



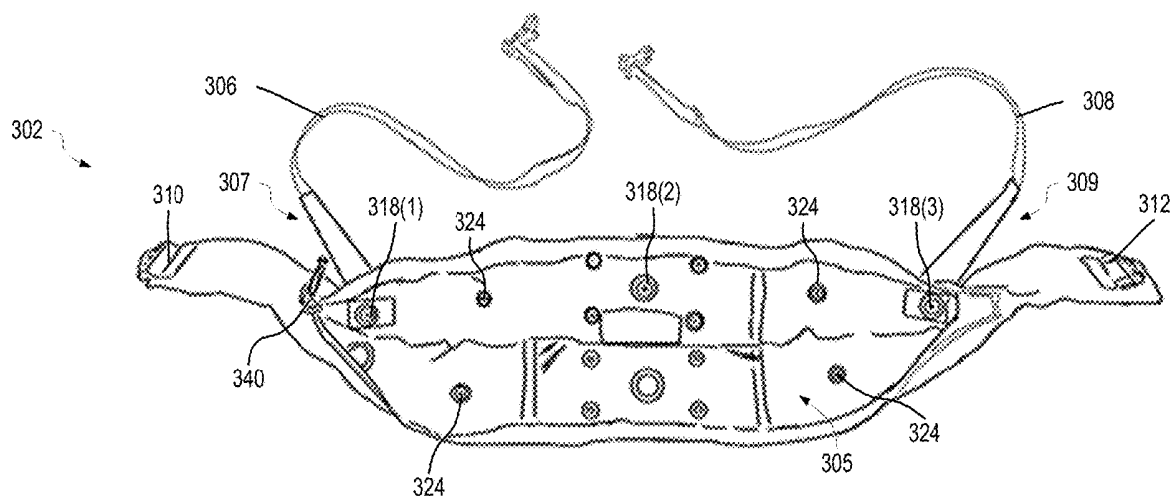
US 20200060545A1

(19) **United States**(12) **Patent Application Publication**
Maher et al.(10) **Pub. No.: US 2020/0060545 A1**(43) **Pub. Date: Feb. 27, 2020**(54) **ROUND-THE-CLOCK MONITORING OF AN ANIMAL'S HEALTH STATUS***A61B 7/04* (2006.01)*A61F 7/00* (2006.01)(71) Applicant: **VetMeasure, Inc.**, Ames, IA (US)(72) Inventors: **Kevin Daniel Maher**, Ames, IA (US);
Joel Adrian Moritz, Jr., Fort Collins, CO (US); **Dennis Matthew Schultz**, Fort Collins, CO (US); **Ian Adkins Huber**, Broomfield, CO (US); **Thomas Grant Morrison**, Fort Collins, CO (US)(52) **U.S. Cl.**CPC *A61B 5/0022* (2013.01); *A01K 27/002* (2013.01); *A01K 29/005* (2013.01); *A61B 5/01* (2013.01); *A61B 5/02055* (2013.01); *A61B 7/04* (2013.01); *A61B 5/0416* (2013.01); *A61B 5/7425* (2013.01); *A61B 5/0008* (2013.01); *A61B 5/7221* (2013.01); *A61F 7/0097* (2013.01); *A61B 5/7217* (2013.01); *A61B 5/6831* (2013.01)(21) Appl. No.: **16/550,201**(22) Filed: **Aug. 24, 2019****Related U.S. Application Data**

(60) Provisional application No. 62/722,508, filed on Aug. 24, 2018.

Publication Classification(51) **Int. Cl.***A61B 5/00* (2006.01)*A01K 27/00* (2006.01)*A01K 29/00* (2006.01)*A61B 5/01* (2006.01)*A61B 5/0205* (2006.01)(57) **ABSTRACT**

A system and associated methods for round-the-clock monitoring of an animal's health status includes an animal harness that is worn by the animal, and one or both of a mobile device and a remote server. The animal harness includes a plurality of sensors for collecting health measurements of the animal. The animal harness also includes a transceiver that communicates the health measurements to one or both of the mobile device and the remote server, where a user may view the health measurements. Firmware in the animal harness, an application running in the mobile device, and software in the remote server processes and corrects the health measurements to generate a health status of the animal and notifications are generated when the animal's health is not within a safe range defined by the user.



