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(54) **SENSOR BAND FOR MULTIMODAL SENSING OF BIOMETRIC DATA**

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A61B 5/11	(2006.01)

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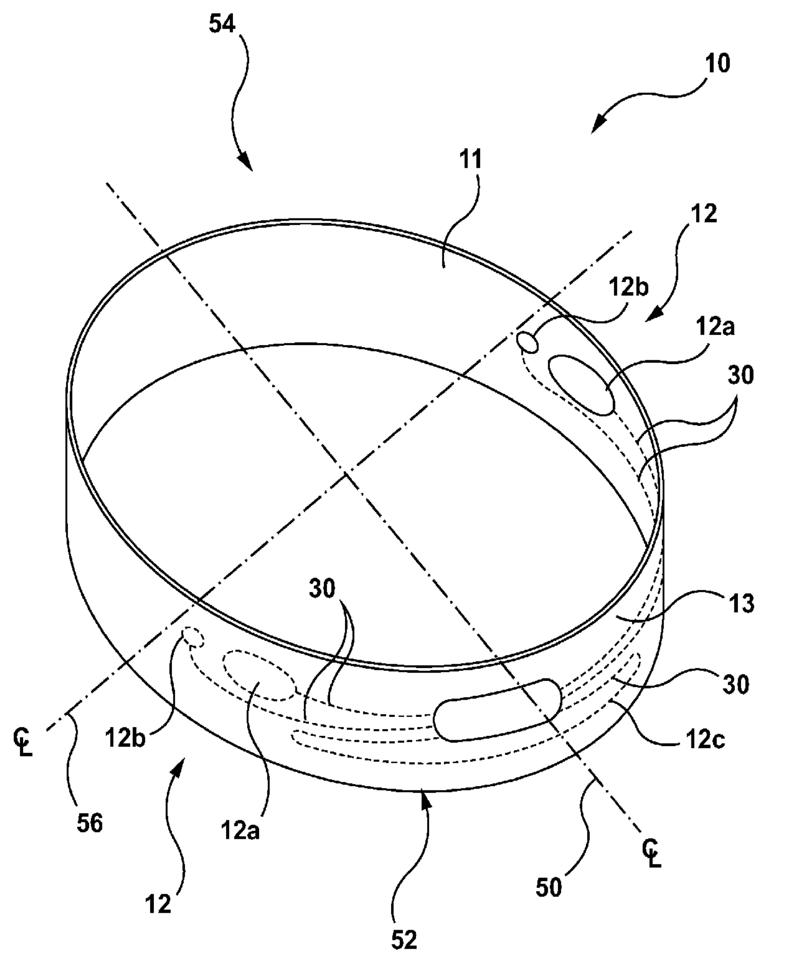
(57) **ABSTRACT**

A resilient fabric band providing a sensor platform for a wearer in order to sense, a plurality of biometric data, the band comprising: a pair of ECG sensors coupled to an interior surface of a body of the band, each of the pair of ECG sensors located on either side of a front to back centerline of the body; a pair of bio impedance sensors coupled to the interior surface of the body of the band, each of the pair of bio impedance sensors located on either side of the front to back centerline; a strain gauge sensor coupled to the body of the band; a computer device mounted on the body of the band via a housing, the computer device including a power source, a computer processor, a memory for storing instructions for execution by the computer processor, and a network interface for transmitting data sensed by the sensors; and a plurality of communication pathways connecting the computer device to each of the sensors, the communication pathway for sending power from the power supply to the sensors as controlled by the computer processor and for receiving sensed data from the sensors by the computer processor.



