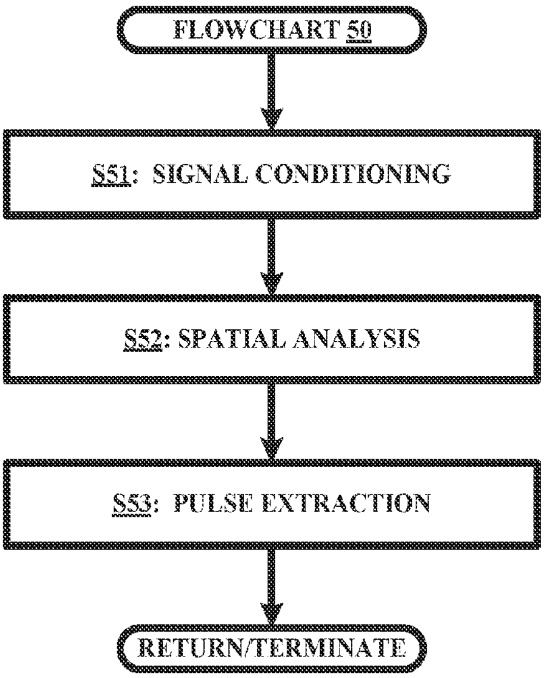

FLOWCHART 50
S51: SIGNAL CONDITIONING
S52: SPATIAL ANALYSIS
S53: PULSE EXTRACTION
RETURN/TERMINATE

FIG. 4

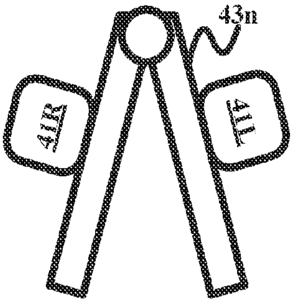


FIG. 5

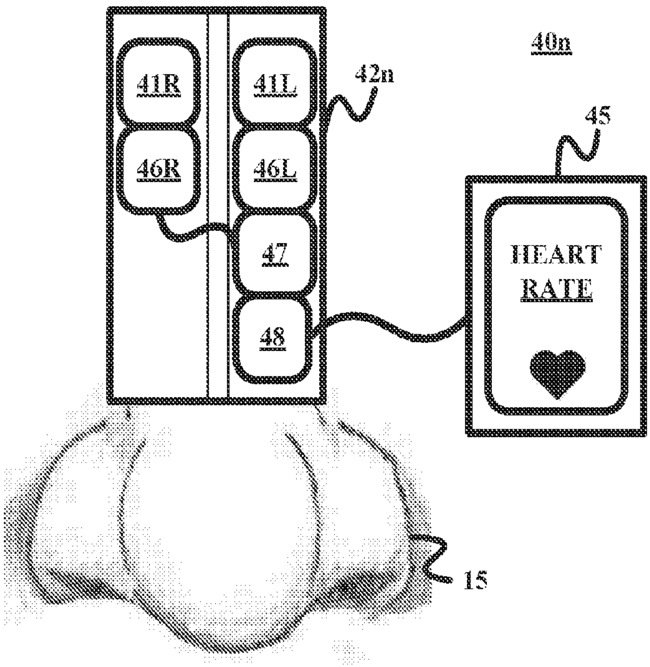


FIG. 6

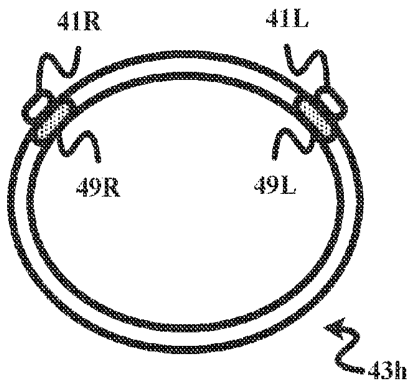


FIG. 7

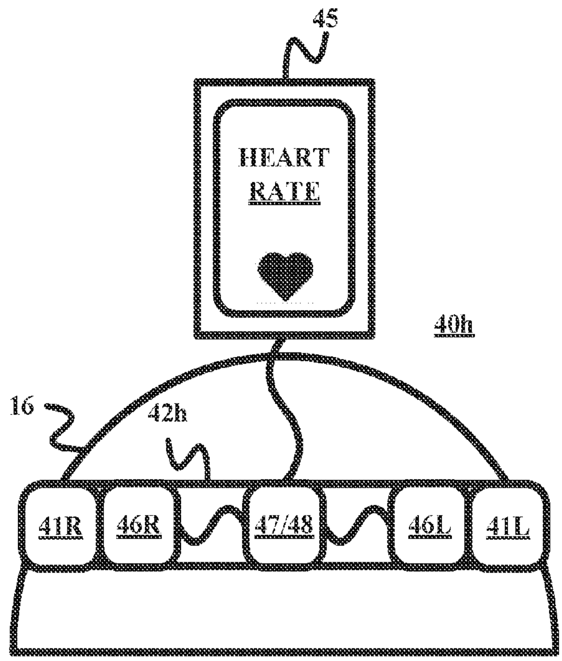


FIG. 8

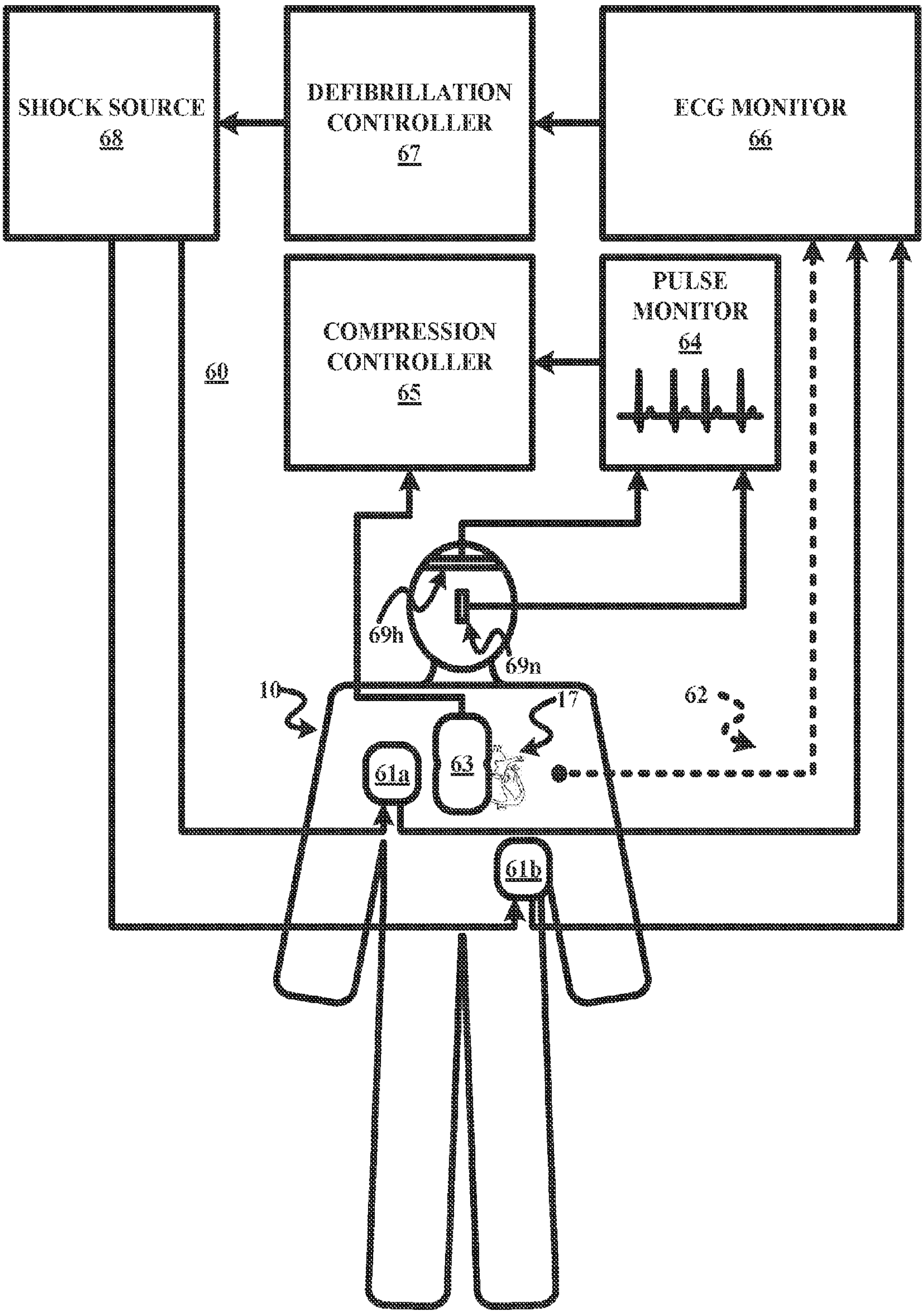

SHOCK SOURCE
68
DEFIBRILLATION CONTROLLER
67
ECG MONITOR
66
COMPRESSION CONTROLLER
65
PULSE MONITOR
64
60
69h
69n
10
17
62
63
61a
61b

FIG. 9

OPPOSING ACCELEROMETERS FOR A HEART RATE MONITOR

[0001] The present invention generally relates to a heart rate monitor employing an accelerometer as a basis for detecting a pulse of a patient. The present invention specifically relates to a heart rate monitor employing multi-axis accelerometers in an angular orientation that facilitates a distinction of a pulse of a patient from motion artifacts derived from extraneous motion of the patient.

[0002] Heart rate monitors as known in the art execute a measurement of a patient's heart rate in real time. In particular, for emergency care directed to triage and guidance of cardiac therapy, heart rate monitors are designed to be simple to use, noninvasive and reliable for pulse detection purposes. To this end, as shown in FIG. **1**, current heart rate monitors are known to employ a multi-axis (XYZ) accelerometer **20** strapped to a chest of a person **10** over any of several easily accessible arteries of person **10** to thereby sense undulating physiological motion **12** of person **10** generated by a circulatory system **11** of person **10** as a basis for detecting the pulse of person **10**. However, XYZ axes **21** of accelerometer **20** experience acceleration derived from a totality of motion of person **10**. Thus, while pulses of person **10** produce measurable physiological motion **12**, motion sources extrinsic to person **10** may produce larger motion artifacts from larger undulating extraneous motion **13** that conceals physiological motion **12** of person **10** (e.g., cardiopulmonary resuscitation ("CPR") efforts on person **10**, transportation/movement of person **10**, etc.). Consequently, the motion artifacts limit the applicability of accelerometer **20** as strapped to the chest of person **10** for pulse detection.

[0003] To overcome the drawback of accelerometer **20**, the present invention as shown in FIG. **2** involves a placement of two (2) multi-axis (XYZ) accelerometers **20**R and **20**L on a body surface of person **10** at an angular orientation whereby respective XYZ axes **21**R and **21**L of accelerometers **20**R and **20**L individually sense physiological motions **12**R and **12**L generated by circulatory system **11** and equally sense motion artifacts generated from extraneous motion **13**. Specifically, respective vertical axes Z_R and Z_L are normal to the body surface of person **10** to individually experience acceleration primarily, if not entirely, derived from respective physiological motions **12**R and **12**L. Conversely, respective longitudinal axes X_R and X_L and respective lateral axes Y_R and Y_L are parallel to the body surface of patient to commonly experience acceleration primarily, if not entirely, derived from extraneous motion **13**. For example, as will be further described herein, accelerometers **20**R and **20**L may be mounted to a nose **15** of person **10** as shown in FIG. **2** or strapped to a head **16** of person **10** as shown in FIG. **2** to individually sense respective physiological motion **12**R and **12**L and to commonly sense extraneous motion **13**. Knowledge of the angular orientation of accelerometers **20**R and **20**L facilitates a mathematical rotation of XYZ axes **21**R and **21**L of accelerometers **20**R and **20**L to a baseline XYZ axes **21**B that permits cancellation of extrinsic extraneous motion **13** and reinforcement of physiological motion **12** due to the difference in the orientation of the forces exerted by the totality of motion sensed by accelerometers **20**R and **20**L.