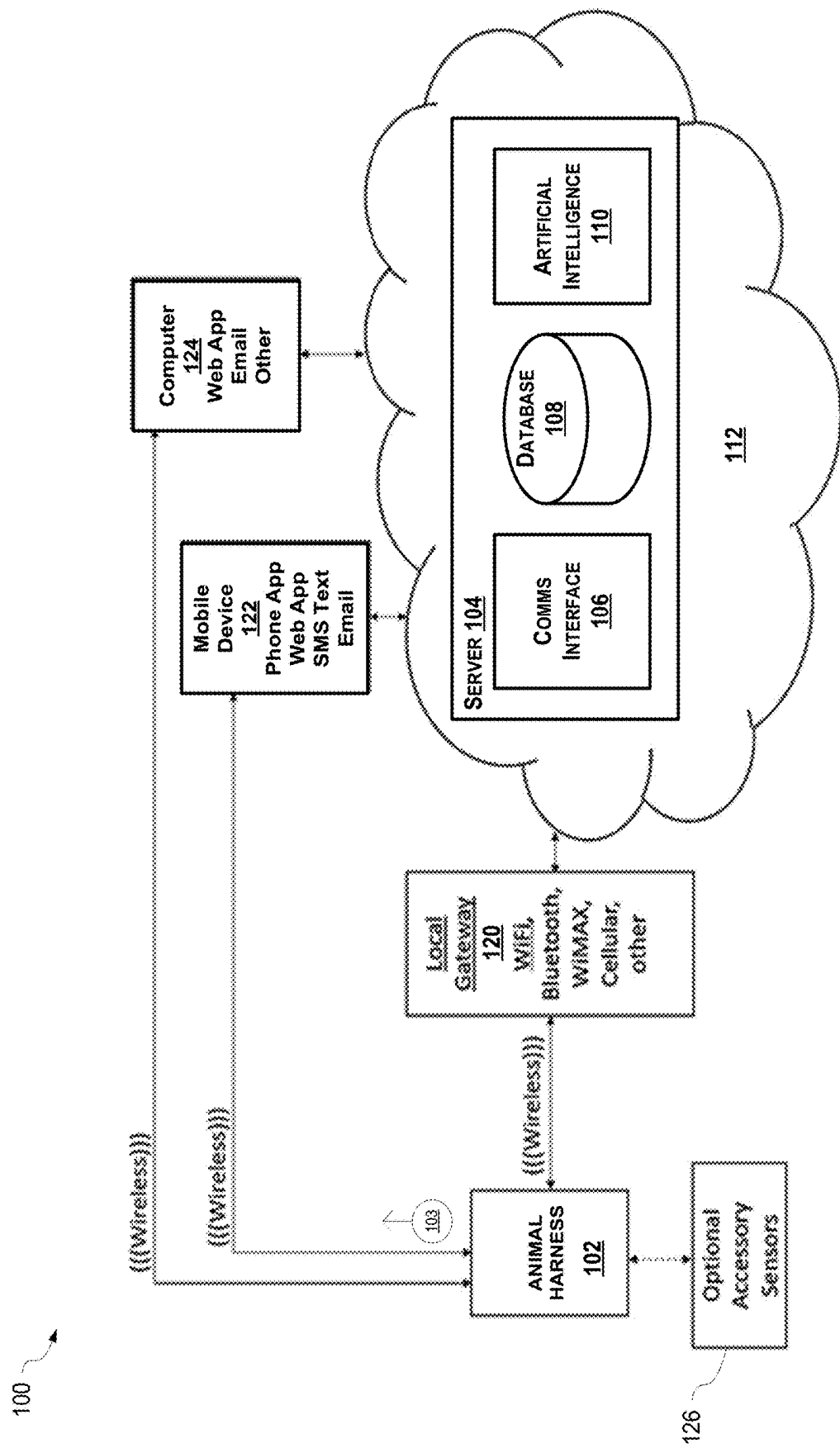


Figure 1

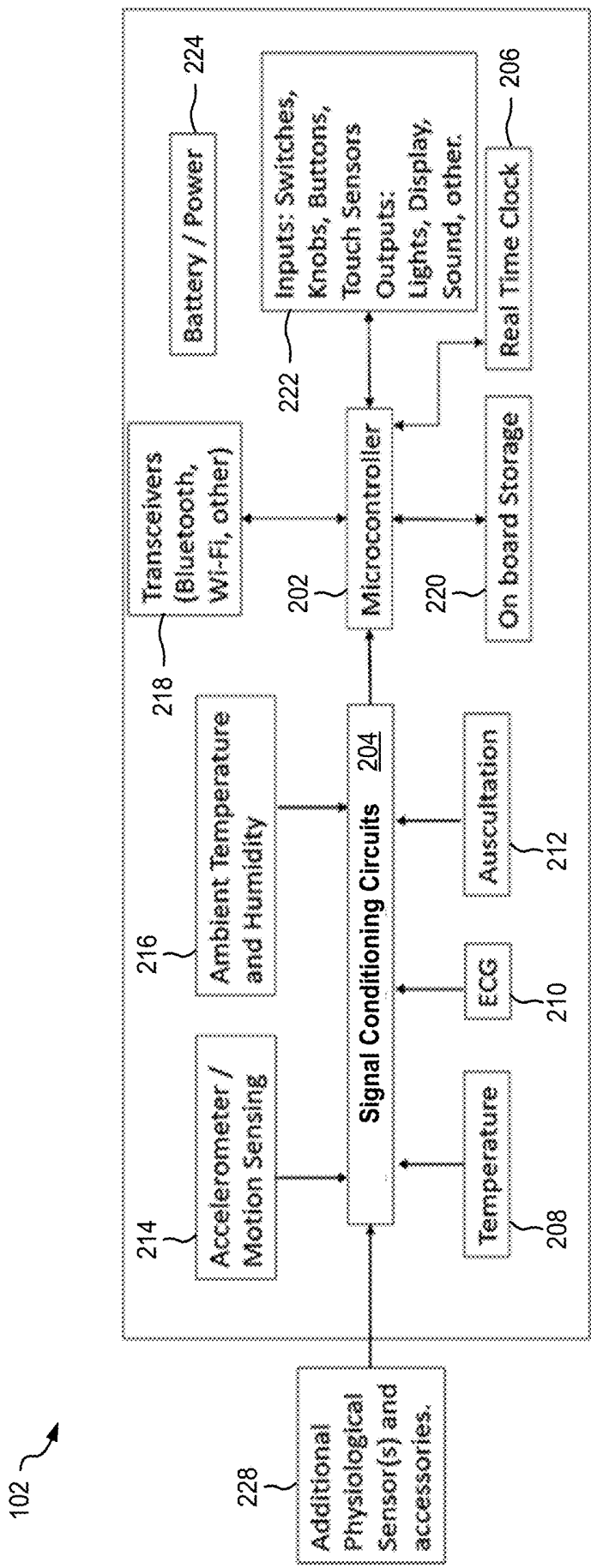


Figure 2

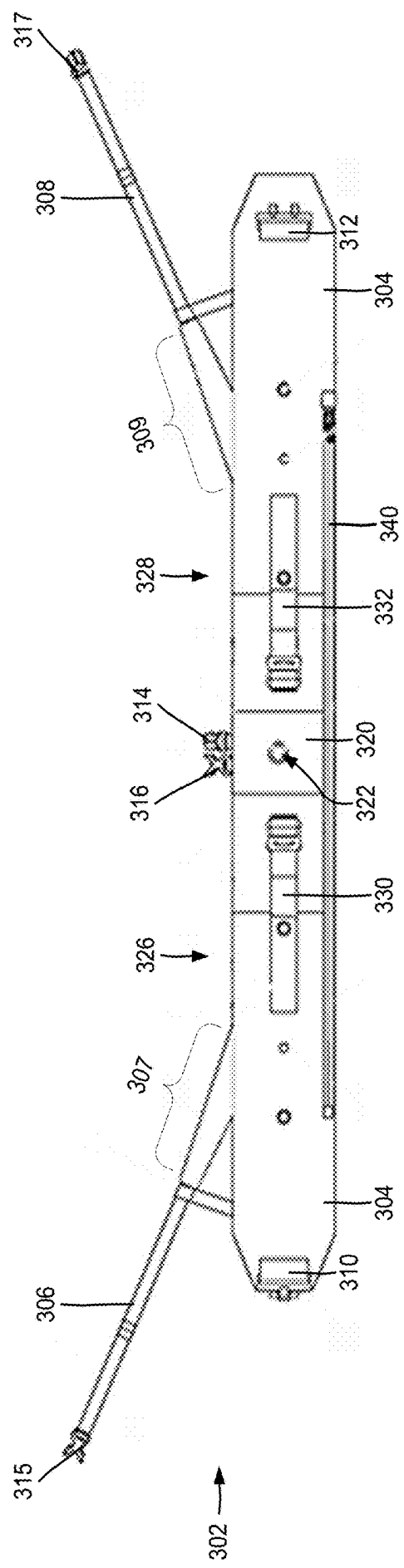


Figure 3A

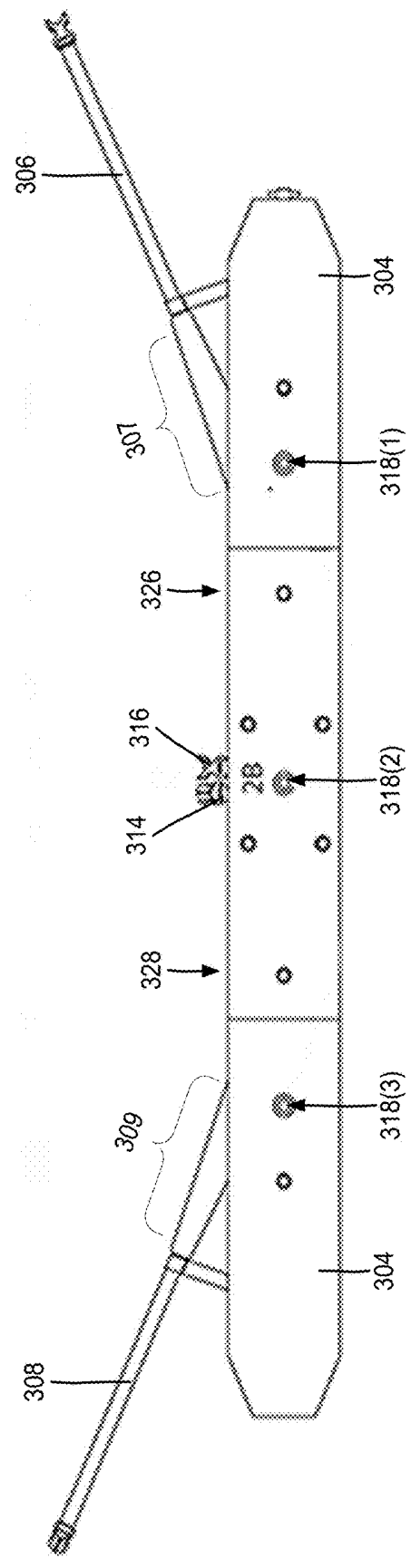


Figure 3B

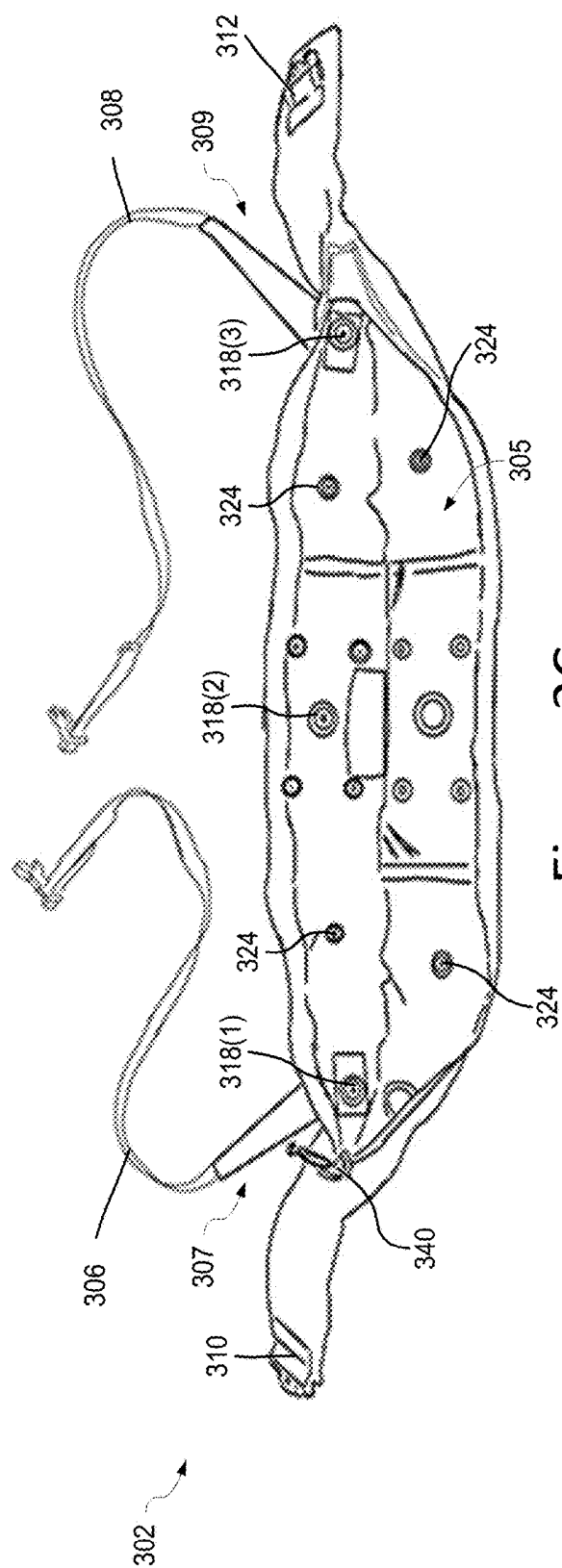


Figure 3C

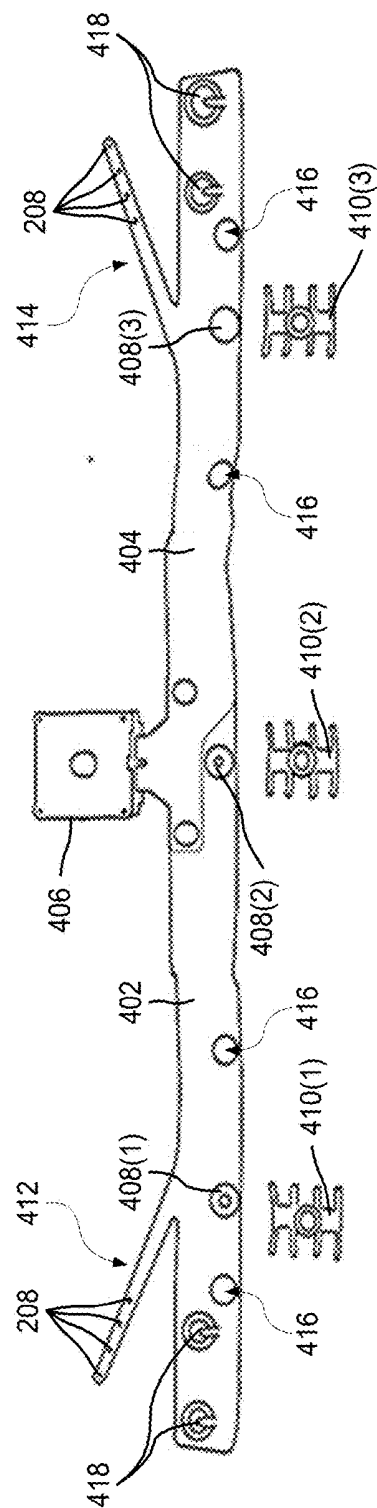


Figure 4

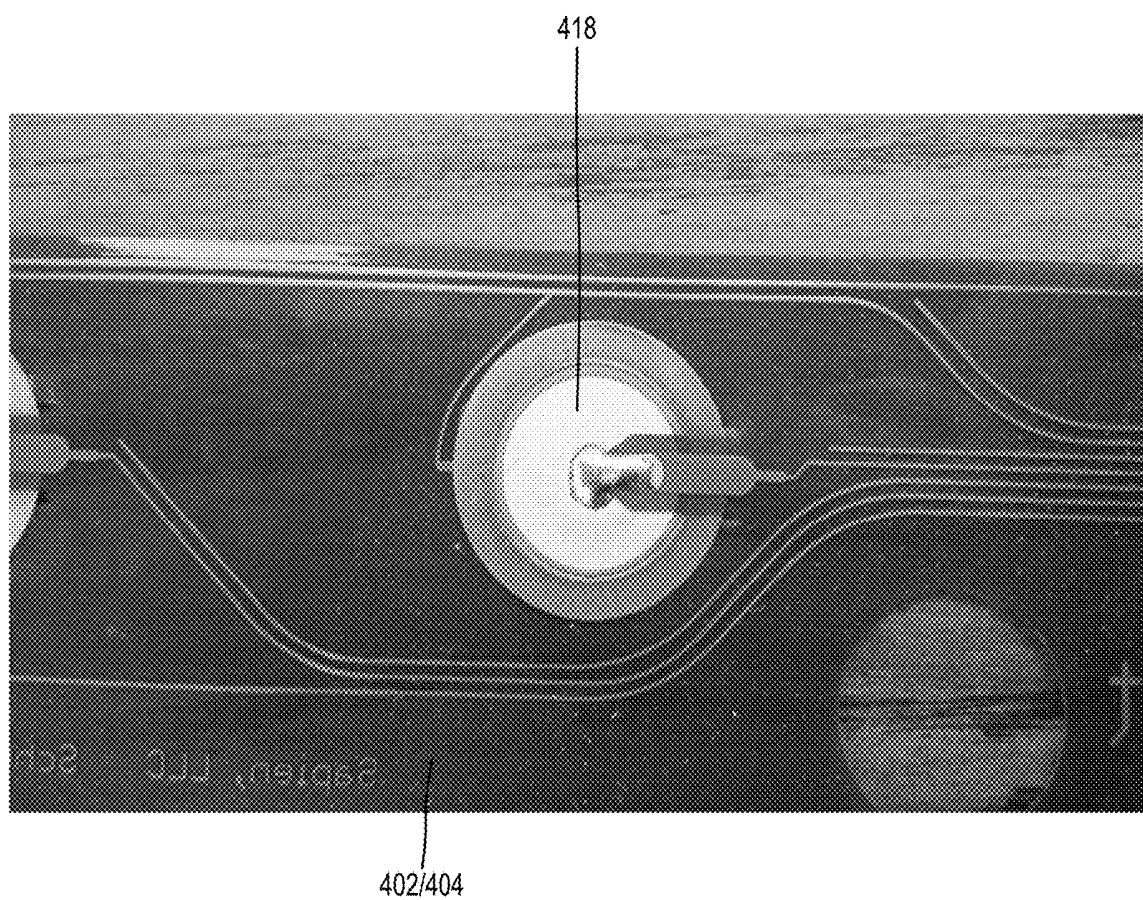


Figure 5

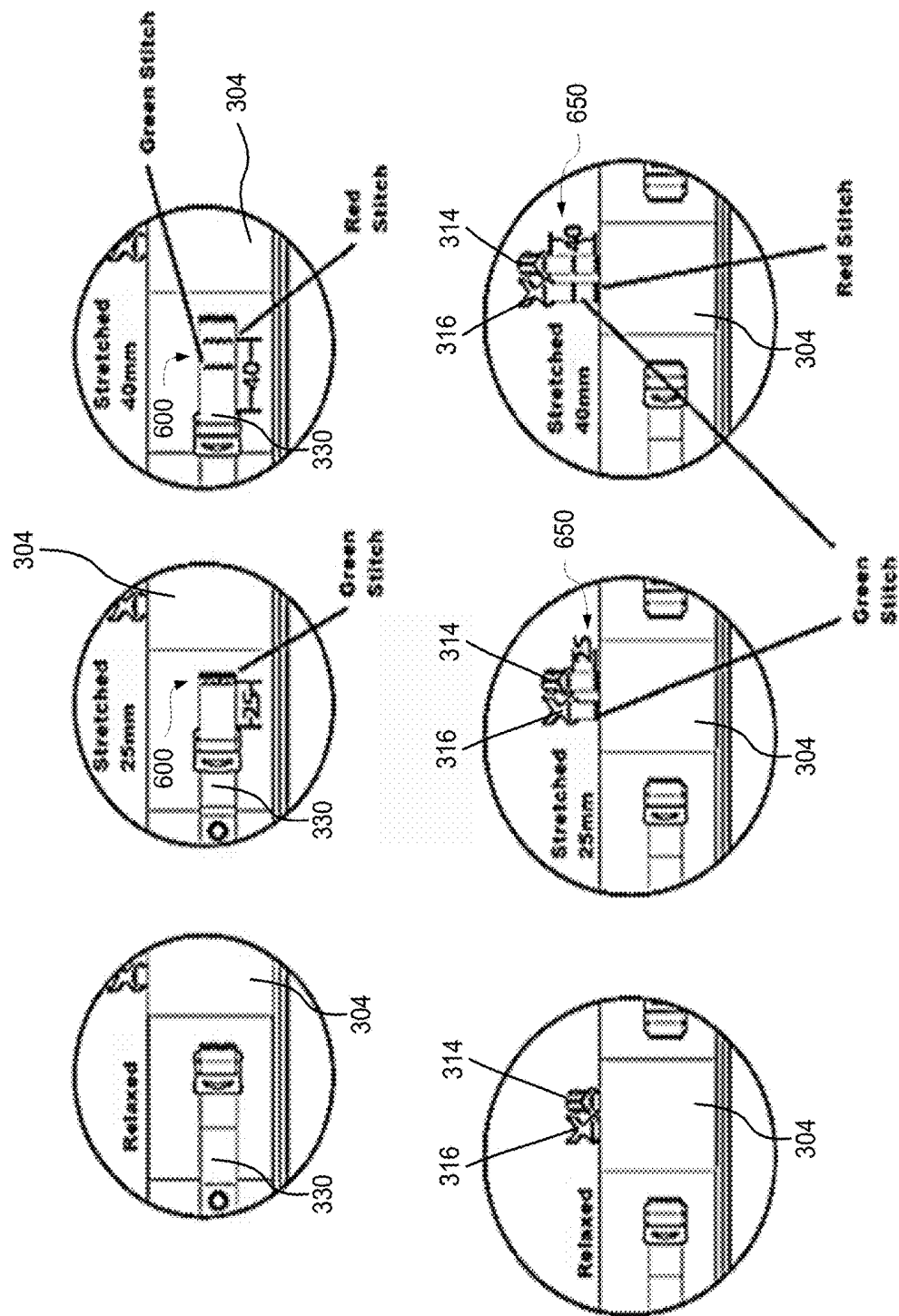


Figure 6

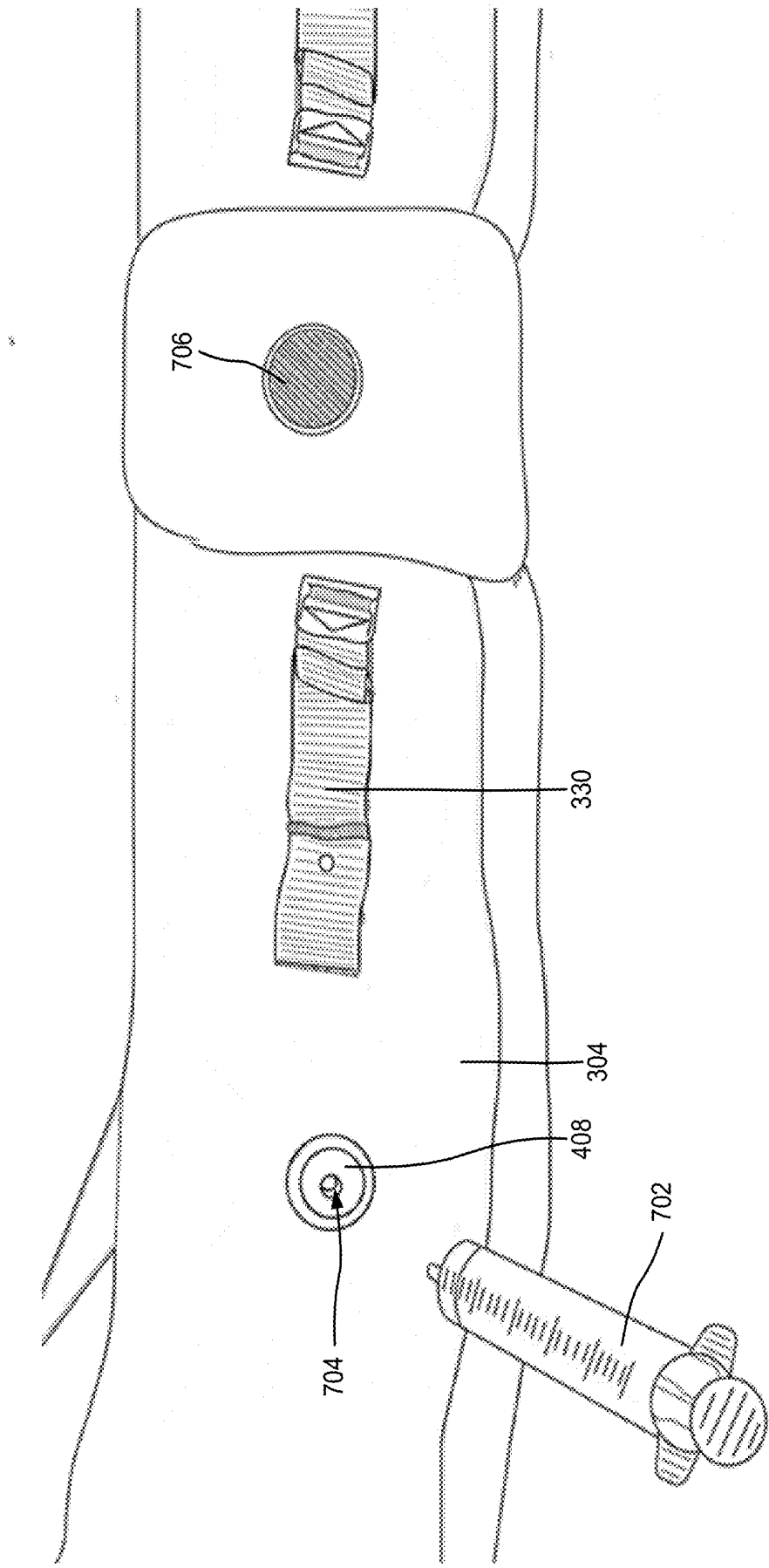


Figure 7

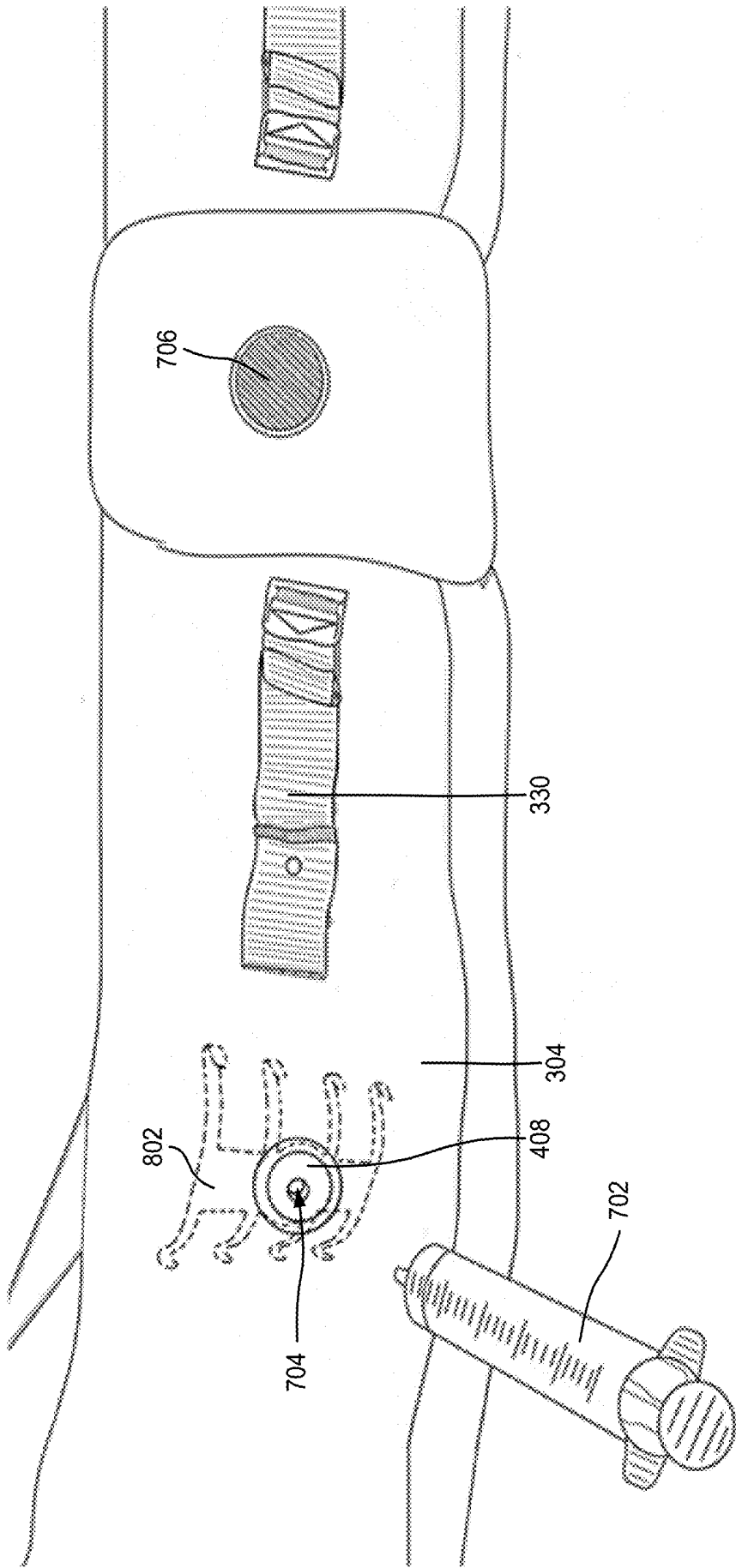


Figure 8

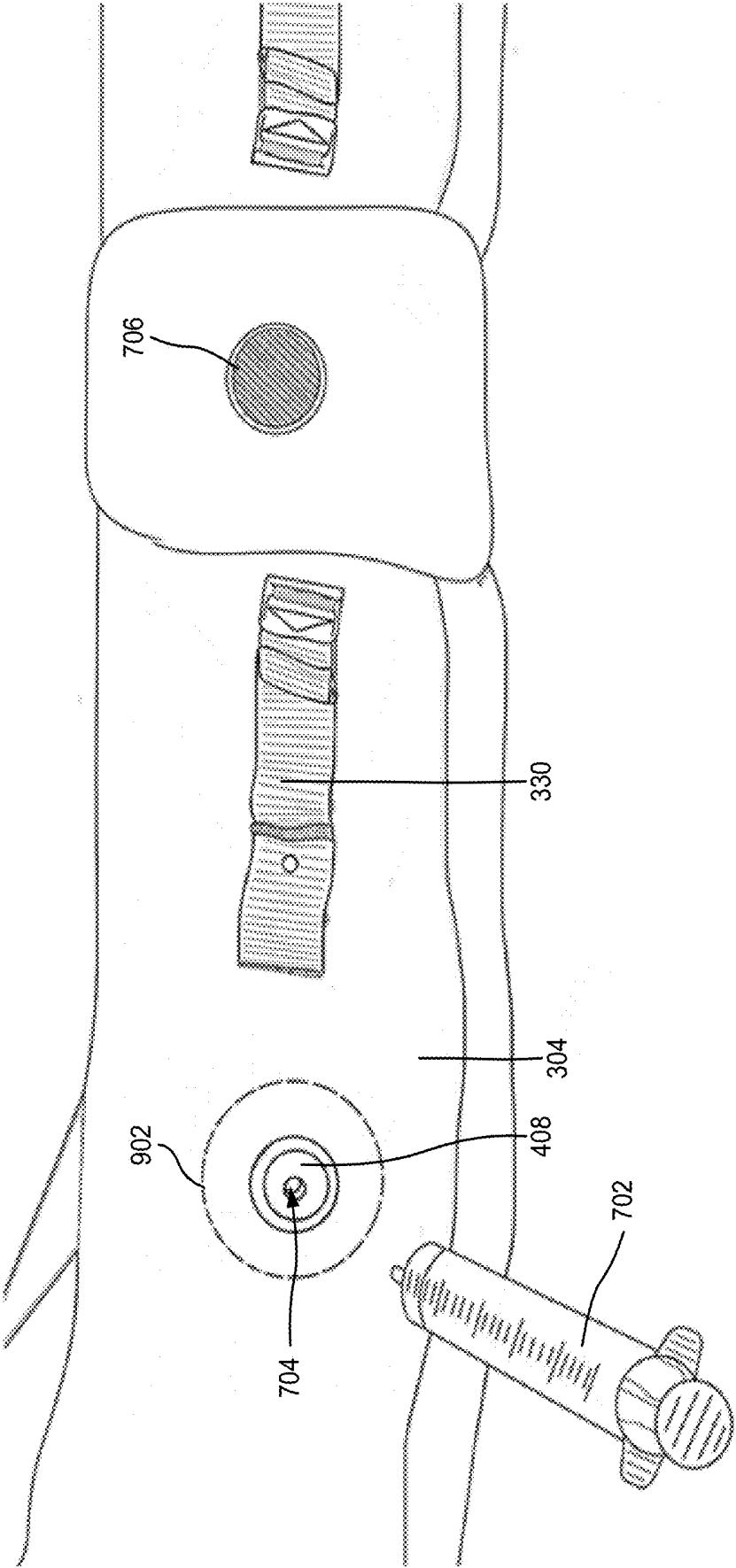


Figure 9

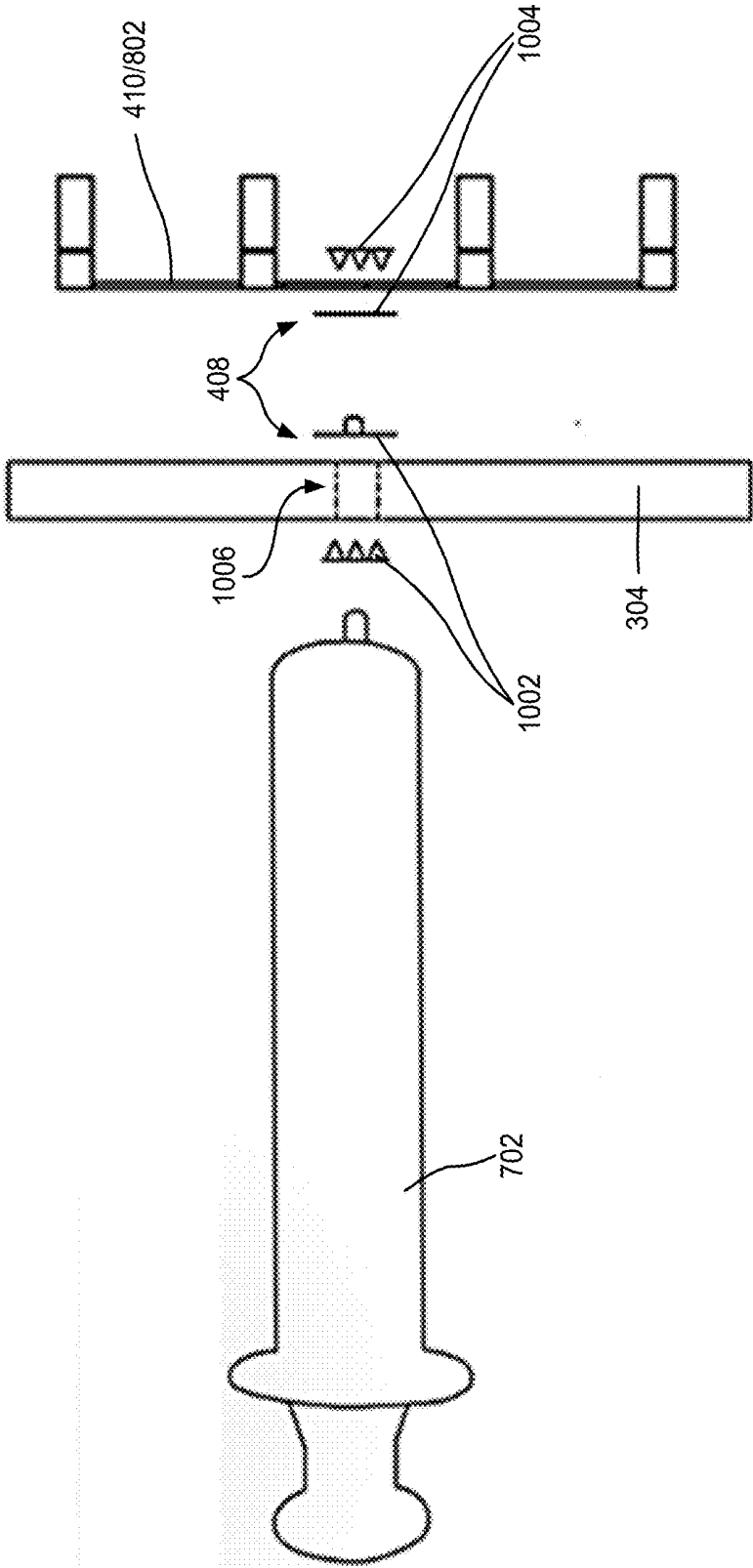


Figure 10

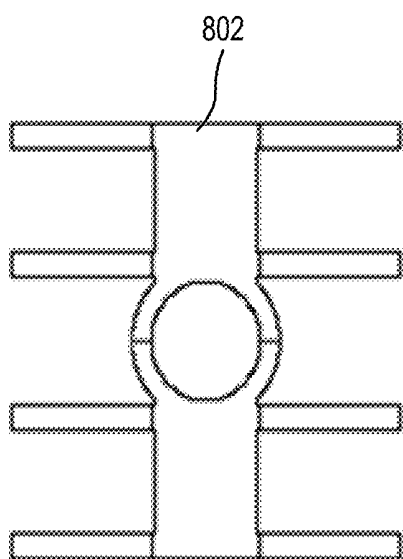


Figure 11A

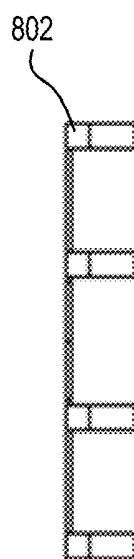


Figure 11B

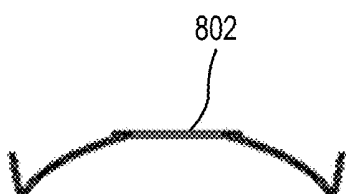


Figure 11C

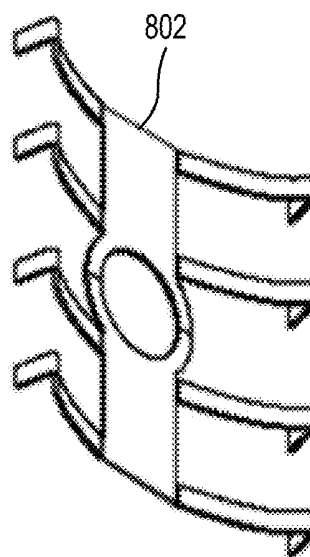


Figure 11D

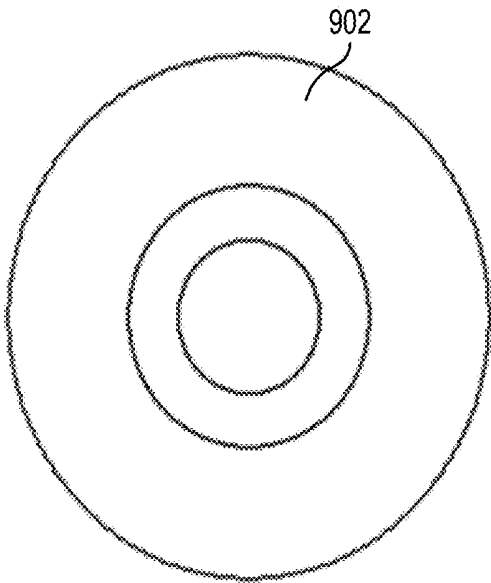


Figure 12A

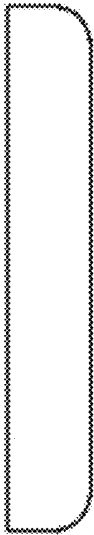


Figure 12B

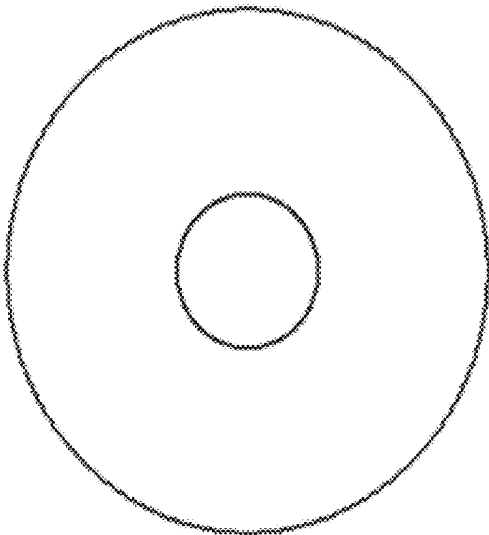


Figure 12C

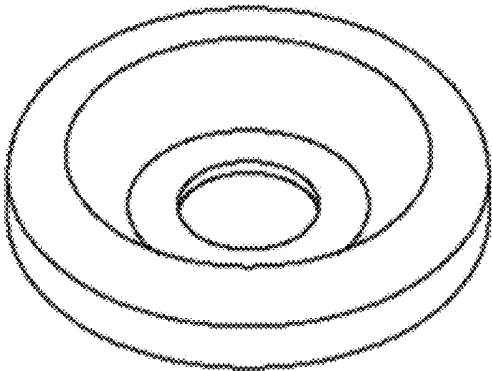


Figure 12D

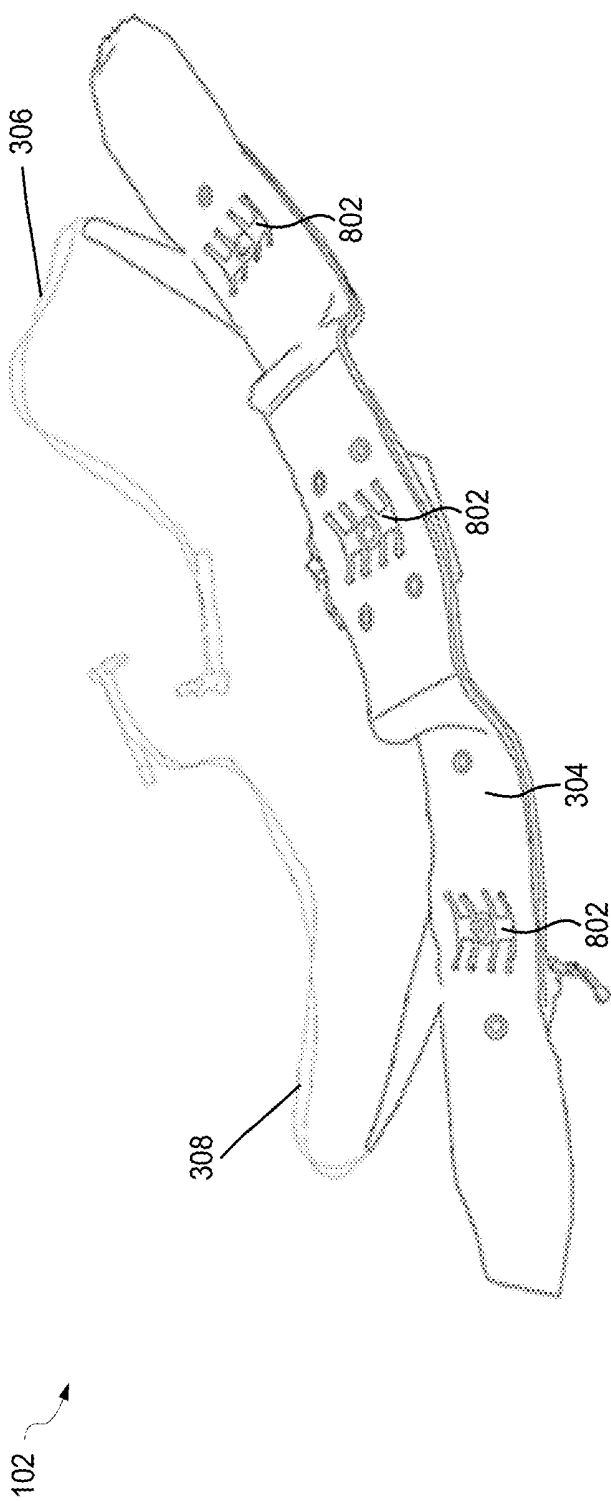


Figure 13

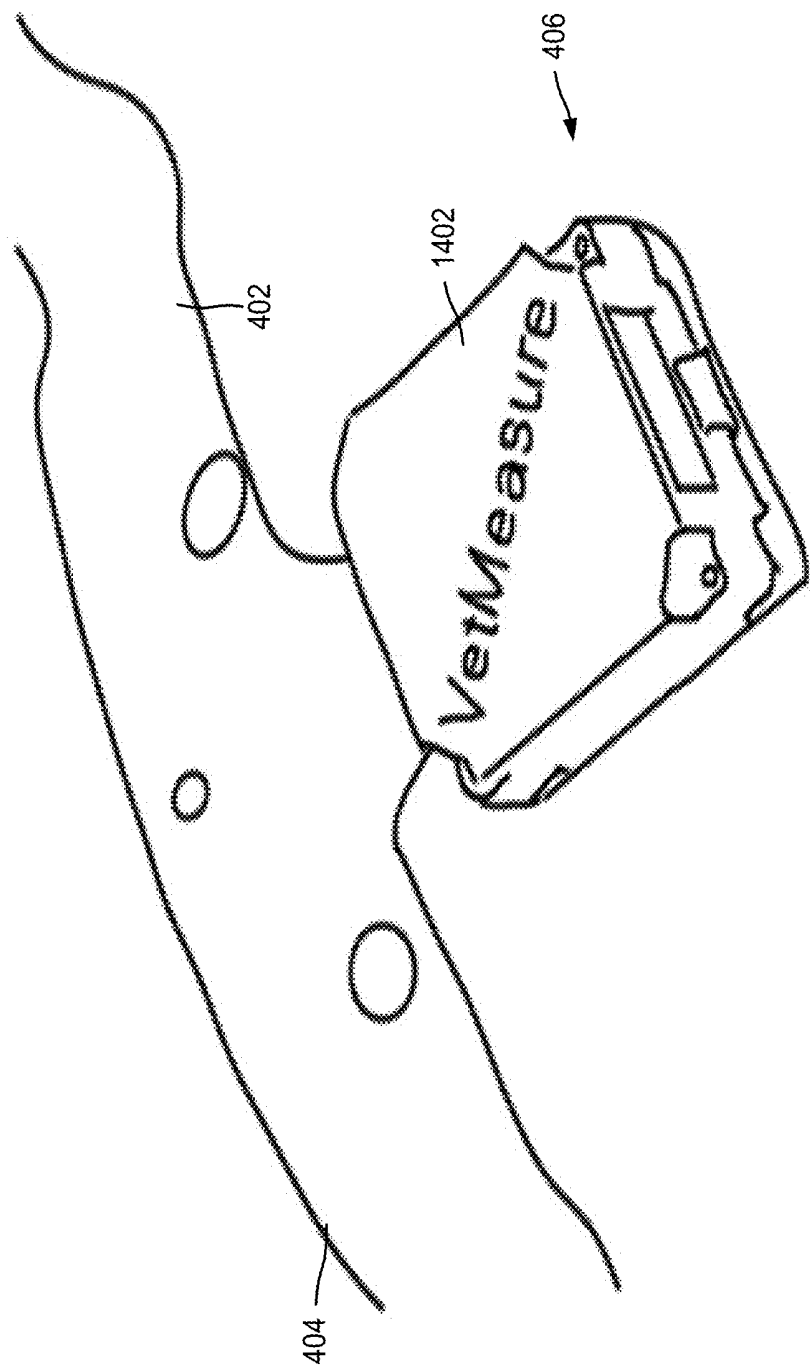


Figure 14

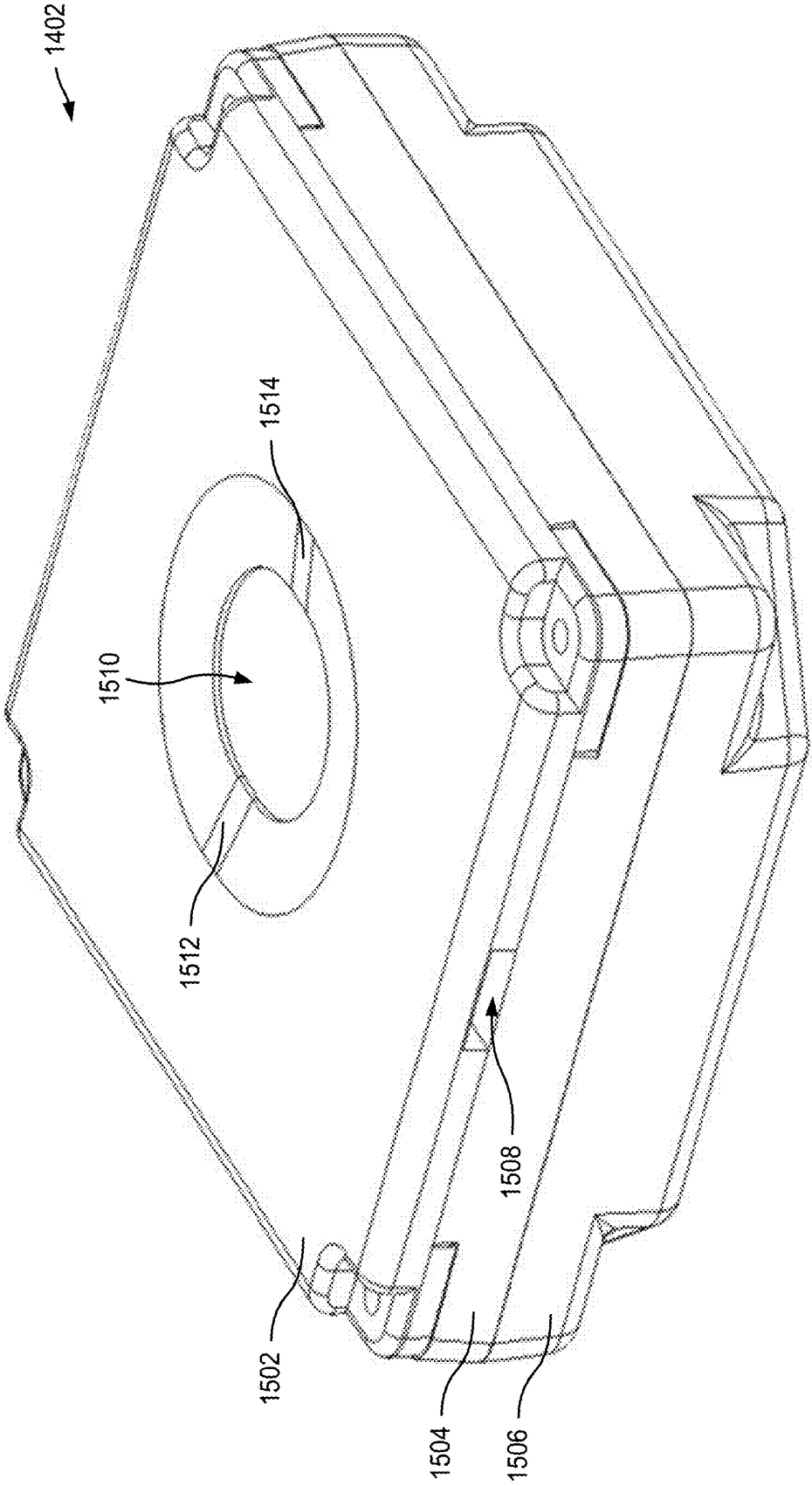


Figure 15

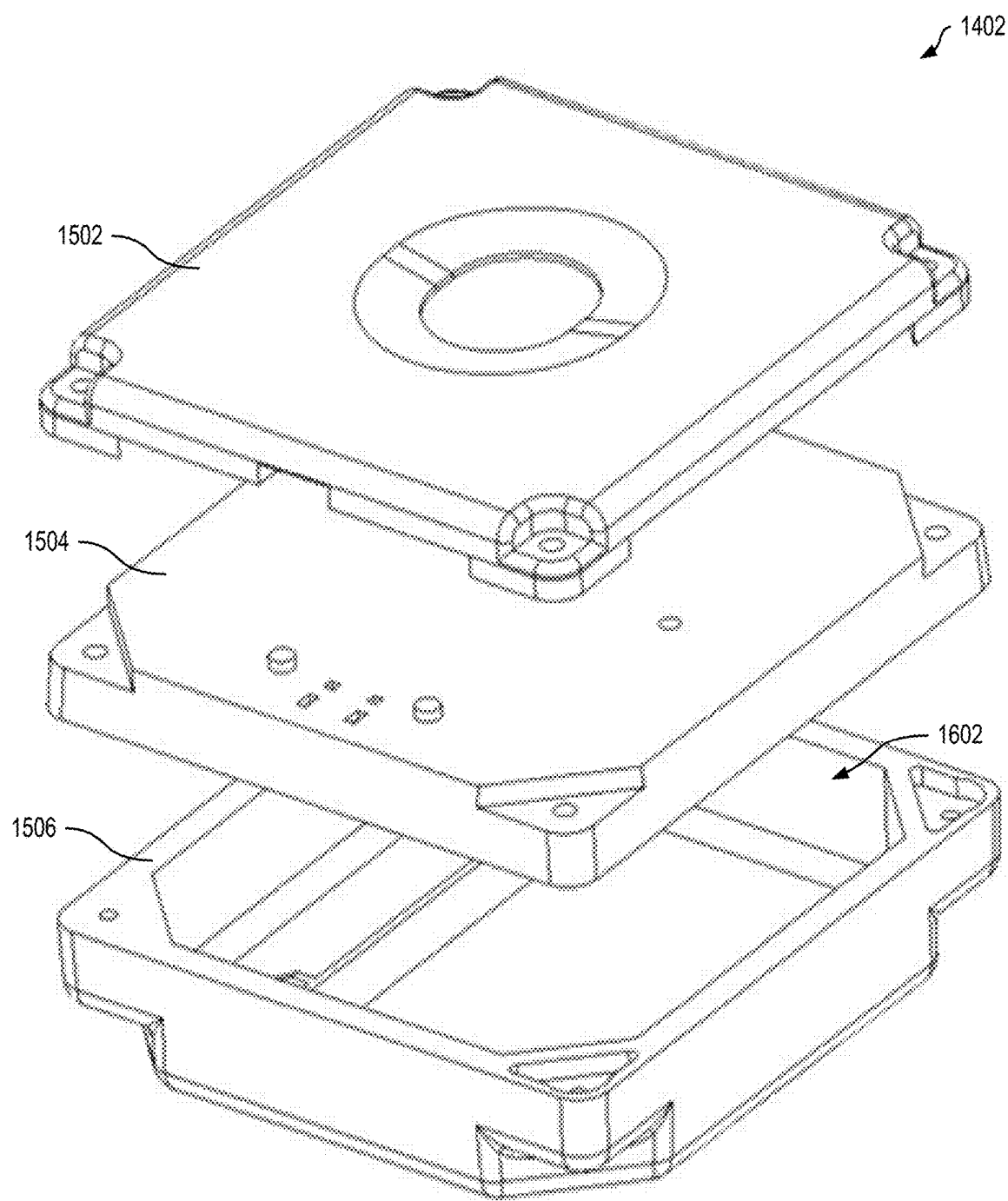


Figure 16

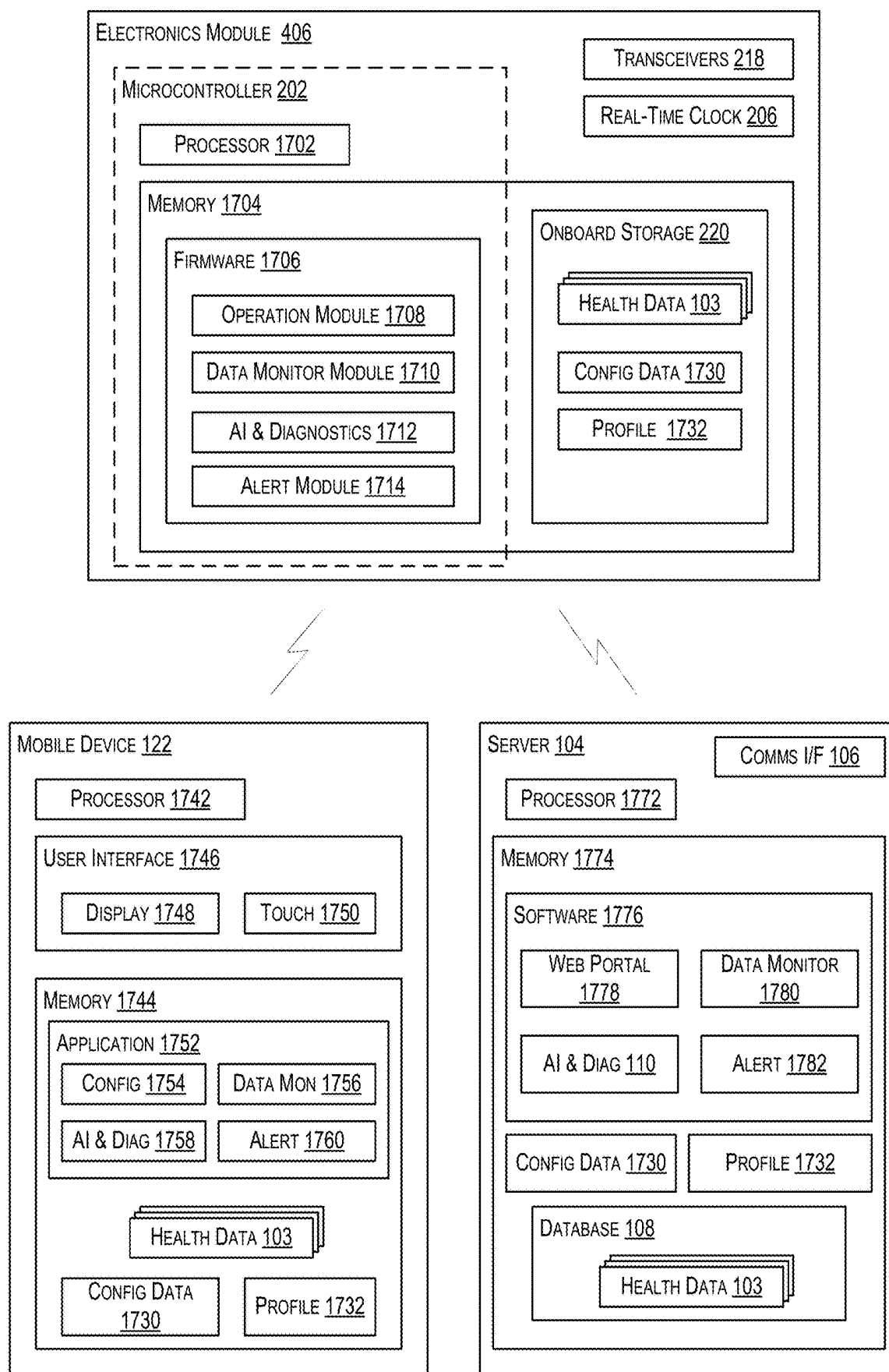


Figure 17

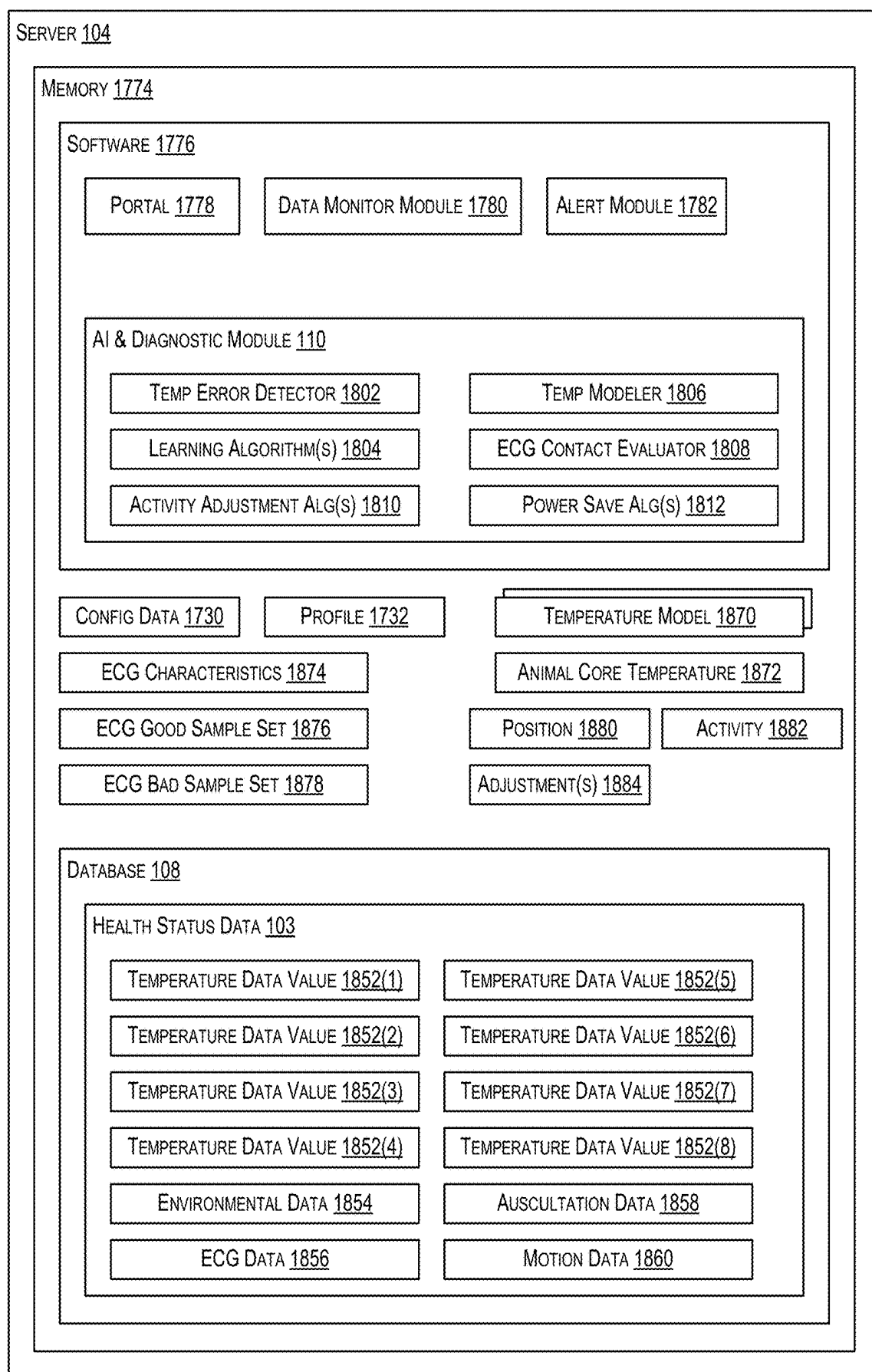


Figure 18

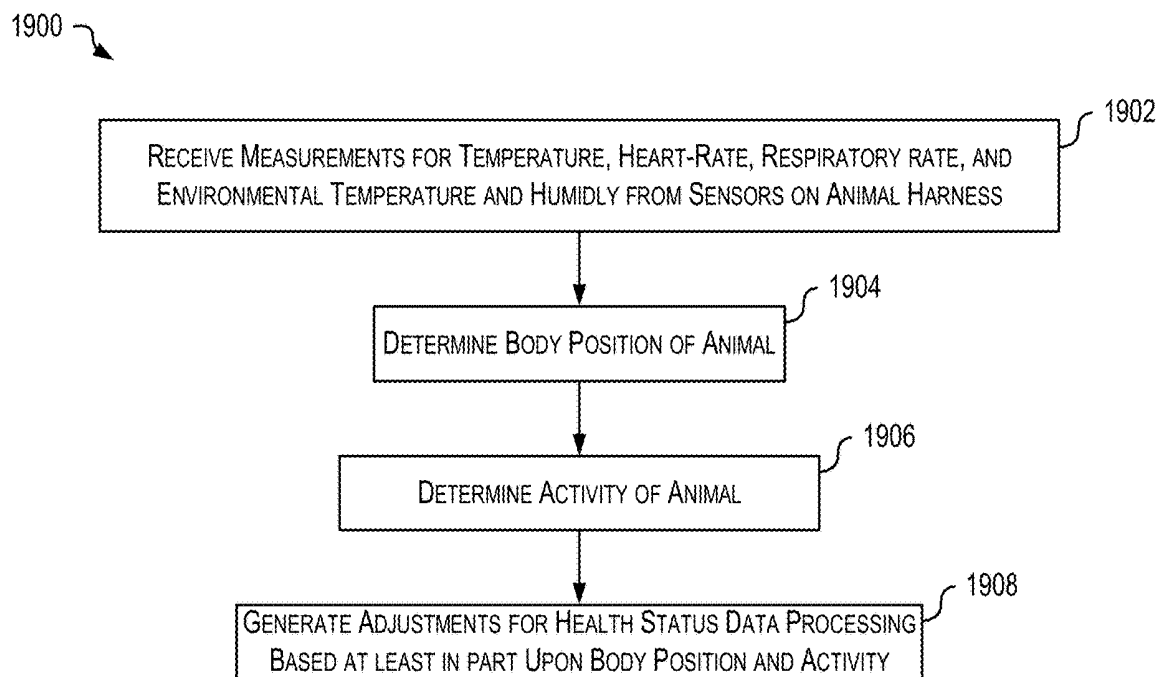


Figure 19

ROUND-THE-CLOCK MONITORING OF AN ANIMAL'S HEALTH STATUS

RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Patent Application Ser. No. 62/722,508, titled "Round-The-Clock Monitoring of An Animal's Health Status," filed Aug. 24, 2018, and incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] Electronic equipment for monitoring an animal's health.

BACKGROUND

[0003] Animal health monitoring has previously been limited to sensors in a collar worn by an animal. See U.S. Pat. No. 8,830,068.

SUMMARY OF THE INVENTION

[0004] On aspect of the present embodiments includes the realization that it is difficult and time consuming to continually monitor a health status of an animal, particularly when that animal is mobile and active. The present embodiments solve this problem by providing an animal harness that attaches to the animal. The animal harness includes a plurality of sensors positioned on the animal and a controller that, at intervals, takes a measurement from at least one of the sensors. At intervals, the controller may wirelessly transfer data from the measurements to an application (App) running on a nearby mobile device (e.g., a smartphone) and/or a remote server. Advantageously, the harness holds the sensors in position on the animal such that health status of the animal is monitored without the need of a person to be present.

