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(54) **Title**: OPPOSING ACCELEROMETERS FOR A HEART RATE MONITOR

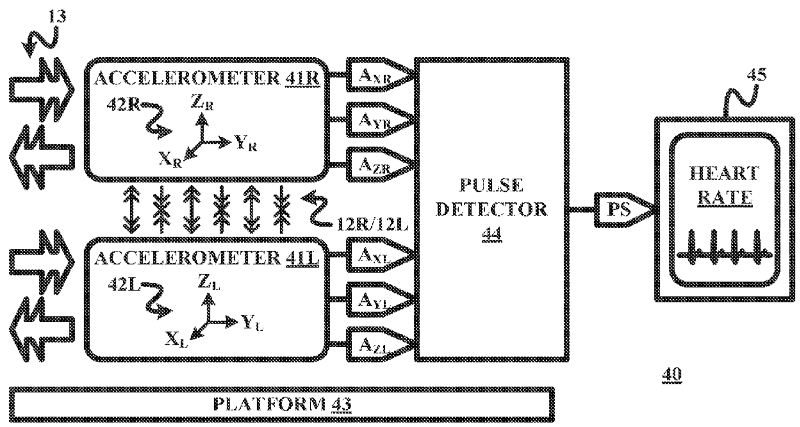

FIG. 3

(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 (41R, 41L) and a pulse detector (44). The multi-axis accelerometers (41R, 41L) 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 (42R, 42L) and to generate common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}) indicative of a sensing by the accelerometers (41R, 41L) of extraneous motion by the person (10) relative to the acceleration sensing axes (42R, 42L). The pulse detector (44) is operably connected to the multi-axis accelerometers (41R, 41L) to generate a pulse signal (PS)as a function of a vertical alignment of the acceleration sensing axes (42R, 42L) combining the differential mode signals (A_{ZR}, A_{ZL}) and cancelling the common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}).

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OPPOSING ACCELEROMETERS FOR A HEART RATE MONITOR

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.

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.

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 20R and 20L on a body surface of person 10 at an angular orientation whereby respective XYZ axes 21R and 21L of accelerometers 20R and 20L individually sense physiological motions 12R and 12L 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 12R and 12L. 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 20R and 20L 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 12R and 12L and to commonly sense extraneous motion 13. Knowledge of the angular orientation of accelerometers 20R and 20L facilitates a mathematical rotation of XYZ axes 21R and 21L of accelerometers 20R and 20L to a baseline XYZ axes 21B 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 20R and 20L.

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.

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.

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.

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.

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.

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

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

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

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

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

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.

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

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.

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

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).

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

Accelerometer 41R 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 42R.

Accelerometer 41L 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 42L.

In practice, heartbeat monitor 40 may employ additional accelerometers 41.

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.

Platform 43 is structurally configured in accordance with the present invention for positioning respective vertical axes Z_R and Z_L of accelerometers 41R and 41L 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 41R and 41L 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 42R and XYZ axes 42L 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 12R and 12L, 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.

One embodiment of platform 43 is a hinged or jointed nose clip 43n as shown in FIG. 5, which is structurally configured to flexibly affix accelerometers 41R and 41L 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 41R and 41L 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 41R and 41L 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.

Another embodiment of platform 43 is a headband/head strap 43h as shown in FIG. 7, which is structurally configured with hardened surfaces 49R and 49L to respectively affix accelerometers 41R and 41L to opposite right and left temples of the person whereby surfaces 49R and 49L will rigidly maintain the angular orientation of accelerometers 41R and 41L 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 41R and 41L 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.

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.

A stage S51 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 41R and 41L. Examples of the known signal conditioning include, but are not limited to, signal amplification and analog-to-digital conversion.