[0004] One form of the present invention is a method for pulse detection of a person by a heart rate monitor including a plurality of multi-axis accelerometers. The method involves the accelerometers generating differential mode signals indicative of a sensing by the accelerometer of physiological motion of the person relative to acceleration sensing axes, and the accelerometers generating common mode signals indicative of a sensing by the accelerometers of extraneous motion by the person relative to the acceleration sensing axes. The method further involves the heart rate monitor generating a pulse signal as a function of a vertical alignment of the acceleration sensing axes combining the differential mode signals and cancelling the common mode signals.

[0005] For purposes of the present invention, the term "physiological motion" is broadly defined herein as any motion of a body or a portion thereof generated by a circulatory system of the body to any degree, whether natural (e.g., a pulse from a self-regulated heartbeat) or induced (e.g., a pulse induced by a CPR chest compression), and the term "extraneous motion" is broadly defined herein as any motion of a body or a portion thereof resulting from an application of a force from a source external to the body.

[0006] A second form of the present invention is heart rate monitor for detecting a pulse of a person that employs a platform, a plurality of multi-axis accelerometers and a pulse detector. In operation, the multi-axis accelerometers are adjoined to the platform to generate differential mode signals indicative of a sensing by the accelerometers of physiological motion of the person relative to acceleration sensing axes and to generate common mode signals indicative of a sensing by the accelerometers of extraneous motion by the person relative to the acceleration sensing axes The pulse detector generates a pulse signal as a function of a vertical alignment of the acceleration sensing axes combining the differential mode signals and cancelling the common mode signals.

[0007] A third form of the invention is a cardiac therapy system (e.g., an automated external defibrillator or an advanced life support defibrillator/monitor) employing the aforementioned heart rate monitor and a pulse monitor responsive to the pulse signal to monitor the pulse of the patient.

[0008] The foregoing forms and other forms of the present invention as well as various features and advantages of the present invention will become further apparent from the following detailed description of various embodiments of the present invention read in conjunction with the accompanying drawings. The detailed description and drawings are merely illustrative of the present invention rather than limiting, the scope of the present invention being defined by the appended claims and equivalents thereof.

[0009] FIG. **1** illustrates an exemplary placement of a multi-axis accelerometer on a body surface of a patient as known in the art.

[0010] FIG. **2** illustrates exemplary placements of two (2) multi-axis accelerometers on a body surface of a patient in accordance with the present invention.

[0011] FIG. **3** illustrates an exemplary embodiment of a heart rate monitor in accordance with the present invention.

[0012] FIG. **4** illustrates a flowchart representative of an exemplary embodiment of pulse detection method in accordance with the present invention.

[0013] FIG. **5** illustrates an exemplary embodiment of a nose clip in accordance with the present invention.

[0014] FIG. **6** illustrates an exemplary embodiment of a heart rate monitor incorporating the nose clip shown in FIG. **5** in accordance with the present invention.

[0015] FIG. **7** illustrates an exemplary embodiment of a headband/head strap in accordance with the present invention.

[0016] FIG. **8** illustrates an exemplary embodiment of a heart rate monitor incorporating the headband/head strap shown in FIG. **7** in accordance with the present invention.

[0017] FIG. **9** illustrates an exemplary embodiment of a cardiac therapy device incorporating a heat rate monitor in accordance with the present invention.

[0018] To facilitate an understanding of the present invention, exemplary embodiments of a heartbeat monitor of the present invention will be provided herein directed to a stand-alone monitor and an incorporation of the heartbeat monitor of the present invention into a cardiac therapy device (e.g., an automated external defibrillator or an advanced life support).

[0019] Referring to FIG. **3**, a heartbeat monitor **40** of the present invention employs a pair of multi-axis (XYZ) accelerometers **41**R and **41**L, a platform **43**, a pulse detector **44** and a display **45**.

[0020] Accelerometer **41**R structurally configured as known in the art for generating a longitudinal acceleration sensing signal A_{XR}, a lateral acceleration sensing signal A_{YR}, and a vertical acceleration sensing signal A_{ZR} responsive to a sensing of motion force(s) acting upon an XYZ axes **42**R.