[0005] Another aspect of the present embodiments includes the realization that an animal being monitored does not remain stationary and that this activity and changes in animal position may result in errant measurements. The present embodiments solve this problem by detecting when measurements are being affected by animal activity and/or an animal position and warning a user that measurements are affected. Advantageously, by detecting when activity and/or position of the animal results in errant measurements, false alarms on the animal's health status may be avoided.

[0006] Another aspect of the present embodiments includes the realization that environmental conditions of an animal may affect measurements of the animal's health. For example, the use of a warming blanket may directly affect temperature measurement taken from the animal. The present embodiments solve this problem by recognizing when the environmental conditions of the animal affect the measurements and provide a warning to a user that the measurements are being affected by environmental conditions.

[0007] The purpose of this new monitor system (e.g., also known as MeasureON! harness & VetMeasure app) is to be utilized by veterinarians, veterinary technicians, animal owners, livestock producers, animal caretakers, animal trainers and handlers, and others to monitor the health metrics and environmental conditions of an animal of all species, including humans. The initial target customer is the innovative veterinarian, who may incorporate this new monitor system into a veterinary practice to monitor high risk patients, specifically during the surgery and post-surgi-

cal recovery periods. The new monitor system may be sent home with the patient for continuous at-home monitoring to establish an accurate baseline for return visits, as well as to ensure recovery is occurring on schedule and the owner is complying with veterinarian recommendations. The system may include a wearable monitoring device containing many sensors and capabilities, or discreet monitoring and measurement equipment.