A stage S52 of flowchart 50 encompasses pulse detector 44 implementing technique(s) for spatially analyzing an angular orientation of XYZ axes 42R and 42L relative to a baseline axes (e.g., one of XYZ axes 42R or XYZ axes 42L, or a distinct baseline XYZ axes such as 21B shown in FIG. 2). In one embodiment, gravity acceleration vectors of XYZ axes 42R and 42L are used as excitation field to determine a tile angle between accelerometers 41R and 41L or to a distinct baselines axes (e.g., baseline XYZX axes 21B shown in FIG. 2) to facilitate a mathematical rotation of XYZ axes 42R and 42L 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.

A stage S53 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 42R and 42L 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}.

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 42R and 42L. 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 41R and 41L 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 41R and 41L.

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.

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

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.

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 40n and 40h in FIGS. 6 and 8, display 45 is provided in stand-alone housing.

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.

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.

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 69n mounted on a nose of patient 10 as shown in FIG. 9 or a headband/head strap based heartbeat monitor 69h wrapped/strapped around a head of patient 10 as shown in FIG. 9. The displays for heartbeat monitors 69n and 69h (e.g., display 45 shown in FIG. 3) are incorporated within a pulse monitor 64, and the pulse detectors for heartbeat monitors 69n and 69h (e.g., pulse detector 44 shown in FIG. 3) may also be incorporated within pulse monitor 64.

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

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

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.

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.

Claims

1. A method (50) for pulse detection of a person (10) by a heart rate monitor (40) including a plurality of multi-axis accelerometers (41R, 41L), the method comprising:

the accelerometers (41R, 41L) generating 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 (42R, 42L) of the multi-axis accelerometers (41R, 41L);

the accelerometers (41) generating common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}) indicative of a sensing by the accelerometers (41R, 41L) of extraneous motion by the person (10) relative to the acceleration sensing axes (42R, 42L); and

the heart rate monitor (40) generating a pulse signal (PS) as a function of a vertical alignment of the acceleration sensing axes (42R, 42L) combining the differential mode signals (A_{ZR}, A_{ZL}) and cancelling the common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}).

2. The method of claim 1, wherein the accelerometers (41R, 41L) are mounted on a nose of the person (10).

3. The method of claim 1, wherein the accelerometers (41R, 41L) are positioned over temples of the person (10).

4. The method of claim 1, further comprising:

displaying a pulse of the person (10) responsive to the pulse signal (PS).

5. A heart rate monitor (40) for detecting a pulse of a person (10), the heart rate monitor (40) comprising:

a platform (43);

a plurality of multi-axis accelerometers (41R, 41L) 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 (42R, 42L) and to generate common mode signals (A_{XR}, A_{XL},

A_{YR}, A_{YL}) indicative of a sensing by the accelerometers (41R, 41L) of extraneous motion by the person (10) relative to the acceleration sensing axes (42R, 42L); and

a pulse detector (44) operably connected to the multi-axis accelerometers (41R, 41L) to generate a pulse signal (PS) as a function of a vertical alignment of the acceleration sensing axes (42R, 42L) combining the differential mode signals (A_{ZR}, A_{ZL}) and cancelling the common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}).

6. The heart rate monitor (40) claim 5, wherein the platform (43) is a nose clip operable to mount the accelerometers (41R, 41L) on a nose of the person (10).

7. The heart rate monitor (40) claim 5, wherein the platform (43) is a headband operable to position the accelerometers (41R, 41L) over temples of the person (10).

8. The heart rate monitor (40) claim 5, wherein the platform (43) is a head strap operable to position the accelerometers (41R, 41L) over temples of the person (10).

9. The heart rate monitor (40) claim 5, further comprising:

a display (45) operably connected to the pulse detector (44) to display a pulse of the person (10) responsive to the pulse signal (PS).

10. A cardiac therapy device (60), comprising:

heart rate monitor (69) for detecting a pulse of a person (10), the heart rate monitor (40) including

a platform (43),

a plurality of multi-axis accelerometers (41R, 41L) 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 (42R, 42L) and to generate common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}) indicative of a sensing by the accelerometers (41R, 41L) of extraneous motion by the person (10) relative to the acceleration sensing axes (42R, 42L), and

a pulse detector (44) operably connected to the multi-axis accelerometers (41R, 41L) to generate a pulse signal (PS) as a function of a vertical alignment of the acceleration sensing axes (42R, 42L) combining the differential mode signals (A_{ZR}, A_{ZL}) and cancelling the common mode signals (A_{XR}, A_{XL}, A_{YR}, A_{YL}); and

a pulse monitor (64) operably connected to the pulse detector (44) to monitor a the pulse of the person (10) responsive to the pulse signal (PS).