[0021] Accelerometer **41**L structurally configured as known in the art for generating a longitudinal acceleration sensing signal A_{XL}, a lateral acceleration sensing signal A_{YL}, and a vertical acceleration sensing signal A_{ZL} responsive to a sensing of motion force(s) acting upon an XYZ axes **42**L.

[0022] In practice, heartbeat monitor **40** may employ additional accelerometers **41**.

[0023] Also in practice, heartbeat monitor **40** may alternatively or concurrently employ two (2) or more multi-axis (XY) accelerometers, and may alternatively or concurrently employ two (2) or more groupings of single-axis (X) accelerometers serving as multi-axis accelerometers.

[0024] Platform **43** is structurally configured in accordance with the present invention for positioning respective vertical axes Z_R and Z_L of accelerometers **41**R and **41**L normal to body surface of a person, and for positioning respective longitudinal axes X_R and X_L and respective lateral axes Y_R and Y_L of accelerometers **41**R and **41**L parallel to the body surface of the person. As exemplary shown in FIG. **2**, platform **43** is further structurally configured to angularly orientate XYZ axes **42**R and XYZ axes **42**L whereby respective vertical axes Z_R and Z_L are normal to the body surface of the person to individually experience acceleration primarily, if not entirely, derived from respective physiological motion **12**R and **12**L, and whereby respective longitudinal axes X_R and X_L and respective lateral axes Y_R and Y_L are parallel to the body surface of patient to commonly experience acceleration primarily, if not entirely, derived from extraneous motion **13**. Consequently, for purposes of the present invention, vertical acceleration sensing signal A_{ZR} and vertical acceleration sensing signal A_{ZL} are deemed differential mode signals while longitudinal acceleration sensing signal A_{xR}, lateral acceleration sensing signal A_{YR}, longitudinal acceleration sensing signal A_{XL}, and lateral acceleration sensing signal A_{YL} are deemed common mode signals.

[0025] One embodiment of platform **43** is a hinged or jointed nose clip **43***n* as shown in FIG. **5**, which is structurally configured to flexibly affix accelerometers **41**R and **41**L to opposite right and left sides of a bridge of a nose of the person whereby the underlying nasal bone will rigidly maintain the angular orientation of accelerometers **41**R and **41**L with respect to one another and the nose of the person. More particularly, dorsal nasal arteries of the person are intimately connected via the opthalmic artery to the internal carotid, and thus to the blood supply of the brain. A pulse at the bridge of the nose is preserved, if it is preserved anywhere in physiological distress, and in particular it is not subject to peripheral shutdown common in patients needing emergency care. Consequently, respective vertical axes Z_R and Z_L (FIG. **3**) of accelerometers **41**R and **41**L will experience physiological motion from pulsation of the dorsal nasal arteries primarily normal to the plane of the temporal bone, and respective longitudinal axes X_R and X_L and respective lateral axes Y_R and Y_L will experience motion artifacts of the nose of the person primarily along the plane of the nasal bone.

[0026] Another embodiment of platform **43** is a headband/head strap **43***h* as shown in FIG. **7**, which is structurally configured with hardened surfaces **49**R and **49**L to respectively affix accelerometers **41**R and **41**L to opposite right and left temples of the person whereby surfaces **49**R and **49**L will rigidly maintain the angular orientation of accelerometers **41**R and **41**L with respect to one another and the temples of the person. As with the dorsal nasal arties, the temporal arteries is substantially preserved and not subject to peripheral shutdown common in patients needing emergency care. Consequently, respective vertical axes Z_R and Z_L (FIG. **3**) of accelerometers **41**R and **41**L will experience physiological motion from pulsation of the temporal arteries primarily normal to the plane of the nasal bone, and respective longitudinal axes X_R and X_L and respective lateral axes Y_R and Y_L will experience motion artifacts of the temples of the person primarily along the plane of the temples.

[0027] Referring back to FIG. **3**, pulse detector **44** is structurally configured with hardware, software, firmware and/or circuitry for executing a pulse detection method of the present invention as represented by a flowchart **50** shown in FIG. **4**.