[0008] This new monitor system helps prevent heat stroke and/or heat stress in an animal by providing real-time analysis of the animal's body temperature and environmental conditions. The new monitor system also measures pulse/heart rate, ECG, respiratory rate, and activity level of the animal. The system also monitors the temperature and relative humidity level in the immediate vicinity of the animal. All these features combined generate an individual health profile for the animal which aids the veterinarian and/or animal owner/caretaker in diagnosis and/or treatment for health-related concerns.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a block diagram showing one example animal health monitoring system, in embodiments.

[0010] FIG. 2 is a block diagram showing the animal harness of FIG. 1 in further example detail, in embodiments.

[0011] FIGS. 3A and 3B are schematic diagrams illustrating an outside and an inside, respectively, of a soft chassis that forms the physical structure of the animal harness of FIGS. 1 and 2, in embodiments.

[0012] FIG. 3C is a perspective view of the opened soft chassis of FIGS. 3A and 3B, in embodiments.

[0013] FIG. 4 shows flexible panels and an electronics module that may be inserted into the soft chassis of FIG. 3C, in embodiments.

[0014] FIG. 5 shows a Piezo element attached to one flexible panel of FIG. 4.

[0015] FIG. 6 shows example tension indicators on adjustable length straps and axillary straps of the animal harness of FIG. 1, in embodiments.

[0016] FIG. 7 is a top view of a left side of the animal harness of FIG. 1 with gel being applied through a gel-port of the snap connector electrode, in embodiments.

[0017] FIG. 8 shows the left side of the animal harness with gel being applied through a 'gel-port' of the snap connector electrode to a comb-style electrode attached on the opposite side of the animal harness, in embodiments.

[0018] FIG. 9 shows gel being applied through a 'gel-port' of the snap connector electrode to a cup-style electrode attached on the opposite side of the animal harness, in embodiments.

[0019] FIG. 10 shows a cross-section of the gel syringe, the chassis/panels, and the snap connector electrode of FIG. 8.

[0020] FIG. 11 FIGS. 11A-11D show top, side, end, and perspective views, respectively, of the comb-style ECG electrode of FIGS. 4, 8, and 10, in embodiments.

[0021] FIGS. 12A-12D show top, side, bottom, and perspective views, respectively, of the cup-style ECG electrode of FIG. 9, in embodiments.