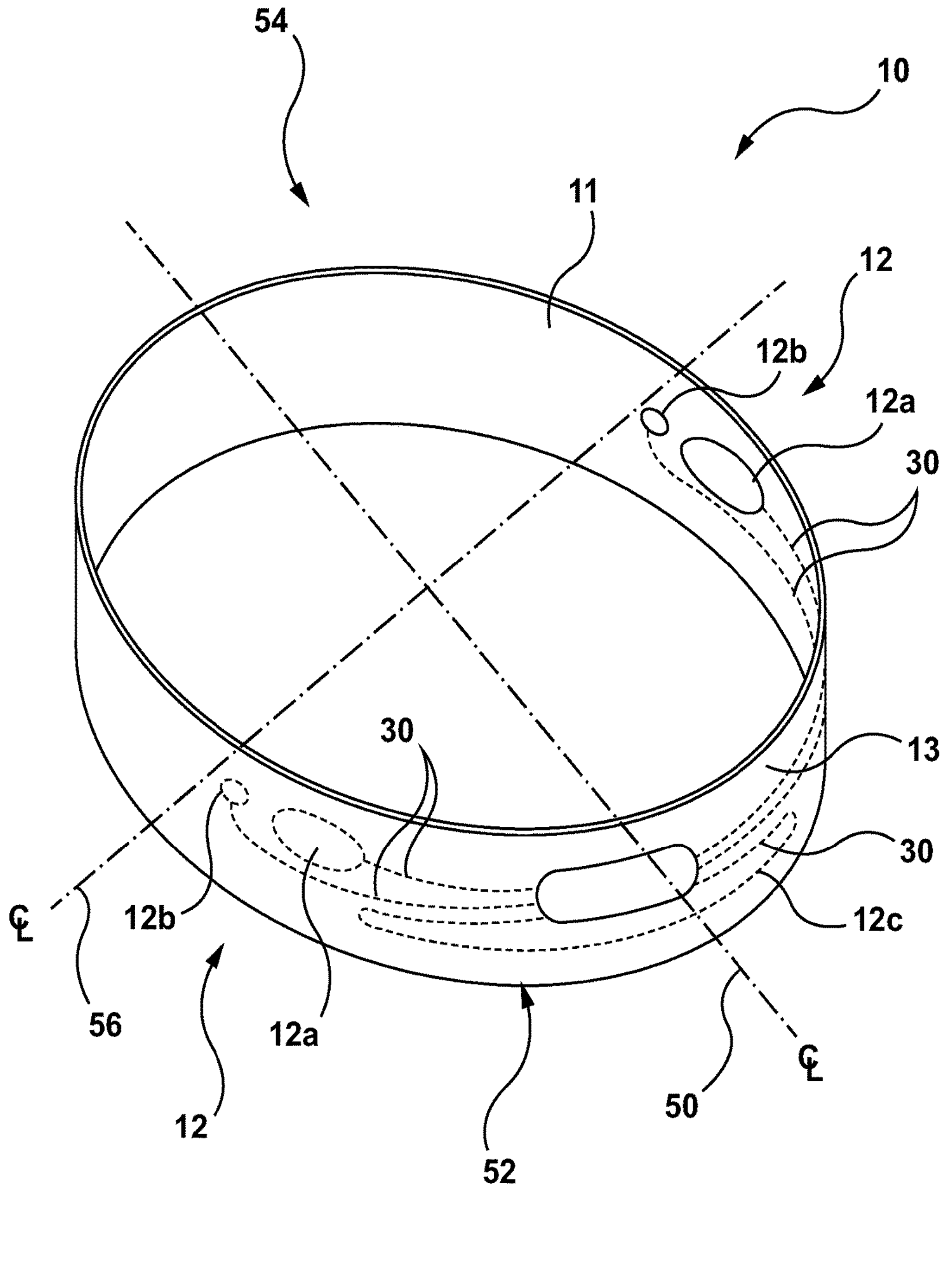


FIG. 1

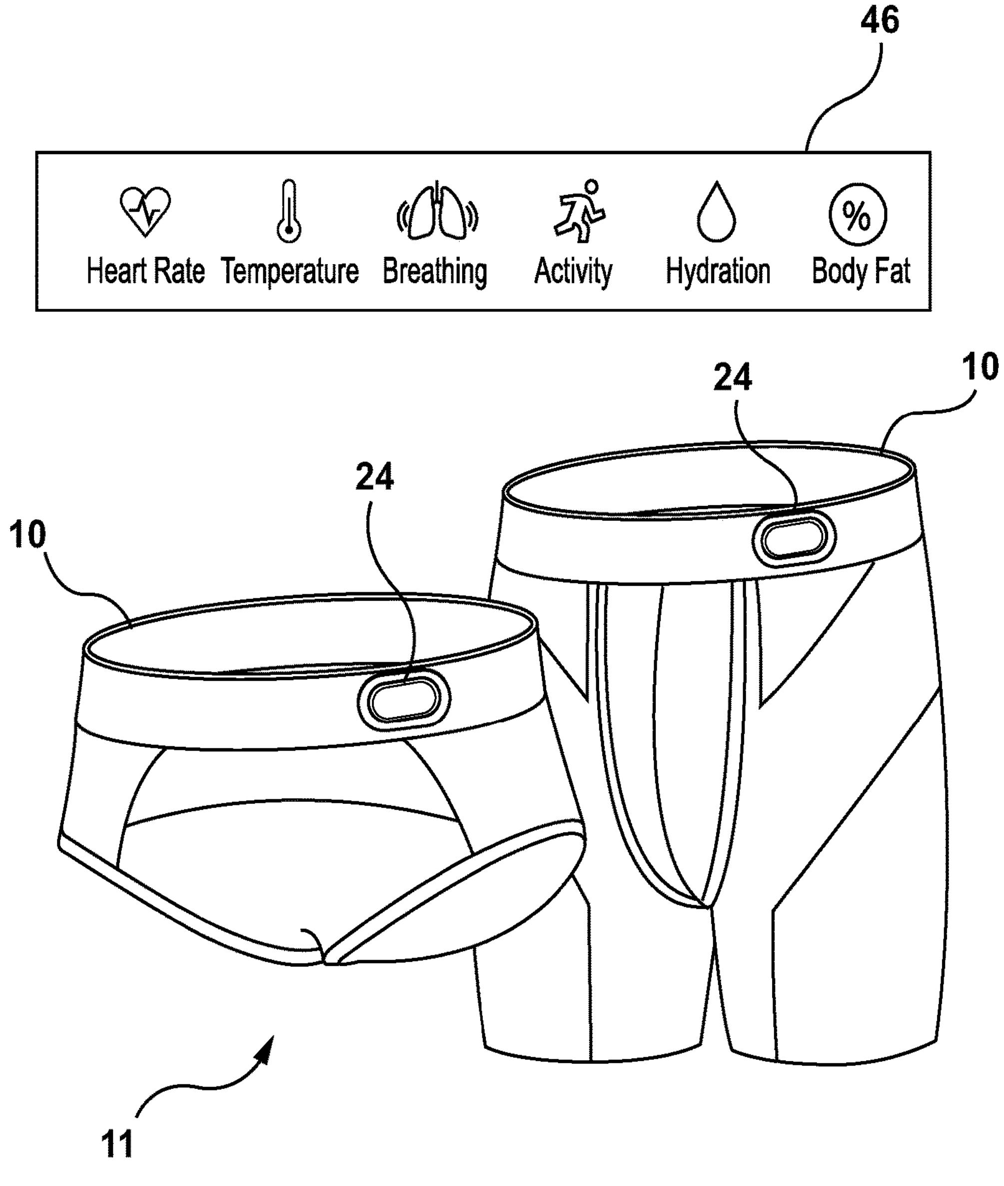

46
Heart Rate
Temperature
Breathing
Activity
Hydration
Body Fat
24
10
24
10
11

FIG. 2

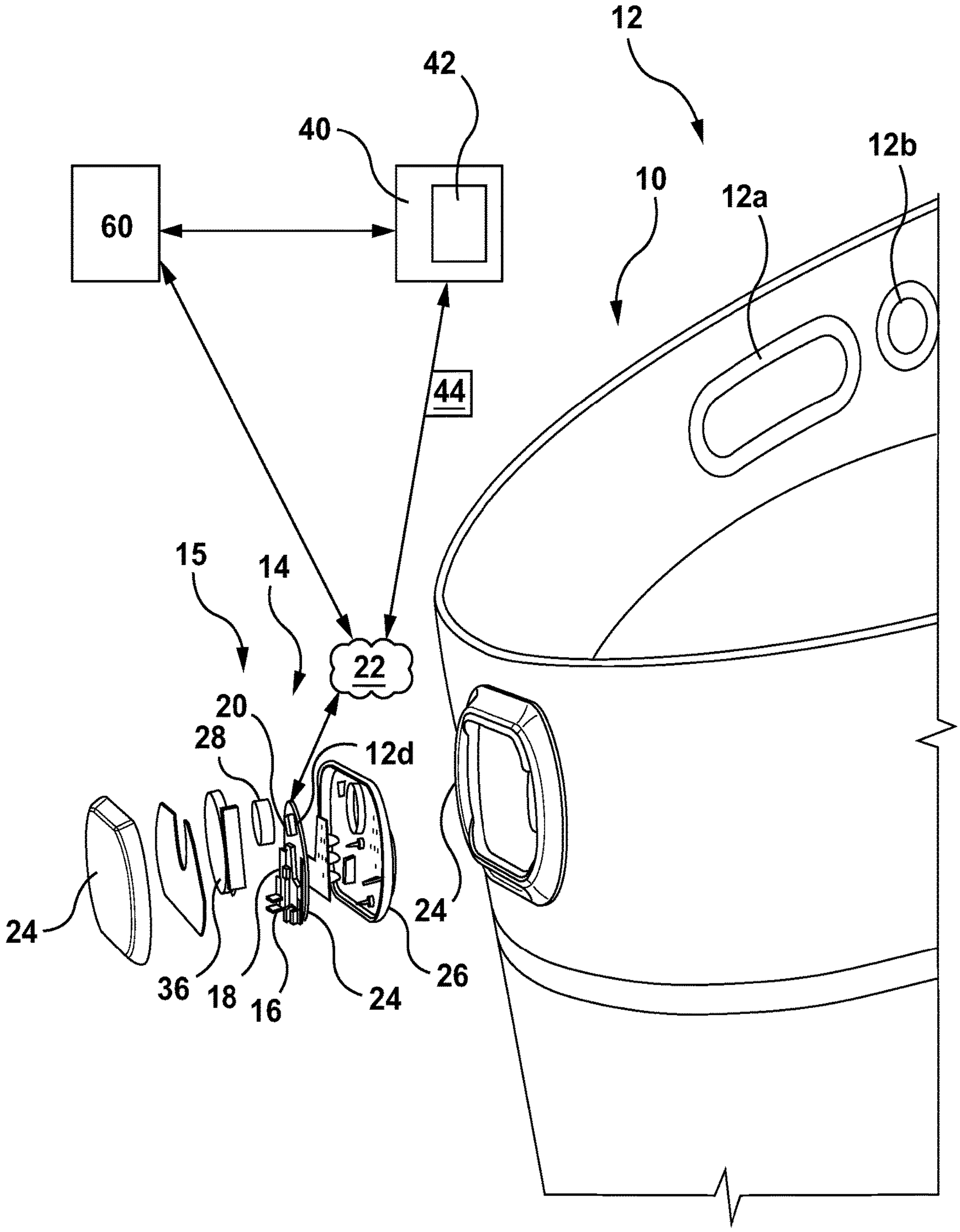
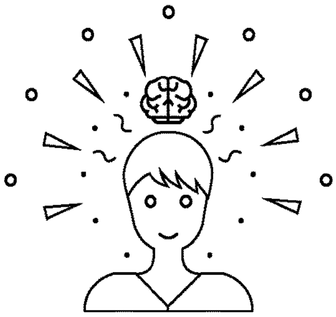


FIG. 3



Improve your State of Mind

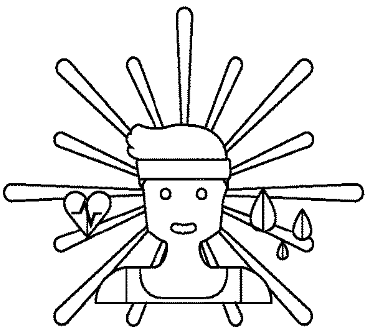
Detect what makes you stressed, and use our app to get you back into the right