[0028] A stage S**51** of flowchart **50** encompasses pulse detector **44** implementing technique(s) for conditioning acceleration sensing signals X_R, Y_R, Z_R, X_L, Y_L and Z_L as needed for accelerometers **41**R and **41**L. Examples of the known signal conditioning include, but are not limited to, signal amplification and analog-to-digital conversion.

[0029] A stage S**52** of flowchart **50** encompasses pulse detector **44** implementing technique(s) for spatially analyzing an angular orientation of XYZ axes **42**R and **42**L relative to a baseline axes (e.g., one of XYZ axes **42**R or XYZ axes **42**L, or a distinct baseline XYZ axes such as **21**B shown in FIG. **2**). In one embodiment, gravity acceleration vectors of XYZ axes **42**R and **42**L are used as excitation field to determine a tile angle between accelerometers **41**R and **41**L or to a distinct baselines axes (e.g., baseline XYZX axes **21**B shown in FIG. **2**) to facilitate a mathematical rotation of XYZ axes **42**R and **42**L in all three dimensions to align vertical axes Z_R and Z_L whereby individual physiological motion vectors, common motion artifact vector and the gravity acceleration vectors are identifiable by pulse detector **44**.

[0030] A stage S**53** of flowchart **50** encompasses pulse detector **44** implementing technique(s) for extracting the physiological motion vectors to communicate a pulse signal

PS (FIG. 3) to display **45**. Generally, pulse detector **44** extracts corresponding physiological motion vectors, motion artifact vectors and the gravity vectors from vertically aligned XYZ axes **42**R and **42**L by combining the differential mode signals A_{ZR} and A_{ZL} and cancelling common mode signals A_{XR}, A_{XL}, A_{YR} and A_{YL}.

[0031] Specifically for combining/cancelling the signals, particularly when vertical axes Z_R and Z_L are not pointed in opposite directions on the body surface of the person, advanced signal processing methods known in the art (e.g., Principal Component Analysis (PCA) or Independent Component Analysis (ICA)) may be utilized to extract the physiological motion vectors from vertically aligned XYZ axes **42**R and **42**L. For example, PCA may sort the signal components from the biggest to the smallest. The gravity acceleration vectors and common motion artifact vectors are bigger signals than the physiological motion vectors, and the gravity acceleration vectors and the common motion artifact vectors identified by PCA and removed. By further example, ICA may extract the independent components if they are linearly combined. Since the physiological motion vectors, the gravity acceleration vectors and the common motion artifact vectors are independent to each other and the recordings by accelerometers **41**R and **41**L are a linear sum, the physiological motion vectors may be identified from the ICA results. Furthermore, since the pulses from both sides of the bridge of nose are correlated and synchronized, the extracted physiological motion vectors by ICA should by default be the sum of the blood pulses recorded by the two accelerometers **41**R and **41**L.

[0032] Referring back to FIG. **3**, in practice, pulse detector **44** may employ one or more modules with each module being affixed to platform **43**, within a stand-alone housing or incorporated within display **45**.

[0033] For example, as respectively shown for heartbeat monitors **40***n* and **40***h* in FIGS. **6** and **8**, pulse detector **44** employs modules in the form of signal conditioners **46**R and **46**L, a spatial analyzer **47** and a pulse extractor **48** affixed to nose clip **45***n* and headband/head strap **45***h*.

[0034] Referring back to FIG. **3**, display **45** is structurally configured as known in the art for visually displaying pulse signal PS or visual indications thereof and optionally providing audio information related to pulse signal PS. For example, as shown, display **45** may provide a heartbeat readout of pulse signal PS and provide a pulsating heart as an indication of pulse signal PS.

[0035] In practice, display **45** may be affixed to platform **43**, within a stand-alone housing or incorporated within a cardiac therapy device. For example, as shown in as respectively shown for heartbeat monitors **40***n* and **40***h* in FIGS. **6** and **8**, display **45** is provided in stand-alone housing.

[0036] Referring to FIG. **9**, a cardiac therapy device **60** of the present invention employs a pair of electrode pads/paddles **61**, optional ECG leads **62**, a compression pad **63**, a pulse monitor **64**, a compression controller **66**, an ECG monitor **66** (internal or external), a defibrillation controller **67**, and a shock source **67** as known in the art.