[0022] FIG. 13 is a bottom-inside perspective view of the animal harness of FIGS. 1-12 assembled with three comb-style ECG electrodes, in embodiments.

[0023] FIG. 14 shows a housing with the electronics module electrically and physically coupled with the flexible panels of FIG. 4, in embodiments.

[0024] FIG. 15 is a perspective view showing the top side of the housing of FIG. 14, in embodiments.

[0025] FIG. 16 is an exploded view of the housing of FIGS. 14 and 15, in embodiments.

[0026] FIG. 17 is a block diagram showing example functionality implemented by the animal health monitoring system of FIG. 1, in embodiments.

[0027] FIG. 18 is a block diagram showing the server of FIG. 1 in further example detail, in embodiments.

[0028] FIG. 19 is a flowchart illustrating one example method for improving accuracy of health metrics determined for an animal wearing animal harness, in embodiments.

DETAILED DESCRIPTION OF INVENTION

Animal Health Monitoring System

[0029] FIG. 1 is a block diagram showing one example animal health monitoring system 100 that monitors an animal's health status round-the-clock (e.g., continuously). System 100 may also be referred to as the VetMeasure system. System 100 includes an animal harness 102 that attaches around a heart girth of the animal and straps in front of the chest to surround the thoracic region to measure, at intervals, health measurements that may include one or more of animal body temperature, animal pulse/heart rate, animal respiration rate, animal activity level, environmental temperature, and environmental humidity. System 100 also includes at least one remote server 104 that may receive the health measurements (shown as health status data 103) from animal harness 102. Although shown as a single message, different parts of health status data 103 may be sent to each of server 104 and/or mobile device 122 at different rates, as described in detail below. Server 104 is a digital computer operating within "the cloud" 112 and that is accessible via the Internet for example. Server 104 may include a communication interface 106, a database 108, and artificial intelligence and diagnostics module 110 that cooperate to receive, store, and evaluate measurement data from animal harness 102. Communication interface 106 may implement one or more of Internet services, email, short-message-service (SMS), and so on. Database 108 may store health status data 103 received from animal harness 102. AI and diagnostics module 110 may evaluate database 108 and received health status data 103 to determine a health status of the animal.

[0030] Animal harness 102 may communicate wirelessly with server 104 via one or more of a local gateway 120 (e.g., a Wi-Fi access point), a mobile device 122 (e.g., a user's smartphone), and another computer 124 (e.g., a laptop or desktop computer). Animal harness 102 may implement at least one wireless protocol, such as Wi-Fi, WiMAX, cellular, Z-wave, Bluetooth, and so on, and may thereby communicate with server 104 via one or more of local gateway 120, mobile device 122, and computer 124. Animal harness 102 may also couple with other optional accessory sensors 126 that may operate as stand-alone devices. Mobile device 122 may run an application (e.g., an app) that allows a user to wirelessly interact with animal harness 102, such as for configuration, viewing data, and so on. Communication interface 106 may implement a web interface (e.g., a web site and/or portal) that allows an authorized user to interact

with server 104 to view data stored in database 108 for example, and/or to configure and/or use AI and diagnostics module 110 to evaluate health status data 103 as it is received and/or stored in database 108. Server 104, communication interface 106, and/or AI and diagnostics module 110 may provide other tools for viewing and/or processing health status data 103. Server 104 may use other methods for communication with animal harness 102 and/or the user without departing from the scope hereof.

Animal Harness

[0031] FIG. 2 is a block diagram showing animal harness 102 of FIG. 1 in further example detail. Animal harness 102 may include a microcontroller 202 that has at least one processor and memory storing machine readable instructions that, when executed by the processor control the processor to implement the functionality of the animal harness 102 as described herein. Animal harness 102 includes a real-time clock 206 that maintains a current time of day, which may be used to denote a time when a measurement was taken.

[0032] Animal harness 102 includes a plurality of sensors including one or more of a temperature sensor 208, an ECG sensor 210, an auscultation sensor 212, an accelerometer/motion sensor 214 (e.g., accelerometer), and ambient temperature and humidity sensor 216 (e.g., ambient temperature and ambient humidity). Sensors 208, 210, 212, 214, and 216, are built into animal harness 102 and may be electrically coupled with signal conditioning circuits 204 that may implement one or more of filtering, amplifying, and analog to digital conversion. Microcontroller 202 processes signals from sensors 208, 210, 212, 214, and 216, and may transmit the information as sensor health status data 103 via a transceiver 218 (e.g., using one or more protocols selected from the group comprising Bluetooth, Wi-Fi, and cellular networks, 2, 3, 4, and 5 g data networks) included with animal harness 102.

[0033] Sensor health status data 103 may include an identifier that uniquely identifies one or both of animal harness 102 and/or the animal wearing the harness, and may include data from one or more of sensors 208, 210, 212, 214, and 216, (e.g., a body temperature, ECG measurement, movement measurement, and so on), each tagged with a time that the sensor measurement was taken. When a connection to remote server 104 is unavailable, microcontroller 202 may store the sensor data and corresponding time in an onboard storage 220 (e.g., a non-volatile memory) of animal harness 102 for later transmission. In certain embodiments, animal harness 102 may send (e.g., via Bluetooth and/or Wi-Fi) health status data 103 to mobile device 122 and/or computer 124 where it may be displayed in real time (e.g., as a graph or other type of visual output).

[0034] Animal harness 102 may also include a user interface 222 that allows a user to interact directly (as opposed to using mobile device 122 for example) with animal harness 102. User interface 222 may include one or more input devices, such as switches, knobs, buttons, and touch sensors, and one or more output devices, such as lights, a display, audio (e.g., a sound generator, a piezoelectric element) and so on. Animal harness 102 also include an electrical power store 224 (e.g., a battery) that powers components of animal harness 102. As noted above, one or more additional physiological sensors 228 may be communicatively coupled (e.g., wired and/or wirelessly) with ani-

mal harness **102** and their data processed, stored, and/or transmitted within health status data **103**.

Physical Harness

[0035] FIGS. 3A and 3B are schematic diagrams illustrating an outside and an inside, respectively, of a soft chassis **302** that forms the physical structure of the animal harness **102** of FIGS. 1 and 2. FIG. 3C is a perspective view of the soft chassis **302** of FIGS. 3A and 3B with a zipper **340** opened and with flexible panels removed. FIG. 4 shows flexible panels **402** and **404** and an electronics module **406** that may be inserted into the soft chassis **302** of FIG. 3C. FIGS. 3A, 3B, 3C and 4 are best viewed together with the following description. Although shown as two flexible panels, flexible panels **402** and **404** may be formed as a single panel without departing from the scope hereof.

[0036] Soft chassis **302** is formed of fire-retardant materials and includes a main body **304** that is essentially one long hollow strap or tube that is sized to pass around the girth of the animal and joins together using clasps **310** and **312** positioned at opposite ends of main body **304**. Soft chassis **302** has two adjustable length axillary straps **306** and **308** that are positioned and sized to pass around right and left forelegs, respectively, of the animal, crossing in front and connecting, at distal ends, to connectors **314** and **316**, respectively, of main body **304** to secure animal harness **102** onto the animal.

[0037] Flexible panels **402** and **404** provide electrical connectivity between an electronics module **406** and one or more of temperature sensors **208**, ECG sensors **210**, and auscultation sensors **212**. Accelerometer/motion sensors **214** and ambient temperature and humidity sensors **216** may be included within electronics module **406**. As shown in FIG. 10, to electrically (and physically) couple flexible panels **402** and **404** with removable ECG electrodes **410(1)-(3)**, a male side **1002** of snap connector electrode **408** (e.g., a Dritz snap connector) passes through a hole **1006** in a gold plated copper pad of the flexible panel. A female side **1004** of snap connector electrode **408** is attached to removable ECG electrodes **410**. Male side **1002** passes through a hole **318** in soft chassis **302**, and mates with female side **1004** of the snap on removable ECG electrodes **410**. Advantageously, the snap hold flexible panels **402**, **404** in place within soft chassis **302**, and makes good electrical connection between the gold pad on the flexible panel and the removable ECG electrodes **410**. Movement and/or breathing of the animal serves to close this connection, making it unlikely to come undone while worn. Removable ECG electrodes **410(1)-(3)** are shown as comb-style electrodes, but could be other styles. As shown in FIG. 4, in certain embodiments, animal harness **102** uses three snap connector electrodes **408(1)-(3)** and three removable ECG electrodes **410** to collect ECG data and/or pulse/heart rate of the animal.

[0038] Removable ECG electrodes **410** are designed for operation on a very hairy surface (e.g., an animal's coat), possibly without requiring a conductive electrolyte or gel, such as when signal processing is used. This type of removable ECG electrode **410** is very useful if a good ECG signal is desired without shaving fur from the animal. However, removable ECG electrodes **410** may be made from **316** stainless steel and used with one or more of a Hydrogel, Saline, and Alcohol as the conductive electrolyte to improve conductivity between the electrode and the skin of the animal.

Activity:

[0039] Accelerometer/motion sensors **214** may include a 3-axis accelerometer that measures one or both of the animal's motion and orientation in space. Motion sensors **214** may be used to monitor activity of the animal, the gait of the animal, and the orientation of the animal. In certain embodiments, accelerometer/motion sensors **214** are configured to indicate (e.g., change the logic on an external pin from high to low) when acceleration on a certain axis exceeds a certain threshold. Animal harness **102** may count these acceleration events while in a very low power state to estimate the relative activity level of the animal (e.g., low activity, active, and very active) based on the number of these events over a ten second period. Similarly, these counts may be stored and averaged to give a more representative estimate of activity over a period (e.g., one minute). In other embodiments, raw acceleration information from all axes of accelerometer/motion sensors **214** may be sampled at high or low rates and transmitted to the server or user for viewing and additional analysis.

Environmental Conditions:

[0040] Ambient temperature and humidity sensor **216** may be positioned on an external surface of electronics module **406**, where it is protected from damage by a plastic cover and from dirt by a breathable mesh window in soft chassis **302** (e.g., when electronics module **406** is inserted into a pocket **320** of soft chassis **302**). This configuration allows protection of ambient temperature and humidity sensor **216** while allowing adequate ambient airflow to the sensor such that it may accurately read the environmental temperature and relative humidity in the immediate vicinity of the animal wearing animal harness **102**. Ambient temperature and humidity sensor **216** (e.g., environmental conditions of the animal) may be sampled once every ten seconds and may be sent to mobile device **122** and/or server **104**.

Pulse/Heart Rate

[0041] Animal harness **102** positions snap connector electrodes **408(1)** and **408(3)** and corresponding removable ECG electrodes **410(1)** and **410(3)** on either side of the animal and positions snap connector electrode **408(2)** and corresponding removable ECG electrode **410(2)** in the center of the animal's back (to reduce signal noise). In one embodiment, electronics module **406** samples ECG sensors **210** at a rate of **150Hz** in a low power mode, for example. Every ten seconds, the ECG signal is processed with filters, thresholds, and differential analysis tools to detect R and S components of the ECG waveform. The Beats Per Minute (BPM) is calculated based on the number of RS waveforms detected in the ten second sample. In one embodiment, the BPM estimate for six, ten second samples are stored and averaged to reduce the effects of random error and provide the user with more representative BPM value for any given minute. However, other averaging periods (e.g., averaging the last three samples) may be used without departing from the scope hereof. Processed BPM measurement and raw ECG signals may be sent to the user or the server for viewing and analysis.

[0042] Flexible panels **402** and **404**, and electronics module **406**, fit inside a cavity **305** of soft chassis **302**, and zipper **340** may be closed. Soft chassis **302** protects sensors **208**, **210**, **212**, **214**, and **216**, flexible panels **402** and **404**, and

electronics module **406** and holds the sensors **208**, **210**, **212**, **214**, and **216** positioned on flexible panels **402** and **404** tightly against the body of the animal (e.g., canine).

[0043] Temperature sensors **208** are positioned on offshoots **412** and **414** of flexible panels **402** and **404**, respectively, that fit into a cavity formed within lower portions **307** and **308** of axillary straps **306** and **308**, respectively. That is, cavity **305** of main body **304** extends into lower portions **307** and **309**. Lower portions **307** and **308** may be thermally insulated on the side of the strap facing away from the body of the animal when animal harness **102** is worn. This insulation mitigates the effects of outside environmental conditions on the readings of temperature sensors **208** and allows for accurate estimations of animal body temperature. In one embodiment, animal harness **102** includes eight temperature sensors **208**, four positioned on each offshoot **412** and **414**, to measure animal temperature from the axillary region of the animal. These eight temperature sensors **208** allows a temperature profile of the axillary region of the animal to be measured for both sides of the animal to provide better estimates of body temperature for animals of different body types and sizes.

[0044] Temperature data may be sensed every ten seconds, temperature data is captured from all eight temperatures. Electronics module **406** may determine a maximum value of the eight temperature sensors may be stored as the Max Body Temperature (MBT). Animal harness **102** may keep track of the last six MBT measurements (e.g., taken every ten seconds over **60** seconds) and an average of these MBT values, and all individual sensor values, may be reported to server **104** and/or mobile device **122**.

[0045] The multiple sensors located along the length of the axillary strap provides redundancy and makes the readings more robust and independent to changes in body type and size of different animals.

[0046] In certain embodiments, a radiation shield is formed of a reflective material that is positioned outside temperature sensors **208** to retain animal body heat on the sensor (e.g., instead of the heat radiating away). For example, the insulation at lower portions **307** and **308** may include a metallicized or reflective film. This reflective insulation may also reflect radiative heat from external influences away from temperatures sensors **208**.

[0047] In certain embodiments, at least lower portions **307** and **308** of animal harness **102** have a black material positioned towards the animal, and a white or reflective material on the outer surface. These colors are selected to provide more accurate body temperature measurements using temperature sensors **208**. In certain embodiments, a majority of animal harness **102** may include reflective and/or colored material, that is selected to reduce the effects of radiative heat from the environment from influencing temperature measurements and/or from heating the animal.

[0048] Zipper **340** runs down the length of main body **304** that allows the chassis to open and expose cavity **305**. Pocket **320** has a circular hole **322** covered in mesh (see mesh **706**, FIGS. **7**, **8** and **9**) is formed in the center of main body **304** on top of soft chassis **302** to receive electronics module **406** when flexible panels **402** and **404** are inserted into cavity **305**. Hollow lower portions **307** and **309** of axillary straps **306** and **309** receive offshoots **412** and **414** flexible panels **402** and **404** with temperature sensors **208**. One or more snaps **324** at key locations of cavity **305** in soft

chassis **302** snap through holes **416** in flexible panels **402** and **404** to retain flexible panels **402** and **404** in place.

[0049] In certain embodiments, main body **304** has folding regions **326** and **328** where it may partially fold over on itself, the folding amount being controlled by adjustable length straps **330** and **332**, respectfully, that attach at either end of the corresponding folding region **326** and **328**. Accordingly, a user may adjust a length of main body **304** (effectively adjusting the circumference of animal harness **102** when clasps **310** and **312** of main body **304** are connected) to accommodate different sized animals.

[0050] Axillary straps **306** and **308** may also be adjustable in length, and each has one connector **315** and **317**, respectfully, at distal ends that attach to connectors **314** and **316**, respectively, on main body **304**. Connectors **314** and **315** of axillary strap **306** are reversed as compared to connectors **316** and **317** of axillary strap **308** such that only one axillary strap may be fastened to one of the connectors on main body **304**. When animal harness **102** is worn by an animal, the hollow lower portions **307** and **309** of axillary straps **306** and **308** passes through the axillary region (e.g., armpit) of the animal, thereby holding temperature sensors **208** therein against the axillary region of the animal. Axillary straps **306** and **308** then cross the chest and opposite shoulder of the animal and connect to connectors **314** and **316** of main body **304** at the back of the animal. Fastening axillary straps **306** and **308** over the chest and across the opposite shoulder of the animal to the connector at the back allows the straps, and thus temperature sensors **208**, to be tightened securely to ensure good heat transfer from the animal to the sensors, without pulling tension or pressure into the shoulder joint of the axillary region, which would restrict motion and cause rubbing.

[0051] Two piezoelectric disc elements **418** are located at both left and right ends of flexible panels **402** and **404** (e.g., four altogether) and may function as auscultation sensors **212** and/or operate to emit vibrations and/or sounds. Each piezoelectric disc element **418** may be used to detect small and large vibrations and pressure changes. In certain embodiments, differences in signals from different ones of piezoelectric disc elements **418** may be used to determined relative locations of anatomical structures, movements of the animal, flow, and/or activity of bodily processes. Piezoelectric disc elements **418** may also be used to determine cardiac anomalies in the animal. One or more piezoelectric disc elements **418** may be driven or powered to produce a signal that may be measured on other (or the same) piezoelectric disc elements **418**, the attenuation of this signal may be used to determine composition of the body, direction or speed of fluid (e.g., blood) flow, or other items of interest, similarly or identical to ultrasound measurements. One or more of piezoelectric disc elements **418** may be used to sense chest expansion, respiratory rate, and/or heart rate. Flexible panels **402** and **404** are replaceable by the manufacturer or by the user should one of the flexible panels **402** and/or sensors **208**, **210**, **212**, **214**, and **216** be damaged or broken. When the pressure on the discs changes, a voltage is generated across the element which is sampled by the onboard Analog to digital Converter (e.g., in signal conditioning circuits **204**). To estimate chest expansion, and therefore respiratory rate, the signal from the four sensors are averaged, then filtered through a bandpass filter. The number of times that the resulting signal crosses a threshold is counted and the respiratory rate in terms of Breaths Per

Minute, or BrPM is estimated. The piezo elements are sampled at 15 Hz and the signal is analyzed every ten seconds. Results from six processed samples may be stored and averaged to reduce the effects of random error and to provide a more representative estimate of Breaths Per Minute. Processed data and raw signals may be sent to the user or server for viewing and analysis.

[0052] Flexible panels 402 and 404 may be removed from soft chassis 302 and soft chassis 302 may be washed and flexible panels 402 and 404 may be carefully cleaned separately. In certain embodiments, flexible panels 402 and 404 comprise one or more flex-circuits (flexible printed circuit) that position sensors 208, 210, 212, 214, and 216 and/or snap connector electrodes 408 relative to the animal and provide electrical coupling between the sensors and/or electrodes and electronics module 406.

[0053] Animal harness 102 (including at least soft chassis 302, PCBs, flexible panels 402, 404, and housing of electronics module 406 (see housing 1402 of FIG. 14) are constructed from fire retardant materials. This is advantageous, since animal harness 102 is a high performance wearable electronics device with large capacity and possibly more volatile batteries. That is, the chassis, panels, circuit boards, and plastic components (or any single component) of animal harness 102 are made from fire retardant or fire-resistant materials.