11. The cardiac therapy device (60) of claim 11, wherein the platform (43) is a nose clip operable to mount the accelerometers (41R, 41L) on a nose of the person (10).

12. The cardiac therapy device (60) of claim 11, wherein the platform (43) is a headband operable to position the accelerometers (41R, 41L) over temples of the person (10).

13. The cardiac therapy device (60) of claim 11, wherein the platform (43) is a head strap operable to position the accelerometers (41R, 41L) over temples of the person (10).

14. The cardiac therapy device (60) of claim 11, wherein the heart rate monitor (69) further includes:

a display (45) operably connected to the pulse detector (44) to display a pulse of the person (10) responsive to the pulse signal (PS).

15. The cardiac therapy device (60) of claim 14, wherein the pulse monitor (64) incorporate the display (45).

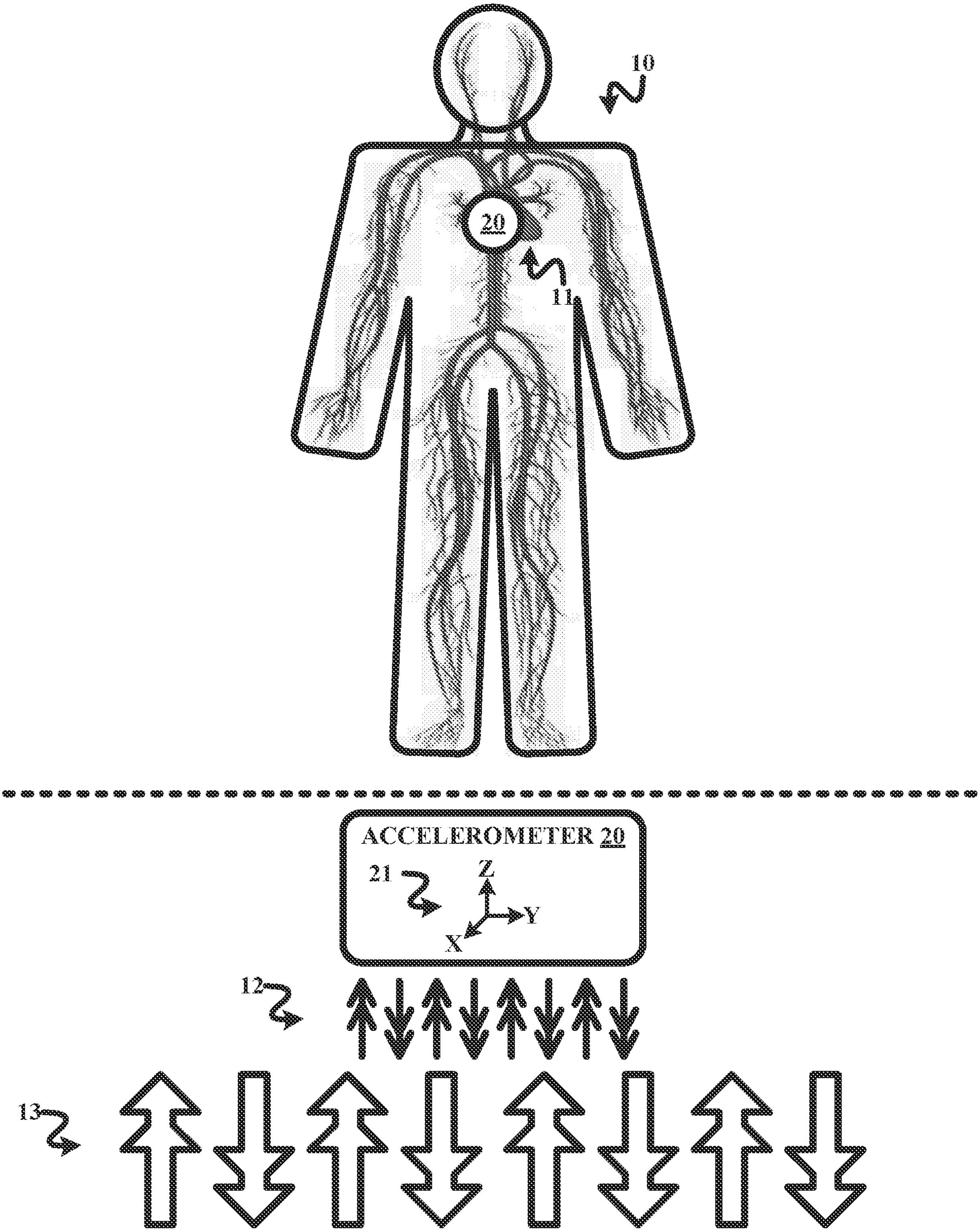

FIG. 1 (PRIOR ART)

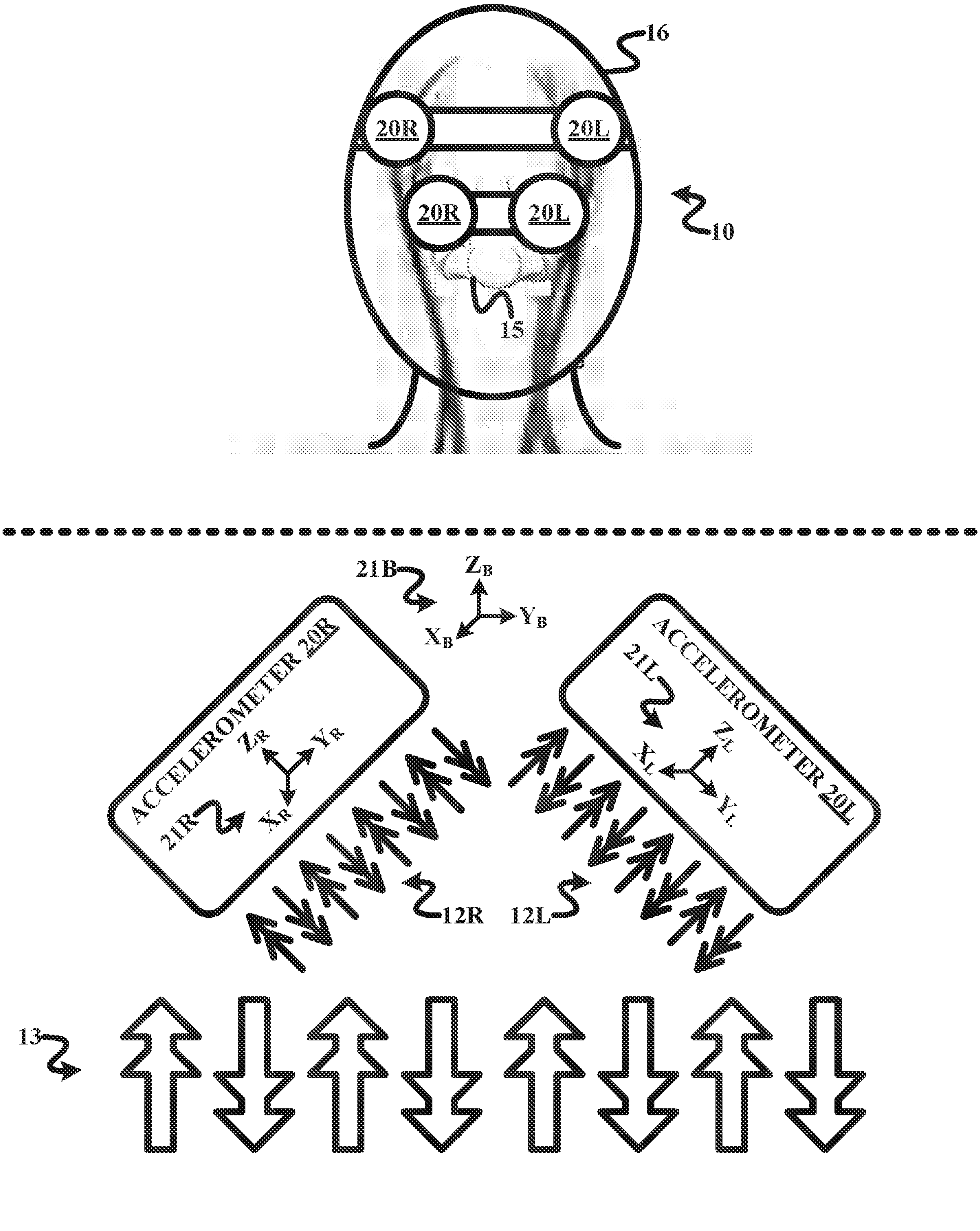
16
20R
20L
20R
20L
10
15
21B
Z_B
Y_B
X_B
ACCELEROMETER 20R
Z_R
Y_R
X_R
21R
ACCELEROMETER 20L
21L
Z_L
X_L
Y_L
12R
12L
13