[0037] In operation, responsive to an ECG signal from ECG monitor **66** , defibrillation controller **67** controls shock source **68** in delivering a defibrillation shock via electrode pads/paddles **61** to a heart **17** of patient **10** in accordance with one or more shock therapies (e., synchronized cardioversion). Additionally, responsive to a pulse signal from pulse monitor **65**, compression controller **66** provides audio instructions to a user of compression pad **63** in accordance with one or more compression therapies.

[0038] As related to the pulse signal, cardiac therapy device **60** further employs a heartbeat monitor of the present invention, such as, for example, a nose clip based heartbeat monitor **69***n* mounted on a nose of patient **10** as shown in FIG. **9** or a headband/head strap based heartbeat monitor **69***h* wrapped/strapped around a head of patient **10** as shown in FIG. **9**. The displays for heartbeat monitors **69***n* and **69***h* (e.g., display **45** shown in FIG. **3**) are incorporated within a pulse monitor **64**, and the pulse detectors for heartbeat monitors **69***n* and **69***h* (e.g., pulse detector **44** shown in FIG. **3**) may also be incorporated within pulse monitor **64**.

[0039] In practice, the pulse detectors (e.g., pulse detector **44** shown in FIG. **3**) for heartbeat monitors **69***n* and **69***h* may concurrently or alternatively provide the pulse signal to defibrillation controller **65** and/or compression controller **66**.

[0040] Also practice, monitors **64** and **66** may be combined and/or controllers **65** and **67** may be combined.

[0041] Referring to FIGS. **2-9**, those having ordinary skill in the art will appreciate numerous benefits of the present invention including, but not limited to, a simple to use, noninvasive and reliable pulse detection, particularly in emergency care for triage and guidance of therapy.

[0042] While various embodiments of the present invention have been illustrated and described, it will be understood by those skilled in the art that the embodiments of the present invention as described herein are illustrative, and various changes and modifications may be made and equivalents may be substituted for elements thereof without departing from the true scope of the present invention. In addition, many modifications may be made to adapt the teachings of the present invention without departing from its central scope. Therefore, it is intended that the present invention not be limited to the particular embodiments disclosed as the best mode contemplated for carrying out the present invention, but that the present invention includes all embodiments falling within the scope of the appended claims.

1. A method for pulse detection of a person by a heart rate monitor including a plurality of multi-axis accelerometers, the method comprising:

mounting, via a platform, the accelerometers on a nose of the person, wherein the platform comprises a hinged nose clip structurally configured to flexibly affix the accelerometers to opposite right and left sides of a bridge of the nose of the person, whereby an underlying nasal bone rigidly maintains an angular orientation of the accelerometers with respect to each other and the nose of the person;

generating, via the accelerometers, differential mode signals indicative of a sensing by the accelerometers of physiological motion of the person relative to acceleration sensing axes of the multi-axis accelerometers;

generating, the accelerometers, common mode signals indicative of a sensing by the accelerometers of extraneous motion by the person relative to the acceleration sensing axes; and

generating, via the heart rate monitor, a pulse signal as a function of a vertical alignment of the acceleration sensing axes combining the differential mode signals and cancelling the common mode signals.

2. (canceled)

3. The method of claim **1**, wherein the plurality of multi-axis accelerometers further comprise accelerometers for being positioned over temples of the person, the method further comprising:

mounting, via the platform, the accelerometers over the temples of the person, wherein the platform comprises one of a headband or head strap structurally configured with hardened surfaces to respectively affix the accelerometers at the hardened surfaces to opposite right and left temples of the person.

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

displaying, via a display, a pulse of the person responsive to the pulse signal.