[0054] FIG. 5 shows an example piezoelectric disk element 418 electrically and physically connected to one of flexible panels 402, 404 of FIG. 4, such that piezoelectric disk element 418 may measure pressure changes and motion of the chest of an animal configured with animal harness 102. In this example, the back of piezoelectric disc elements 418 is soldered to flexible panel 402, 404, and the top of piezoelectric disc elements is 'lap-soldered' to a 'tab' in flexible panel 402, 404. Advantageously, piezoelectric disk element 418 generates a signal indicative of movement (e.g., flex) in flexible panels 402, 404.

Tension Indicators

[0055] FIG. 6 shows first example tension indicator 600 on adjustable length strap 330 and a second example tension indicator 650 on axillary straps 306 and 308, and also showing connectors 314 and 316 of axillary straps 306 and 308. Tension indicators 600 and 650 are each formed of green stitching and red stitching that provide a visual indication, to a person attaching animal harness 102 to an animal, of when animal harness 102 is adjusted correctly. This facilitates use of animal harness 102 with animals of different sizes and body types. For example, tension indicator 600 ensures correct tension of main body 304 around the torso of the animal and tension indicators 650 ensure correct tension of axillary straps 306 and 308 around the axillary region of the animal. Tension indicators 600 are made from elastic material with colored stitching at different lengths, where the elastic material attaches to adjustable length straps 330 and 332. The elastic is partially covered by a piece of fabric, so that as the elastic stretches with the tightening of adjustable length straps 330 and 332, different colors of stitching are revealed. This ensures that the person attaching animal harness 102 may repeatedly tension main body 304 correctly, irrespectively of the size and body type of the animal. Tension indicators 650 for axillary straps 306 and 308 are constructed similarly, but attach to connectors 314 and 316 located in the middle of main body 304. These

locations of tension indicators ensure quick tensioning, and quick visibility of indicators. Chassis may be constructed with or without adjustable straps, or with or without tension indicators, and may include elastic portions designed to provide an acceptable tension range over a range or variety of different animals.

Gel Being Applied to Electrode Through 'Gel-Port'

[0056] FIG. 7 is a top view of a left side of animal harness 102 of FIG. 1 with gel being applied through a gel-port of snap connector electrode 408. When animal harness 102 is being worn by an animal, a conductive gel or liquid may be applied directly to snap connector electrodes 408 (e.g., a removable ECG electrode 410) through a gel-port 704 (e.g., a hole) in snap connector electrodes 408. Snap connector electrodes 408 electrically connects with flexible panel 402/404. A standard plastic syringe 702 without a needle, or a squeeze bottle, may be filled with the conductive gel or liquid and applied directly through snap connector electrodes 408 and onto skin underneath, while animal harness 102 is attached to the animal. The conductive gel or liquid increases conductivity between the animal's skin and snap connector electrodes 408, or with other electrodes attached thereto.

[0057] FIG. 8 shows gel being applied to electrode through gel-port 704 of snap connector electrode 408 that has a comb-style ECG electrode 802 (which is an example of removable ECG electrode 410, FIG. 4) attached on an opposite side. FIG. 9 shows gel being applied to electrode through 'gel-port' with cup-style electrode 902 (which is another example of removable ECG electrode 410, FIG. 4) attached on an opposite side. FIG. 10 is a cross-section showing gel syringe 702, soft chassis 302, gel-port 704, and snap connector electrodes 408 coupled with comb-style ECG electrode 802.

[0058] Comb-style electrode.

[0059] FIGS. 11A-11D show top, side, end, and perspective views, respectively, of comb-style ECG electrode 802 of FIGS. 4, 8, and 10. Comb-style ECG electrode 802 may be made from hardened 316 stainless steel (to prevent corrosion and interactions with the skin), cut out by water-jet or stamped out of sheet metal and bent. Prongs are bent back at the tips for animal/patient comfort, and the prongs or legs of the electrode are bent towards the animal to make contact with the skin, and to flex with animal movement, position changes, and external forces. The hole in the middle is for installation of standard dritz snaps, that allow the device to be attached to the chassis/panel assembly. The design is intended to be cheap and easy to mass produce. Materials other than 316 stainless steel may be used including other metals and plastics/polymers.

Cup-Style Electrode

[0060] FIGS. 12A-12D show top, side, bottom, and perspective views, respectively, a cup-style ECG electrode 902 designed for use with the conductive gel (e.g., a hydrogel). Cup-style ECG electrode 902 may be used with the animal harness 102 for animals with sensitive skin that does not tolerate comb-style ECG electrode 802. Cup-style ECG electrode 902 may be attached to harness which is then placed on an animal. Once animal harness 102 is on the animal, the conductive gel is applied to the electrode via gel-port 704, the conductive gel works its way through the

fur to the animal's skin, and electrical contact is established between the skin and cup-style ECG electrode **902** such that ECG may be measured. Cup-style ECG electrode **902** is design is designed to hold/retain the conductive gel. Cup-style ECG electrode **902** makes less pressure points than comb-style ECG electrode **802**, making it more comfortable for the animal. The hole in the center of the cup is for installation of a standard snap (e.g., Dritz), allowing the cup-style ECG electrode **902** to be attached to soft chassis **302** and one of flexible panels **402** and **404**. Cup-style ECG electrode **902** may be manufactured from machined **6061** aluminum, but may be made and manufactured from other materials and methods such as metals and plastics, or casting or forming.

An Assembled Animal Harness

[0061] FIG. **13** is a bottom-inside perspective view of animal harness **102** of FIGS. **1-12** assembled with three comb-style ECG electrodes **802**. Animal harness **102** is fully assembled and viewed from the bottom, which is the side in contact with the animal's body. Note the location of the three comb-style ECG electrodes **802** configured with main body **304**.

Electronics Module Housing and Partial Panel

[0062] FIG. **14** shows a housing **1402** with electronics module **406** electrically and physically coupled with flexible panels **402** and **404**, a portion of which are shown in FIG. **14**. As described above, flexible panels **402** and **404** are flex circuits with tracks that electrically couple sensors **208**, **210**, **212**, **214**, and **216** to electronics module **406**. Electronics module **406** includes a housing **1402** for protecting electronic components (e.g., microcontroller **202**, signal conditioning circuits **204**, real-time clock **206**, ambient temperature and humidity sensors **216**, transceivers **218**, onboard storage **220**, user interface **222**, and power store **224**) that form electronics module **406**.

[0063] FIG. **15** is a perspective view showing a top side of housing **1402** of FIG. **14**. FIG. **16** is an exploded view of housing **1402**. FIGS. **15** and **16** are best viewed together with the following description. Housing **1402** may be formed of a top layer **1502**, a middle layer **1504**, and a bottom layer **1506** (e.g., fabricated from plastic) that may be held together by screws (not shown) and sealed with a gasket or silicone sealant. In certain embodiments, housing **1402** may include an RF 'reflector' or ground plane (not shown) located at a certain distance (e.g., on an inside surface of bottom layer **1506** or as a layer of a printed circuit board within a lower cavity **1602**) from an antenna of transceiver **218** (see FIG. **2**) and positioned between an antenna of transceiver **218** and the body of the animal. The RF reflector prevents RF radiation from an antenna of transceiver **218** entering the body of the animal, reflects the RF radiation away from the animal, and improves transmission efficiency and connectivity. A charge port **1508** (e.g., a micro-USB style connector) may be located on housing **1402** for charging power store **224**. The charge port may be positioned to prevent access when animal harness **102** being worn by an animal, thereby inhibiting users from charging power store **224** while animal harness **102** is on the animal, as this would be a safety issue.

[0064] A touch sensor **1510** and LED(s) **1512**, **1514** (e.g., part of user interface **222**), environmental temperature and

humidity sensors **216**, and charge port **1508** are located between top layer **1502** and middle layer **1504**, which allows touch sensor **1510** to be touched, the LED(s) **1512/1514** to be seen, and environmental temperature and humidity sensors **216** to be exposed to environmental conditions, while being protected from damage. Power store **224** and most other electronic components are positioned between middle layer **1504** and bottom layer **1506**, within cavity **1602**.

[0065] Waterproofing between flexible panels **402**, **404** and housing **1402** of electronics module **406** (e.g., waterproofing of electrical connections between inside and outside of housing **1402**) is effective and simple, as compared to other options that are bulky and difficult to manufacture. Flexible panels **402** and **404** exit a seam between middle layer **1504** and bottom layer **1506** of housing **1402** and are sealed using gaskets and/or silicone sealant.

[0066] Wear and tear on animal harness **102** may result in a broken sensor. Advantageously, flexible panels **402** and **404** are independently replaceable, thereby allowing only the panel with the broken sensor to be replaced, without requiring replacement of other part of animal harness **102**. Particularly, flexible panels **402** and **404** may be replaced by a user, and thus expensive factory or technician servicing is not required. Further, flexible panels **402** and **404** may include a flexible connector service loop (e.g., a strain relief loop) that keeps forces exerted on flexible panels **402** and **404** away from a terminating connector (e.g., within housing **1402**). This strain relief loop reduces the likelihood that a connection may open or become broke between flexible panels **402**, **404** and a lever operated ZIF connector attached to a rigid printed circuit board (PCB) of electronics module **406**. Flexible panels **402** and **404** are reinforced around a hole therethrough, bent backward over themselves, and fixed in place with a screw through the hole, such that flexible panels **402** and **404** are unlikely to be pulled from the connection, and such that the connection is isolated from forces on flexible panels **402** and **404**.

Firmware and Algorithms

[0067] FIG. **17** is a block diagram showing example functionality implemented by animal health monitoring system **100**, and showing firmware **1706** of electronics module **406**, application **1752** (e.g., an App) of mobile device **122**, and software **1776** of remote server **104**. Electronics module **406** includes microcontroller **202** (see FIG. **2**) that may include at least one processor **1702** and memory **1704** storing firmware **1706**. Firmware **1706** may include machine readable instructions that, when executed by processor **1702**, implement functionality of animal harness **102** as described herein. Mobile device **122** includes at least one processor **1742**, a user interface **1746** (with a display **1748** and touch input **1750** for example), and memory **1744** storing application **1752**. Application **1752** is for example an app (e.g., iOS, Google, etc.) that is downloaded onto mobile device **122** and includes machine readable instructions that, when executed by processor **1742**, implement functionality of mobile device **122** as described herein. Server **104** includes at least on processor **1772** and memory **1774** storing software **1776**. Software **1776** may include machine readable instructions that, when executed by processor **1772**, implement functionality of server **104** as described herein.

[0068] Firmware **1706** may include an operation module **1708** that, based at least in part upon configuration data **1730**, controls processor **1702** to, at intervals, read one or

more of sensors 208, 210, 212, 214, and 216, determine health status data 103, tag health status data 103 with a current time and date from real-time clock 206, and store the tagged health status data 103 in onboard storage 220. Configuration data 1730 may be set by a user (e.g., via application 1752) to control operation of animal harness 102. Configuration data 1730 may define one or more of an interval for taking measurements from sensors 208, 210, 212, 214, and 216, login credentials for connecting to local gateway 120, and so on.

[0069] Electronics module 406 includes transceivers 218 for communicating with other devices and transferring sensed and/or determined health status data 103 (see FIG. 1). Transceivers 218 may implement one or both of Bluetooth and Wi-Fi. Transceivers 218 may implement other wireless protocols (e.g., Ant+, Z-wave, and so on) for communicating with other devices as needed. Animal harness 102 does not require a dedicated hub or base station for receiving sensed or determined data. Rather, health status data 103 is stored in onboard storage 220 of electronics module 406 until a connection with at least one of mobile device 122 and remote server 104 is established. When the connection is established, operation module 1708 may transfer health status data 103 from onboard storage 220 to the connected device. For example, when mobile device 122 establishes a Bluetooth connection with electronic module 406, operational module 1708 may transfer health status data 103 to application 1752 that store health status data 103 in memory 1744. Application 1752 may, in turn, transfer, via one or more of Wi-Fi, cellular, the Internet, etc., health status data 103 to server 104 where software 1776 stores health status data 103 in database 108. In another example, when mobile device 122 establishes a Wi-Fi connection with remote server 104, operational module 1708 may transfer health status data 103 to software 1776 that stores health status data 103 in database 108.

[0070] Although shown in memory 1774, database 108 may be implemented in other memory and/or external to server 104. For example, database 108 may be implemented as network attached storage (NAS).

[0071] Application 1752 may operate with one or more animal harnesses 102, handling the data independently and allowing the user to view and analyze health status data 103 of multiple animals.

[0072] Firmware 1706 may be updated remotely and wirelessly (e.g., over the air) and different firmware may be downloaded to animal harness 102 to allow animal harness 102 to behave and interact in different ways. For example, Firmware 1706 may be updated with a 'Telemetry Mode' function that controls electronics module 406 to stream data at a high rate from one or more of sensors 208, 210, 212, 214, and 216 over Bluetooth and/or Wi-Fi (or another wireless protocol) to mobile device 122 and/or server 104 (or another viewing device) that displays waveforms and/or performs further processing of the streamed data. Accordingly, animal harness 102 may replace much of the existing wired telemetry equipment in a veterinary hospital.

[0073] Additionally, or alternatively, firmware 1706 may be updated (e.g., by upgrading and/or downloading replacement firmware) to include functionality that measures a strength of a home Wi-Fi signal (e.g., from local gateway 120) and alerts the user when the signal becomes too weak (e.g., when the animal wearing animal harness 102 has have left the owners home or yard).

[0074] Functionality of animal harness 102 may be changed by updating and/or replacing firmware 1706. In certain embodiments, a SDK may be developed that allows third party use of animal harness 102 (e.g., by allowing sensors 208, 210, 212, 214, and 216 to be used in different ways) for different functionality.

Web Interface

[0075] Software 1776 of server 104 may include a web portal 1778 that implements one or more of a web site, an API, or other such interface that is accessible via the Internet (WWW) and/or other such networks. Web portal 1778 allows a user to connect to server 104 and view, process, analyze, and/or download health status data 103 and information derived therefrom. For example, web portal 1778 may implement a dashboard type interface where the user may view and manipulate health status data 103, configure animal harness 102, and so on. When animal harness 102 is communicating with server 104 (e.g., connected via Wi-Fi, the Internet, optionally via mobile device 122, etc.), web portal 1778 may allow the user to view live data as it is collected from the animal. For example, web portal 1778 may generate one or more of rolling graphs, max-min displays, and so on. In certain embodiments, the user may, through interaction with web portal 1778, create and/or adjust animal profile 1732 that defines one or more expected ranges of values corresponding to sensors 208, 210, 212, 214, and 216. For example, animal profile 1732 may define a body temperature range with a high limit and a low limit, a pulse/heart rate range with a high limit and a low limit, and so on. Animal profile 1732 may also include animal (e.g., the patient) information such as name, birth date, weight, chest circumference, owner information, medications, and more. The user may set a "safe range" for each health metric measured by animal harness 102, and may configure the manner in which they would like to be alerted (text, email, on-harness visual and audio alerts) should a health metric be determined outside the configured safe range.

[0076] In a veterinary practice setting, each user may assign a patient to the "My Patients" tab to receive alerts when the data is no longer within the "safe range". Each user will see all patients in the "All Active" tab, but will only receive alerts for "My Patients." Data for individual animals may be downloaded by certain users.

[0077] Software 1776 may also include a data monitor module 1780 that processes health status data 103 as it is received from electronics module 406 against animal profile 1732, and where a measured value is outside the defined range within animal profile 1732, data monitor module 1780 may invoke alert module 1782 to send a notification and/or alert to the user. For example, alert module 1782 may send a notification to application 1752 for output from mobile device 122. For example, the notification may be one or both of visual and audible, such that the attention of the user is attracted. Alert module 1782 may also send one or more of SMS text and/or email (e.g., to mobile device 122), and may, by communicating with electronics module 406, generate one or more visual and audio alerts on the animal harness 102. Accordingly, the user is alerted to the change in condition of the animal wearing animal harness 102.

Mobile Device Interface

[0078] Application 1752 may include a data monitor module 1756 that processes health status data 103 as it is

received from animal harness 102. When electronics module 406 is communicatively connected with mobile device 122 (e.g., via Bluetooth and/or Wi-Fi), data monitor module 1756 may display health status data 103 as it is received from electronics module 406. For example, data monitor module 1756 may show a rolling ECG graph on display 1748, may show an average temperature value, and so on.

[0079] Application 1752 may include a configuration module 1754 that interacts with a user, via user interface 1746, to define configuration data 1730, and then transfer configuration data 1730 to firmware 1706 of electronics module 406 where it is stored in memory 1704 and read by operation module 1708. In certain embodiments, the user may, through interaction with configuration module 1754, create and/or adjust animal profile 1732 that defines one or more expected ranges of values corresponding to sensors 208, 210, 212, 214, and 216. For example, animal profile 1732 may define a body temperature range with a high limit and a low limit, a pulse/heart rate range with a high limit and a low limit, a respiratory rate with a high limit and a low limit, and so on.

[0080] In certain embodiments, data monitor module 1756 that processes health status data 103 as it is received from electronics module 406 against animal profile 1732, and where a measured value is outside the defined range within animal profile 1732, data monitor module 1756 may invoke alert module 1760 to generate a notification and/or an alert to notify the user. For example, alert module 1760 may generate control mobile device to generate one or more of a sound, a vibration, and a light.

AI Enhanced Measurement Analysis

[0081] FIG. 18 is a block diagram showing server 104 of FIG. 1 in further example detail, and in particular, showing functionality of AI and diagnostic module 110 with associated data. As described above, health status data 103 may be transferred from animal harness 102 to server 104 and stored within database 108. Continuing with the example of FIGS. 4 and FIG. 18, health status data 103 may include four temperature data values 1852(1)-(4) that correspond to the four temperature sensors 208 positioned within axillary strap 306 and four temperature data values 1852(5)-(8) that correspond to the four temperature sensors 208 positioned within axillary strap 308.

[0082] As described above, data monitor module 1780 may analyze health status data 103 as it is received in real-time from animal harness 102. For example, data monitor module 1780 may determine an animal core temperature 1872 by averaging temperature data values 1852(1)-(8) corresponding to temperature sensors 208 on axillary straps 306 and 308. However, one aspect of the present embodiments includes the realization that as the animal moves, or the environment changes, certain measurements by animal harness 102 may be affected by these changes and therefore may not be correct. Advantageously, AI and diagnostic module 110 within server 104 may detect when health status data 103 includes temperature measurements that may be incorrect and provide correction and/or notification of such erroneous data.

[0083] Although the following description is directed to AI and diagnostic module 110, in certain embodiments, at least part of the described functionality of AI and diagnostic module 110 may also or alternatively be included within one or both of AI and diagnostic module 1758 within mobile

device 122 and AI and diagnostic module 1712 within animal harness 102. Similarly, firmware 1706 may implement a data monitor module 1710 that implements at least part of the functionality provided by data monitor module 1780, and may include an alert module 1714 that implements at least part of the functionality of alert module 1782. Although functionality is described in association with particular modules, this for the purposes of illustration only, and other arrangements of computer equipment and firmware may be used without departing from the scope hereof.