FIG. 2

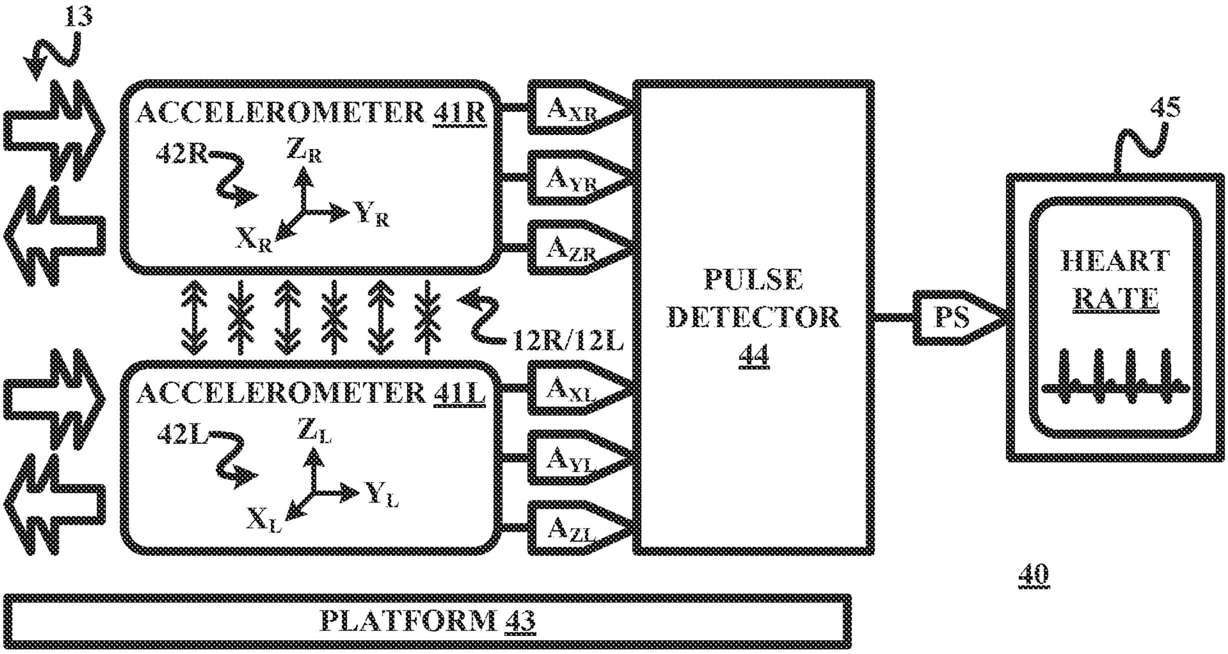
13
ACCELEROMETER 41R
42R
Z_R
Y_R
X_R
A_{XR}
A_{YR}
A_{ZR}
PULSE
DETECTOR
44
PS
45
HEART
RATE
12R/12L
ACCELEROMETER 41L
42L
Z_L
Y_L
X_L
A_{XL}
A_{YL}
A_{ZL}
40
PLATFORM 43