5. A heart rate monitor for detecting a pulse of a person, the heart rate monitor comprising:

a platform;

a plurality of multi-axis accelerometers adjoined to the platform to generate differential mode signals indicative of a sensing by the accelerometers of physiological motion of the person relative to acceleration sensing axes and to generate common mode signals indicative of a sensing by the accelerometers of extraneous motion by the person relative to the acceleration sensing axes, wherein the platform comprises a nose clip operable to mount the accelerometers on a nose of the person, wherein the nose clip further comprises a hinged nose clip structurally configured to flexibly affix the accelerometers to opposite right and left sides of a bridge of the nose of the person, whereby an underlying nasal bone rigidly maintains an angular orientation of the accelerometers with respect to each other and the nose of the person; and

a pulse detector operably connected to the multi-axis accelerometers to generate a pulse signal as a function of a vertical alignment of the acceleration sensing axes combining the differential mode signals and cancelling the common mode signals.

6. (canceled)

7. The heart rate monitor of claim **5**, wherein the plurality of multi-axis accelerometers further comprise accelerometers for being positioned over temples of the person, and wherein the platform further comprises a headband operable to position the accelerometers over temples of the person, wherein the headband is structurally configured with hardened surfaces to respectively affix the accelerometers at the hardened surfaces to opposite right and left temples of the person.

8. The heart rate monitor of wherein the plurality of multi-axis accelerometers further comprise accelerometers for being positioned over temples of the person, and wherein the platform further comprises a head strap operable to position the accelerometers over temples of the person, wherein the head strap is structurally configured with hardened surfaces to respectively affix the accelerometers at the hardened surfaces to opposite right and left temples of the person.

9. The heart rate monitor of claim **5**, further comprising:

a display operably connected to the pulse detector to display a pulse of the person responsive to the pulse signal.

10. A cardiac therapy device comprising:

a heart rate monitor according to claim **5**; and

a pulse monitor operably connected to the pulse detector to monitor a the pulse of the person responsive to the pulse signal.

11. (canceled)

12. The cardiac therapy device of claim **10**, wherein the plurality of multi-axis accelerometers further comprise accelerometers for being positioned over temples of the person, and wherein the platform further comprises a headband operable to position the accelerometers over temples of the person wherein the headband is structurally configured with hardened surfaces to respectively affix the accelerometers at the hardened surfaces to opposite right and left temples of the person.

13. The cardiac therapy device of claim **10**, wherein the plurality of multi-axis accelerometers further comprise accelerometers for being positioned over temples of the person, and wherein the platform further comprises a head strap operable to position the accelerometers over temples of the person, wherein the head strap is structurally configured with hardened surfaces to respectively affix the accelerometers at the hardened surfaces to opposite right and left temples of the person.

14. The cardiac therapy device of claim **10**, wherein the heart rate monitor further includes:

a display operably connected to the pulse detector to display a pulse of the person responsive to the pulse signal.

15. The cardiac therapy device of claim **14**, wherein the pulse monitor incorporates the display.

* * * * *

专利名称(译)	反对心率监测器的加速度计		
公开(公告)号	US20160317040A1	公开(公告)日	2016-11-03
申请号	US15/104258	申请日	2014-12-10
[标]申请(专利权)人(译)	皇家飞利浦电子股份有限公司		
申请(专利权)人(译)	皇家飞利浦N.V.		
当前申请(专利权)人(译)	皇家飞利浦N.V.		
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摘要(译)

用于检测人脉搏（ 10 ）的心率监测器（ 40 ）采用平台（ 43 ），多个多个轴加速度计（ 41 R， 41 L ）和脉冲检测器（ 44 ）。多轴加速度计（ 41 R， 41 L ）连接到平台（ 43 ）以生成差分模式信号（ A ZR ，A ZL ）表示人的生理运动（ 12 ）的加速度计（ 41 ）的感测（ 10 ）相对于加速度传感轴（ 42 R， 42 L ）并产生共模信号（ A XR ，A XL ， YR ，A YL ）表示外来加速度计（ 41 ， L ）的感测人（ 10 ）相对于加速度传感轴（ 42 R， 42 L ）的运动。脉冲检测器（ 44 ）可操作地连接到多轴加速度计（ 41 R， 41 L ）以产生脉冲信号（ PS ） ）作为加速度传感轴（ 42 ， 42 L ）垂直对齐的函数，组合差模信号（ A ZR ， ZL ）并取消共模信号（ A XR ，A XL ，A YR ，A <子> YL </子> ）。