[0084] In one embodiment, AI and diagnostic module 110 includes a temperature error detector 1802 that detects when temperature change indicated by one or more temperature sensors 208 is non-biological (e.g., not resulting from the animal), and provides an indication to a user that data may be incorrect. For example, temperature sensors 208, positioned within axillary straps 306/308 may occasionally move away from the animal's skin and/or become pressed against different surfaces or exposed to other objects within the animal's environment that results in temperature measurements that are not of the animal (e.g., non-biological). Analysis of previously recorded test data indicates that such occurrences are characterized by a rapid change in measured temperature from one or more (but not all) temperature sensors 208. Since it is impossible, or at least improbable, for a core temperature of the animal to change rapidly, such measurements may be detected as being non-biological temperature changes. Thus, temperature error detector 1802 processes health status data 103 in real-time to detect non-biological temperature changes, and when one or more non-biological temperature changes are detected, temperature error detector 1802 may alert a user (e.g., using a message via application 1752) that animal core temperature 1872 may be erroneous. In certain embodiments, based upon such alerts, application 1752 may instruct the user to take corrective action, such as one of tighten animal harness 102, place a pillow or blanket under the animal if sensors are being pressed to a cold floor, and so on.

[0085] In another example, when temperature error detector 1802 determines that a few (e.g., less than the majority) of temperature sensors 208 show non-biological temperature changes, AI and diagnostic module 110 may direct data monitor module 1780 to ignore temperature data values 1852 from these few temperature sensors 208 when generating animal core temperature 1872. Accordingly, animal core temperature 1872 is based on temperature data values 1852 of the other temperature sensors 208 and erroneous values are ignored.

[0086] In certain embodiments, AI and diagnostic module 110 may include a temperature modeler 1806 that uses and controls an animal core temperature model 1870 (e.g., implemented within memory 1774) that models animal core temperature based upon a specific animal type, size, breed, and so on. For example, memory 1774 may include many temperature models 1870 and temperature modeler 1806 uses one of these temperature models 1870 based upon characteristics of the animal wearing animal harness 102. When temperature error detector 1802 detects non-biological temperature changes in one or more temperature data values 1852, temperature error detector 1802 instructs data monitor module 1780 to use temperature model 1870 to generate an estimate of animal core temperature based upon temperature data values 1852. Temperature model 1870 models realistic biological temperature changes and limits

changes to animal core temperature **1872** accordingly, and thereby smooths changes in animal core temperature **1872**.

[0087] In one embodiment, temperature model **1870** provides a maximum temperature change for a given core temperature for the animal using animal harness **102**. Accordingly, data monitor module **1780** may limit the change in animal core temperature **1872** to this maximum temperature change. For example, temperature model **1870** may model a maximum rate of temperature change for an animal based upon temperature changes that occur when a similar animal 'spikes a fever' or when a similar animal goes into severe hypothermia. When temperature model **1870** is being used to generate animal core temperature **1872**, temperature error detector **1802** may send a notification to warn the user that animal core temperature **1872** is an estimate.

[0088] Using temperature model **1870**, occasional non-biological temperature readings are effectively filtered out and a reasonable estimate of the animal's core temperature is estimated, at least over a short period. However, when non-biological temperature readings occur for longer periods, the estimated animal core temperature becomes less accurate and the user is instructed to take corrective action.

[0089] When temperature error detector **1802** (or data monitor module **1780**) determines that one or more temperature data values **1852** exceed a predefined extreme value (e.g., above a maximum value or below a minimum value), irrespective of whether the temperature data value **1852** is determined as non-biological, temperature error detector **1802** alerts the user (e.g., by sending one or more of a notification, a SMS message, and an email) to the extreme temperature value, since it is possible that the animal is being heated or cooled by an external source.

[0090] In certain embodiments, AI and diagnostic module **110** may include reliability indicator (e.g., a diagnostic routine) that evaluates agreement of data within health status data **103** to determine a reliability indication of measurements by animal harness **102** and output to the user via application **1752** of mobile device **122**. For example, where AI and diagnostic module **110** determines that temperature data values **1852(1)-(8)** are in agreement, AI and diagnostic module **110** may determine that reliability of animal core temperature **1872** is high. However, where temperature data values **1852(1)-(8)** indicate a broad range of temperature, AI and diagnostic module **110** may determine that reliability of animal core temperature **1872** is low. Accordingly, the user is aware of the reliability of measurements made by animal harness **102**, and where reliability is low, the user may adjust animal harness **102** to improve reliability. Further, AI and diagnostic module **110** evaluate health status data **103** over time, wherein the reliability indication is averaged such that intermittent erroneous readings resulting from animal activity for example, may be ignored. The determined reliability indication may also indicate suitability of the animal harness **102** for the animal, and/or may indicate the suitability of one algorithm over another and/or suitability of a processing technique (e.g., filtering etc.).

[0091] In certain embodiments, AI and diagnostic module **110** may include at least one learning algorithm **1804** that, at intervals, updates temperature model **1870** to improve accuracy of the modeled temperature. In certain embodiments, learning algorithm **1804** may use other data (e.g., one or more of environmental data **1854**, auscultation data **1858**, ECG data **1856**, and motion data **1860**) to further improve temperature model **1870** and thereby determination of ani-

mal core temperature **1872**. For example, a dog laying down on the floor may be modeled differently from a dog sitting or standing.

[0092] In certain embodiments, animal harness **102** may include one or both of pressure and capacitive sensing at temperature sensors **208** to improve estimates of animal core temperature **1872**. For example, a force sensitive resistor may be used to measure pressure exerted on the animal's skin by temperature sensor **208**. In another example, capacitance between temperature sensor **208** and the animal's skin may be measured to indirectly determine pressure applied by the temperature sensor **208**. Further, the measured capacitance may further provide information on effects of the animal's fur on one or more of temperature sensor force, animal fur type, and tension on axillary straps **306** and **308** of animal harness **102**.

ECG Contact Evaluation

[0093] In certain embodiments, AI and diagnostics module **110** may include an ECG contact evaluator **1808** that determines whether removable ECG electrodes **410** (e.g., comb-style ECG electrodes **802** and/or cup-style ECG electrodes **902**) are making good electrical contact, or not, with the animal's body. ECG contact evaluator **1808** receives ECG data **1856** captured by animal harness **102** over a short period (e.g., ten seconds). For example, when animal harness **102** is strapped to the animals and turned on, operation module **1708** may automatically capture and send, for a short period (e.g., ten seconds) animal health data **103** to server **104**. ECG contact evaluator **1808** processes ECG data **1856** to extract ECG characteristics **1874** based on ECG features indicative of good and/or bad connectivity of removable ECG electrodes **410**. Examples of ECG characteristics **1874** include, but are not limited to, total signal energy, signal energy in a specific region or band of the frequency spectrogram (e.g., above 40 Hz) of the signal, peak values, and so on. ECG contact evaluator **1808** compares ECG characteristics **1874** to each of ECG good sample set **1876** and ECG bad sample set **1878** stored in memory **1774** to determine whether ECG characteristics **1874** indicate that removable ECG electrodes **410** are in good contact with the animal. ECG good sample set **1876** includes sets of characteristics that correspond to ECG data indicated as having good ECG electrode connectivity. ECG bad sample set **1878** includes sets of characteristics that correspond to ECG data indicated as having bad ECG electrode connectivity. In certain embodiments, ECG good sample set **1876** and ECG bad sample sets **1878** may correspond to ECG data **1856** of health status data **103** stored in database **108** and indicated as either good or bad by an operator, or other authorized person, of system **100**.

[0094] In one example of operation, ECG characteristics **1874** define a coordinate within a multi-dimensional mathematical space and ECG contact evaluator **1808** determines whether ECG electrode connectivity is good or bad by identifying, within the multi-dimensional mathematical space, its 'n' nearest neighbors defined by coordinates corresponding to ECG good sample sets **1876** and ECG bad sample sets **1878**, whether those nearest data points correspond to good or bad data sets. ECG contact evaluator **1808** then reports to the user (e.g., using one or more of application **1752**, a notification, a text message, and an email) whether removable ECG electrodes **410** are making good electrical connection or whether further adjustment and/or

application of a conductive gel or liquid is needed. As noted above, this determination may also be made in one or both of mobile device 122 and/or electronics module 406.

[0095] In certain embodiments, one or more of learning algorithm(s) 1804 may be invoked to interact with a person evaluating ECG characteristics 1874, whereby when the person indicates that ECG characteristics 1874 are good, they are added to ECG good sample set 1876 and when the person indicates that ECG characteristics 1874 are bad, they are added to ECG bad sample set 1878, such that system 100 learns, over time, to automatically recognize whether removable ECG electrodes 410 are making good electrical connection with the animal.

[0096] Body position and activity of the animal affects accuracy of certain sensors (e.g., one or more of sensors 208, 210, 212, 214, and 216) and measurements made by animal harness 102. To improve accuracy of measurements determined from animal harness 102, AI and diagnostic module 110 includes at least one activity adjustment algorithm 1810 that adjusts processing of health status data 103 based upon detected position and movement of the animal. Activity adjustment algorithm 1810 determines activity 1882 (e.g., running, walking, stationary, and so on) and/or position 1880 (e.g., standing, lying, sitting, and so on.) of the animal wearing animal harness 102 based upon health status data 103. Activity adjustment algorithm 1810 may then generate one or more adjustments 1884 (e.g., processing parameters) that adjust processing of certain data based upon position 1880 and activity 1882. For example, where position 1880 indicates that the animal is lying on its back, adjustments 1884 are determined to allow for errant measurements resulting from this position.

[0097] FIG. 19 is a flowchart illustrating one example method 1900 for improving accuracy of health metrics determined for an animal wearing animal harness 102. In certain embodiments, method 1900 is implemented in AI and diagnostic module 110 of server 104. However, method 1900 may also, or alternatively, be implemented in electronics module 406 of animal harness 102 and/or application 1752 of mobile device 122.

[0098] In block 1902, method 1900 receives health status data of the animal. In one example of block 1902, AI and diagnostic module 110 receives health status data 103 from animal harness 102. In block 1904, method 1900 determines a body position of the animal from the health status information. In one example of block 1904, activity adjustment algorithms 1810 determines position 1880 of the animal wearing animal harness 102 from health status data 103. In block 1906, method 1900 determines activity of the animal. In one example of block 1906, activity adjustment algorithms 1810 determines activity 1882 of the animal wearing animal harness 102 from health status data 103. In block 1908, method 1900 generates adjustments for health status data processing based, at least in part, upon body position and activity. In one example of block 1908, activity adjustment algorithms 1810 generates adjustments 1884 based at least in part upon position 1880 and activity 1882. Adjustments 1884 are parameters used by data monitor module 1780 when calculating in calculation of one or more of animal body temperature, heart-rate, respiratory rate, and environmental temperature and environmental humidity. For example, contact between one or more sensors 208, 210, 212, 214, and 216 and the animal's skin and/or ECG electrodes 410 and the animal's skin may vary depending on

the position and/or activity level of the animal. By determining the current position 1880 and/or activity 1882 of the animal, activity adjustment algorithms 1810 may predict expected contact issues and make adjustments accordingly. For example, where the animal wearing animal harness 102 is lying on its back, greater filtering of ECG data 1856 may be required since main body 304 of animal harness 102 provides less force to removable ECG electrodes 410 towards the animal's skin (e.g., pressure applied to a back portion of main body 304 results in less tension on a front portion of main body 304). Similarly, certain of temperature data values 1852 may be erroneous where corresponding temperature sensors 208 have reduced pressure from axillary straps 306 and 308 towards the animal's skin. Accordingly, activity adjustment algorithms 1810 may direct temperature modeler 1806 to select a different temperature model 1870 while the animal is lying on its back.

[0099] In certain embodiments, AI and diagnostic module 110 may include at least one power save algorithm 1812 that determines when animal harness 102 is not being worn (e.g., when animal harness 102 is not attached to an animal), and adjusts power usage of animal harness 102 accordingly. In one example, power save algorithm 1812 processes temperature data values 1852 received in health status data 103 to determine whether temperature sensors 208 are measuring body heat of an animal. For example, where temperature data values 1852 indicate similar temperature values to an environmental temperature value of environmental data 1854, and these temperature values are not in a possible body temperature range of the animal, power save algorithm 1812 may determine that animal harness 102 is not attached to, or worn by, an animal, and accordingly, power save algorithm 1812 may notify (e.g., via application 1752 of mobile device 122, a SMS text message, an email, and so on) the user that animal harness 102 is operational but not attached to an animal. Further, power save algorithm 1812 may deactivate at least part of animal harness 102 to save power. For example, power save algorithm 1812 may direct animal harness 102 to enter a power save mode, or to shut off completely. In certain embodiments, operation of animal harness 102 is controlled by power save algorithm 1812 based at least in part upon whether power save algorithm 1812 determines that animal harness 102 is being worn by an animal.

[0100] Temperature error detector 1802 may also determine whether a heating device (e.g., a warming blanket) is warming the animal and affecting animal core temperature 1872. For example, where an animal wearing animal harness 102 is lying on, and/or covered by, a warming blanket (or other such heating device commonly used by animal care givers and/or veterinary staff to maintain a desired cote temperature in a sick animal), temperature data values 1852 and/or environmental data 1854 measured by animal harness 102 may be artificially elevated. In one example of operation, temperature error detector 1802 compares environmental temperature within environmental data 1854 to a threshold value and where the indicated temperature is above the threshold value, temperature error detector 1802 determines that a warming blanket (or other heating device) is being used. Since ambient temperature and humidity sensors 216 are thermally insulated from the animal's body (e.g., by cavity 1602 of housing 1402 of electronics module 406), since ambient temperature and humidity sensors 216 may indicate an elevated temperature when a warming blanket

and/or other heating device is being used. When temperature error detector **1802** determines that a warming blanket (or other heating device) is being used, temperature error detector **1802** may notify the user that animal core temperature **18752** may be artificially elevated. In certain embodiments, when temperature error detector **1802** determines that a warming blanket (or other heating device) is being used, temperature error detector **1802** may direct temperature modeler **1806** to use a different temperature model **1870** to compensate for use of the warming blanket.

[0101] Temperature error detector **1802** may also determine whether the animal is lying on a cold surface (e.g., a tile or concrete floor). For example, some dogs lay down on a cool floor with front legs splayed out, resulting in axillary positioned temperature sensors **208** being pressed directly against the cold floor, affecting temperature measurements therefrom. Advantageously, temperature error detector **1802** determines when the animal lays on the cold floor and notifies the user that animal core temperature **1872** may be artificially lowered. This notification may also instruct the user to take a corrective action, such as placing a blanket or pad under the animal (e.g., for the animal's comfort and/or to improve accuracy of temperature measurements).

[0102] In one example of operation, temperature error detector **1802** determines when temperature measured by one or more temperature sensors **208** decreases rapidly. For example, where one or more temperature data values **1852** is significantly lower than previously received values, temperature error detector **1802** determines that the animal is laying on a cold surface where the corresponding temperature sensors **208** are contacting that surface. For example, temperature error detector **1802** may detect where a temperature gradient (e.g., temperature rate of change) of one or more temperature sensors **208** exceeds a maximum temperature gradient of the animal's body. Temperature error detector **1802** may then notify the user (e.g., via one or more of application **1752**, a notification, a text message, and email, etc.) that animal core temperature **1872** may be adversely affected, that corrective measures may be taken. In certain embodiments, temperature error detector **1802** may also instruct temperature modeler **1806** to select an alternative temperature model **1870** that automatically compensates for the effects of the cold surface on temperature measurements.

[0103] Data monitor module **1780** may detect when one or more of sensors **208**, **210**, **212**, **214**, and **216** malfunctions (e.g., breaks, becomes disconnected, stops working, etc.) and notify the user accordingly. For example, data monitor module **1780** may detect where data corresponding to one sensor **208**, **210**, **212**, **214**, and **216** is inconsistent with other measurements, and/or with previous measurements, or is at a range limit, and so on, and thereby determine that the corresponding sensor has failed. In response to detecting sensor failure, data monitor module **1780** may generate a notification to the user indicating that animal harness **102** needs servicing. In certain embodiments, data monitor module **1780** may also send a report to server **104**, where an operator may contact the user to suggest that the corresponding animal harness needs servicing.

Elastic Tensioning

[0104] In the embodiments shown in FIGS. 3A-3C, and 6-9, animal harness **102** uses adjustable length straps **330** and **332** and adjustable length axillary straps **306** and **308** that allow a user to adjust animal harness **102** to provide the

appropriate tension for correct operation. In an alternative embodiment, adjustable length straps **330** and **332** and axillary straps **306** and **308** include elastic that allow variability in length such that animal harness **102** may be used with a wider range of animal sizes. Particularly, the elastic within animal harness **102** provides the correct tension for consistent operation without requiring specific adjustment by the user when applying the animal harness to the animal. In one example, adjustable length straps **330** and **332** were replaced by elastic straps that provide main body **304** with a consistent tension, irrespective of the size of animal within a given size range, movement of the animal, and so on. That is, animal harness **102** may still be made in different sizes to match a particular type, breed, and age range of the animal, but within that size range, animal harness **102** automatically adjusts to provide the appropriate amount of tension to maintain contact between sensors **208**, **210**, **212**, **214**, and **216** and the animal's body. This eliminates the possibility of animal harness **102** becoming loose and of the user incorrectly adjusting tension of the animal harness.

Test Mode

[0105] AI and diagnostic module **1712** of electronics module **406** may include one or more diagnostic routines that allow factory testing (or technician servicing) of animal harness **102** to ensure correct operation and/or diagnose problems with animal harness **102**. In one embodiment, when mobile device **122** connects with electronics module **406** using Bluetooth (normally used for configuring Wi-Fi credentials in electronics module **406**), a technician may enter a special code (e.g., within the Wi-Fi username and/or password) that is detected by operation module **1708** and electronics module **406** enters a factory test mode (also known as a technician mode or servicing mode), wherein the technician may invoke one or more diagnostic routines within AI and diagnostics module **1712**. For example, these diagnostic routines may provide the technician with an indication of proper assembly of animal harness **102**, results of one or more diagnostic tests, and/or readings from the sensors **208**, **210**, **212**, **214**, and **216**, battery status, such that the technician may verify correct operation of animal harness **102**.