FIG. 3

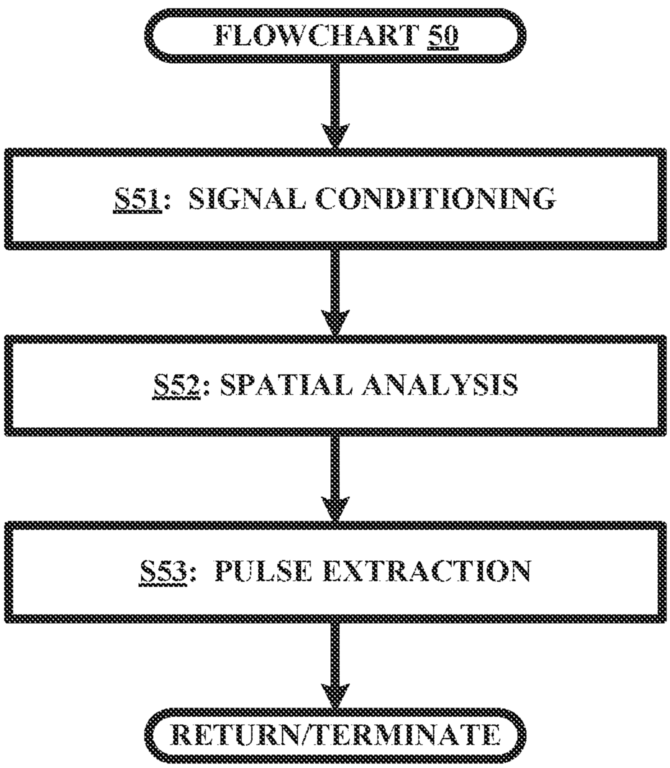
FLOWCHART 50
S51: SIGNAL CONDITIONING
S52: SPATIAL ANALYSIS
S53: PULSE EXTRACTION
RETURN/TERMINATE