Example of Operation:

[0106] Animal harness **102** records ECG (using three ECG electrodes **408/140**), chest expansion or auscultation (using four piezoelectric disk elements **418** of auscultation sensors **212**), 3-axis acceleration (using accelerometer/motion sensors **214**), environmental temperature and environmental humidity (e.g., using ambient temperature and humidity sensors **216**), and temperature data from eight temperature sensors **208** located in the axillary regions of the animal. An onboard real-time clock **206** allows the device to report the time (e.g., with millisecond accuracy) that a measurement was taken. ECG, acceleration, and piezoelectric signal (for chest expansion measurements) are recorded continuously at industry standard sampling rates (150 Hz for ECG and 15 Hz for piezo elements). Temperature measurements, environmental measurements, clock sampling, and processing of raw ECG, piezo, and acceleration data, occur every ten seconds. For example, every ten seconds, onboard logic (e.g., firmware **1706**) may determine whether to report data to server **104** (e.g., via Wi-Fi and/or the Internet) and/or to

mobile device **122** (e.g., via Wi-Fi and/or Bluetooth). The user may configure criteria for reporting data. Animal harness **102** may attempt to send data to server **104** if temperature, pulse/heart rate, and/or respiratory rate measurements are outside maximum and minimum values defined within animal profile **1732** by the user, and/or when a rate of change of these values exceeds a maximum value, which is also user configurable. Animal harness **102** may also attempt to send data to server **104** when a certain amount of time has elapsed since the last data was sent. This time interval is also user configurable. Animal harness **102** also periodically sends high resolution raw sensor data to the server. For example, animal harness **102** may send ten seconds of raw ECG data **1856** (recorded at a sampling frequency of 150 Hz) to the server every five minutes where the data is stored in database **108**. Server **104** may process this data on receipt and compares certain characteristics of the raw ECG signal to other ECG signals in the database (that have been categorized by a human or computer based on signal quality) to determine the quality of the ECG signal. Server **104** may alert the user via the web or mobile application **1752** that electrodes may need to be adjusted, or that additional conductive electrolyte or gel may need to be applied. Periodic high-resolution sensor data may also be used to improve or develop new algorithms, detect sensor wear out, or for other purposes.

[0107] Interacting directly with the animal harness, such as by touching a touch sensor or button (e.g., touch sensor **1510**), may also cause animal harness **102** to attempt to transmit data to mobile device **122** and/or server **104** (e.g., where it may be viewed by the user). The time of this 'touch' event may be recorded on server **104** and used to identify the time of events of interest to the user (e.g., a veterinarian). This may be accompanied by a similar function on mobile device **122** and/or web app or portal of server **104**, each of which may allow the user to enter text and/or voice notes.

[0108] The user may configure system **100** to send email or text, or other alerts when physiological conditions leave the user configured ranges defined within animal profile **1732**.

[0109] The user may also configure system **100** to send text or email alerts when animal harness **102** fails to communicate (e.g., check in) at an interval specified by the user.

[0110] Animal harness **102** may store the last six processed measurements, captured at ten second intervals, and averages a number of these measurements (e.g., three measurements, though more could be averaged) to reduce the effects of random error and to provide a more representative sample of the animal's physiological conditions at any given time. These averaged measurements are reported to server **104** along with at least part of the raw data that was used to generate the averages.

[0111] Every ten seconds, animal harness **102** advertises on Bluetooth Low Energy (BLE) and allows itself to be connected to by a BLE device (e.g., application **1752** running on mobile device **122**) for a short period of time (less than a couple seconds). If a device connects to animal harness **102** in this time, the device may receive the most recent processed data (temperatures, pulse/heart rate, respiratory rate, acceleration/activity, and/or timestamp) from animal harness **102** and then animal harness **102** terminates the connection and returns to normal operation that includes

low power measurements and higher power processing of captured data at intervals, decision making, and transmission or advertising.

[0112] When mobile device **122** connects to animal harness **102** over BLE, the device may also keep the BLE connection active and request that animal harness **102** stream raw data to the device, so that the raw data (e.g., an ECG waveform) may be viewed in real time on the mobile device.

[0113] When animal harness **102** determines that data should be sent to one or both of mobile device **122** and/or server **104** (either because physiological conditions or rates of change are outside the acceptable range set by the user, or because the user configurable amount of time has elapsed since the last data was sent), but animal harness **102** cannot successfully transmit data to either of the mobile device **122** or server **104** (e.g., because Wi-Fi and Bluetooth connection are unavailable), animal harness **102** stores the data in onboard storage **220** (e.g., a non-volatile memory device, such as a FLASH memory chip) and attempts to send the data to one or both of mobile device **122** and/or server **104** when a connection becomes available.

[0114] When animal harness **102** cannot send data or notifications/alerts to either server **104** or mobile device **122**, and determines, based on user configurable parameters that the animal or wearer may be in danger or have unsafe physiological conditions, and if the user has enabled 'local' alerts, alert module **1714** may flash lights (e.g., LED(s) **1512**, **1514**) and trigger an audio alarm built into the device to alert those within proximity that the animal may be in danger or unhealthy.

Diagnosis/Big Data/IVMachine Learning/AI:

[0115] During operation of system **100** over time, health status data **103** of many different animal (e.g., different types, breeds, sizes, conditions, etc.) is sent to server **104** and stored in database **108**. Data in database **108** may include ECG, chest expansion (auscultation), acceleration/movement, animal core temperature, environmental conditions, animal breed, size, weight, and any medication the animal may be on. A user may interact with web portal **1778** of server **104** to retrieve for further analysis and/or view data for an individual animal. The collected data may be analyzed by humans and/or by artificial intelligence to develop new methods and/or algorithms to help diagnose and/or predict health problems in other animals.

[0116] Thus, data from many animals may be used to improve one or more of software **1776**, application **1752**, and firmware **1706** in system **100**. For example, new methods may be added to system **100** to help diagnose and predict health problems in individual animals currently being monitored using animal harness **102**. Data in database **108** may be used to understand the efficacy of drugs and treatments and to understand the effects of different factors on health of animals.

Optional Accessories

[0117] As shown in FIG. 1, system **100** may include one or more optional accessory sensors **126** that operate as stand-alone devices that communicate with animal harness **102**. Each optional accessory sensor **126** may include a transceiver (similar to transceiver **218**) and a microcontroller (similar to microcontroller **202**) with firmware that commu-

nicates with transceiver 218 in electronic module 406 of animal harness 102. Example optional accessory sensors 126 includes a thermometer, a blood pressure monitor, a blood oxygen sensor, a heart-rate monitor, and an activity/acceleration monitor. In certain embodiments, operational module 1708 may include data from one or more optional accessory sensors 126 within health status data 103, such that data from the one or more optional accessory sensors 126 may be displayed, collectively or independently of data collected by sensors of animal harness 102, through one or both of server 104 and mobile device 122. For example, server 104 may generate report(s) on an animal containing processed and raw data captured by animal harness 102 and/or optional accessory sensors 126. In certain embodiments, one or more optional accessory sensors 126 may be used to calibrate one or more sensors 208, 210, 212, 214, and 216 of animal harness 102. System 100 may implement record keeping and practice management onto one or more of application 1752 of mobile device 122 and software 1776 of server 104. Advantageously, system 100 may replace every piece of hardware and software in a veterinary clinic or hospital.

[0118] In one embodiment, application 1752 includes a button that allows the user to record one or more of voice notes, voice-to-text notes, and text notes, in association with health status data 103 captured by animal harness 102. That is, the collected voice note, voice-to-text note, and text note is timestamped and associated with one or both of the user and the animal being monitored by animal harness 102. For example, the voice note, voice-to-text note, and/or text note may be transferred to server 104 and stored within database 108.

[0119] Firmware 1706 of animal harness 102 captures data continually (e.g., at various sample rates, as described above), processes that data, at intervals, and transfers that data to one or both of mobile device 122 and/or server 104. Application 1752 also allows the user to stream raw data captured by animal harness 102 directly to mobile device 122, where application 1752 may display that data to the user in real-time. For example, where the user, interacting with application 1752, request display of live data from animal harness 102 and/or optional accessory sensors 126, application 1752 controls mobile device 122 to connect with animal harness 102, and within ten seconds, displays high resolution sensor data streamed from animal harness 102.

[0120] Application 1752 may also control a camera of mobile device 122 to capture, under control of the user, one or more images of the animal (e.g., showing symptoms, a procedure on the animal, a recovery phase, and so on) that are time stamped and stored in association with the animal being monitored by animal harness 102 and/or the user. For example, the photographs may be transferred to server 104 and stored within database 108.

[0121] Application 1752 and/or web portal 1778 may include additional fields that allow the user to enter other medical data that may be recorded, timestamped, and stored in association with the animal and/or the user. For example, these fields may correspond to data recorded on a regular anesthesia sheet used in surgeries. Accordingly, system 100 may record other medical information and store it in association with the animal and/or the user. That is, the user (e.g., a veterinarian) may use system 100 to replace one or more existing methods used in a clinic or practice to record the medical information. In certain embodiments, system 100

may integrate and/or cooperate with other existing medical data systems. For example, system 100 may also collect and store data on one or more of medical procedure, laboratory work (e.g., blood/sample test results), drugs and medications used and prescribed, observations (e.g., on one or more of: Appearance, Integumentary, Musculoskeletal, Respiratory, Digestive, Genitourinary, Ears, Neural systems, Lymph nodes, Eyes, Circulatory, Mucous membranes), Preanesthetic (e.g., doses, amount given, route, time), Induction (e.g., doses, amount given, route, time), Intubation tube size, Catheter size/gauge, Name/brand of other systems used for monitoring, Inhalant anesthetics, Fluids (e.g., total amount, type), start and stop times of anesthetics and procedures, Pain scale, and so on. System 100 may also include configurable data fields that may be used for other measurements that may not be automatically filled in by system 100. This data may be stored within database 108.

[0122] Software 1776, via web portal 1778 for example, may generate standardized reports from data within database 108.

[0123] In certain embodiments, application 1752 may provide at least two different interfaces: one for a veterinary clinic/practice use, and one for an owner of the animal. For example, application may require a user to have a login/password (or other authorization method) to access an account stored by system 100. Accordingly, application 1752 may be used by both veterinary staff and an animal owner, whereby the account accessed through application 1752 defines the interface used.

[0124] In certain embodiments, electronics module 406 may include a location device (e.g., one or more of a global positioning system, signal triangulation, and so on) that may be activated, at intervals, to determine a current location of animal harness 102 (and thereby the animal). Operation module 1708 may also read acceleration values from one or more axes of accelerometer/motion sensor 214 and determine whether specific activities are being performed by the animal. In one example, the collected accelerometer data may be processed (e.g., by at least one of application 1752 and software 1776), at intervals, to determine gait analysis of the animal and, over time, identify changes in the gait of the animal.

[0125] In certain embodiments, one or both of application 1752 and web portal 1778 may collect and store (e.g., within database 108) food and eating information of the animal, and wherein through the acceleration values, collected by operation module 1708 from one or more axes of accelerometer/motion sensor 214, one or both of application 1752 and software 1776 determines animal calorie burn, which may also be stored, in association with the animal, within database 108.

[0126] Changes may be made in the above system, methods or devices without departing from the scope hereof. For example, although described for use with animals, the harness may also be constructed for use with humans. It should thus be noted that the matter contained in the above description or shown in the accompanying drawings should be interpreted as illustrative and not in a limiting sense. The following claims are intended to cover all generic and specific features described herein, as well as all statements of the scope of the present method and system, which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. An animal harness for round-the-clock monitoring of an animal's health status, comprising:

- an electronics module having a processor and memory storing firmware;
- a plurality of temperature sensors;
- a plurality of auscultation sensors;
- at least one flexible panel electrically coupling the temperature sensors and the auscultation sensors to the electronics module;

a soft chassis having a main body with a cavity for containing and positioning the flexible panel around a heart girth of the animal, wherein the soft chassis positions the temperature sensors are positioned at axillary areas of the animal and positions the auscultation sensors around a chest of the animal to detect chest movement; and

machine readable instructions stored within the memory that, when executed by the processor, control the processor to read health status data from the plurality of temperature sensors and the plurality of auscultation sensors and, at intervals, send the health status data to one or both of a mobile device and a server.

2. The animal harness of claim 1, the soft chassis further comprising two axillary straps, each positioned towards an opposite end of the soft chassis and each being partially hollow to receive an offshoot of the flexible panel having at least one of the temperature sensors attached thereto, the two axillary straps forcing the temperature sensors against the axillary areas of the animal.

3. The animal harness of claim 2, each of the two axillary straps further comprising one or both of thermal insulation and a radiation shield positioned on a side of the axillary strap facing away from the animal.

4. The animal harness of claim 1, each of the auscultation sensors being soldered to the flexible panel.

5. The animal harness of claim 1, further comprising:

- at least three removable ECG electrodes;
- at least three snap connectors, a female side of each one of the three snap connectors being attached to a different one of the three removable ECG electrodes, and a male side of each one of the three snap connectors being attached through one of three holes in the flexible panel and electrically connected, through the flexible panel, to the electronics module; and

wherein each of the three snap connectors are assembled through three holes in the soft chassis to position the three removable ECG electrodes at a left side of the animal, a right side of the animal, and on a back of the animal.

6. The animal harness of claim 5, each of the three removable ECG electrodes being selected from the group comprising a comb-style electrode, and a cup-style electrode.

7. The animal harness of claim 5, further comprising at least one gel-port for application of a conductive gel or liquid to one of the removable ECG electrodes while the animal harness is attached to the animal, the gel-port passing through the snap connector and the removable ECG electrode.

8. The animal harness of claim 1, the soft chassis further comprising at least one adjustable length strap that attach at either side of a folding region of the soft chasses, wherein the adjustable length strap adjust a length of the soft chassis.

9. The animal harness of claim 8, the adjustable length strap having colored stitching to indicate when a tension of the animal harness around the animal is correct.

10. The animal harness of claim 8, the adjustable length strap having elastic that maintains a correct tension of the animal harness around the animal.

11. The animal harness of claim 1, the electronics module further comprising an ambient temperature sensor and an ambient humidity sensor, the soft chassis further comprising a pocket for receiving the electronics module, and having a breathable mesh window.

12. The animal harness of claim 1, the electronics module further comprising at least one motion sensor to sensing one or both of motion and orientation of the animal harness.

13. The animal harness of claim 1, further comprising a plurality of snap fasteners attached to opposite sides of the soft chassis within the cavity, wherein each snap fastener couples together through a different hole within the flexible panel to secure the flexible panel with the soft chassis.

14. A system for round-the-clock monitoring of an animal's health status, comprising:

an animal harness sized to attach around a heart girth of the animal, the animal harness comprising:

- a plurality of sensors for sensing health characteristics of the animal;
- a first wireless transceiver; and
- a first processor and a first memory storing firmware executable by the first processor to read, at intervals, the plurality health measurements and to transmit the plurality of health measurements via the first wireless transceiver;

a mobile device comprising:

- a second wireless transceiver;
- a user interface with a display;
- a second processor and a second memory storing an application having machine readable instructions that, when executed by the second processor, control the second processor to:
 - receive, via the second wireless transceiver, the plurality health measurements;
 - process the plurality health measurements to determine the animal's health status; and
 - display the animal's health status on the display.

15. The system of claim 14, the application further comprising machine readable instructions that, when executed by the second processor, control the second processor to receive and display the health measurements in real-time.

16. The system of claim 15, the plurality of sensors comprising one or more of a temperature sensor, an auscultation sensor, an ECG sensor, a movement sensor, an ambient temperature sensor, and an ambient humidity sensor, and wherein the health measurements comprise one or more of ECG, pulse/heart rate, respiratory rate, animal temperature, animal movement, environmental temperature, and environmental humidity.

17. The system of claim 14, further comprising a remote server having:

- a communication interface;
- a database; and
- a third processor and a third memory storing software having machine readable instructions that, when executed by the third processor, control the third processor to:

receive, via the communication interface, the plurality of health measurements;
 store the plurality of health measurements in the database;
 process the plurality of health measurements to determine a health data of the animal;
 compare the health status to an animal profile, defining safe ranges for each of the health measurements; and
 generating an alert when one or more of the health measurements is outside the corresponding safe range.

18. A method for round-the-clock monitoring of an animal's health status, comprising:

capturing, at intervals using an animal harness to position a plurality of temperature sensors in axillary areas of the animal's body, temperature measurements from each of the plurality of temperature sensors;
 determining an animal core temperature based upon the temperature measurements and an animal core temperature model;
 detecting, based on previously captured temperature measurements, a non-biological temperature rate change in any one or more of the temperature measurements; and
 sending, in response to detecting the non-biological temperature rate change, a notification to a user to indicate that the animal core temperature is estimated.

19. The method of claim 18, further comprising:

determining that the animal harness is not on the animal when all of the temperature measurements are not within a body temperature range of the animal; and
 directing the animal harness to enter a low power mode when the animal harness is not on the animal.

20. The method of claim 18, further comprising:

capturing, at intervals using an environmental temperature sensor mounted on the animal harness, an environmental temperature;
 determining when the environmental temperature is being affected by a warming device; and
 sending, in response to detecting that the environmental temperature is being affected by a warming device, a notification to the user to indicate that the animal core temperature is estimated.

21. The method of claim 18, further comprising:

capturing, at intervals and using the animal harness to position at least three ECG electrodes about the animal's body, an ECG signal;
 extracting ECG characteristics indicative of quality of the ECG signal;
 determining a point in a multi-dimensional mathematical space by using the ECG characteristics as coordinate to the multi-dimensional mathematical space;
 determining a nearest "n" neighboring points within the multi-dimensional mathematical space, wherein the "n" neighboring points are defined by other ECG characteristics of "n" other ECG signals; and
 determining a quality of the ECG signal based upon a previously determined quality of the other ECG signals.

22. The method of claim 18, further comprising selecting, in response to detecting the non-biological temperature rate change, an alternative animal body temperature model to determine the animal core temperature, wherein the alternative animal body temperature model correct the animal core temperature in view of the non-biological temperature rate change.

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专利名称(译)	全天候监控动物的健康状况		
公开(公告)号	US20200060545A1	公开(公告)日	2020-02-27
申请号	US16/550201	申请日	2019-08-24
发明人	MAHER, KEVIN DANIEL MORITZ, JR., JOEL ADRIAN SCHULTZ, DENNIS MATTHEW HUBER, IAN ADKINS MORRISON, THOMAS GRANT		
IPC分类号	A61B5/00 A01K27/00 A01K29/00 A61B5/01 A61B5/0205 A61B7/04 A61F7/00		
CPC分类号	A61B2090/0808 A61B5/7425 A01K29/005 A61B5/0008 A61B2562/0209 A61B2560/0252 A61B5/02438 A61B5/02055 A61B5/7221 A61B5/7217 A61B5/04026 A61B2562/029 A61B2503/40 A61B5/0022 A61B5/01 A61B7/04 A61F7/0097 A61B2560/0209 A61B5/0816 A01K27/002 A61B5/1135 A61B5/6831 A61B5/0416 G16H40/67		
优先权	62/722508 2018-08-24 US		
外部链接	Espacenet USPTO		

摘要(译)

用于全天候监视动物健康状况的系统和相关方法包括动物佩戴的动物安全带，以及移动设备和远程服务器中的一个或两个。动物带具包括用于收集动物的健康测量值的多个传感器。动物安全带还包括收发器，该收发器将健康测量值传送到移动设备和远程服务器之一或两者，用户可以在其中查看健康测量值。动物安全带中的固件，移动设备中运行的应用程序以及远程服务器中的软件会处理并更正健康状况度量以生成动物的健康状况，并且当动物的健康状况不在由以下内容定义的安全范围内时会生成通知用户。