FIG. 4

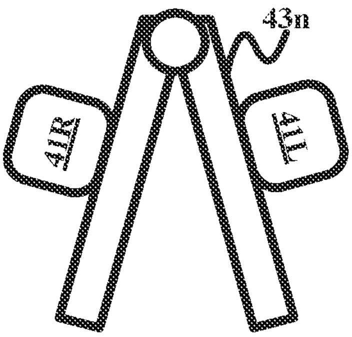

FIG. 5

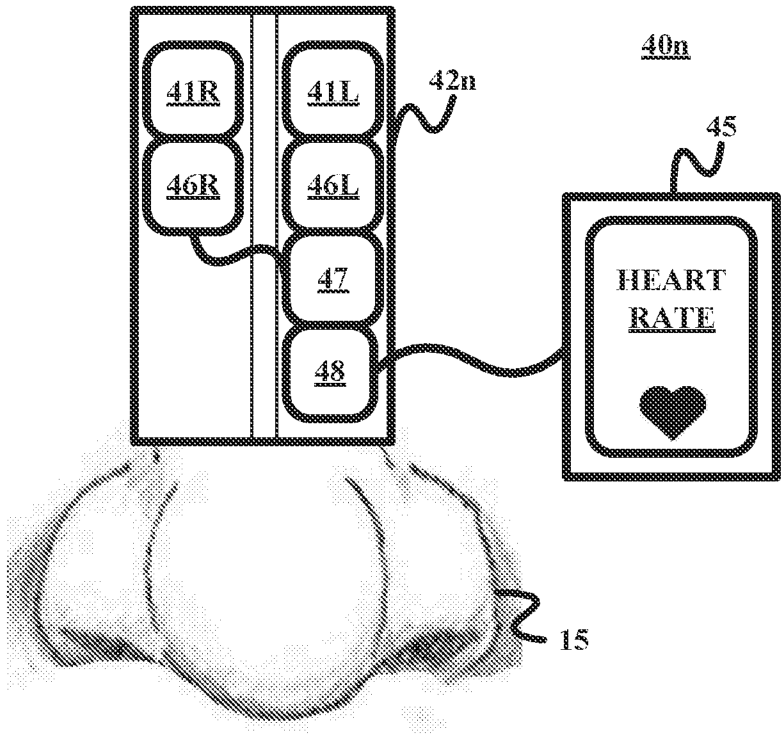

FIG. 6

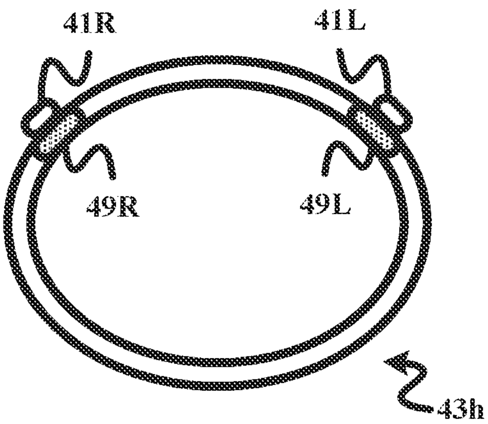

FIG. 7

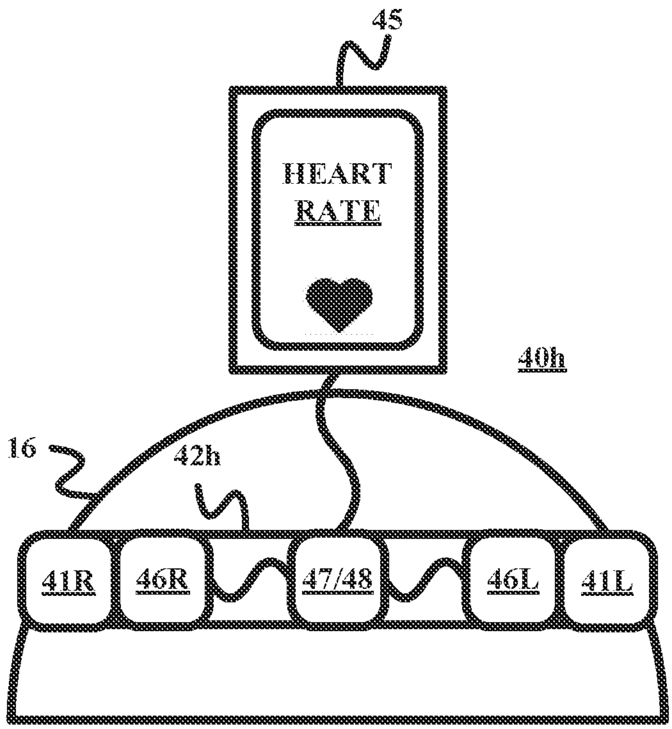

FIG. 8

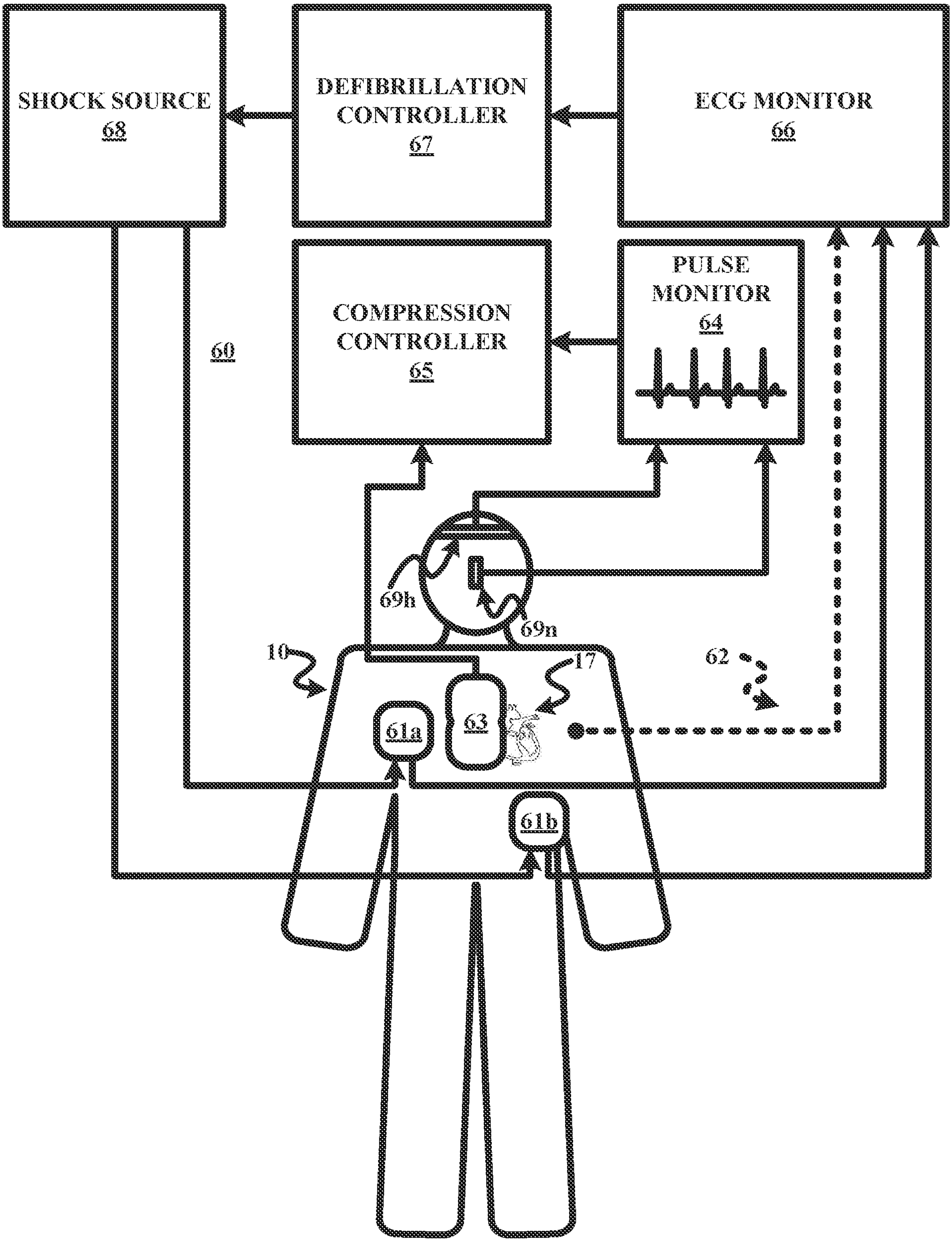
SHOCK SOURCE
68
DEFIBRILLATION
CONTROLLER
67
ECG MONITOR
66
COMPRESSION
CONTROLLER
65
PULSE
MONITOR
64
60
69h
69n
10
17
62
61a
63
61b

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/066745

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

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 A61N

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/133424 A1 (DONALDSON THOMAS ALAN [GB]) 30 May 2013 (2013-05-30) paragraph [0027] - paragraph [0040]	1-15
X	US 2013/131525 A1 (YIN BIN [NL] ET AL) 23 May 2013 (2013-05-23) paragraph [0030] - paragraph [0051]	1-15
A	US 2012/302900 A1 (YIN BIN [NL] ET AL) 29 November 2012 (2012-11-29) paragraph [0057]	1,5
A	EP 2 229 880 A1 (SUISSE ELECTRONIQUE MICROTECH [CH]) 22 September 2010 (2010-09-22) paragraph [0017] paragraph [0037] paragraph [0052]	2-4,6-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

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

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"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
18 March 2015	25/03/2015

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	Gooding Arango, J

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2014/066745

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