state of mind. SKIIN's smart notiifcations can remind you to breathe after a sressful event, and cope with the things life throws at you.

43

43

Optimize Sleep

If you're constantly tired in the mornings, it's probably related to the efficiency of your sleep. SKIIN uses the most advanced sensors located on the waistband of the garment to accurately track your sleep. Wake up feeling refreshed.



Be Active, Feel Better

Being active is important to your physical and mental health. SKIIN can tell you if you're spending enough time on your feet. taking enough steps, and keeping your posture upright.

43

43

Control your Home

Your smart home should react to you: not the other way around. Use SKIIN to control your thermostat. lights and speakers based on your mood and body temperature.

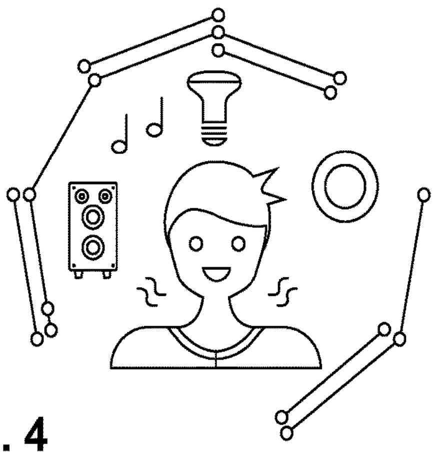


FIG. 4

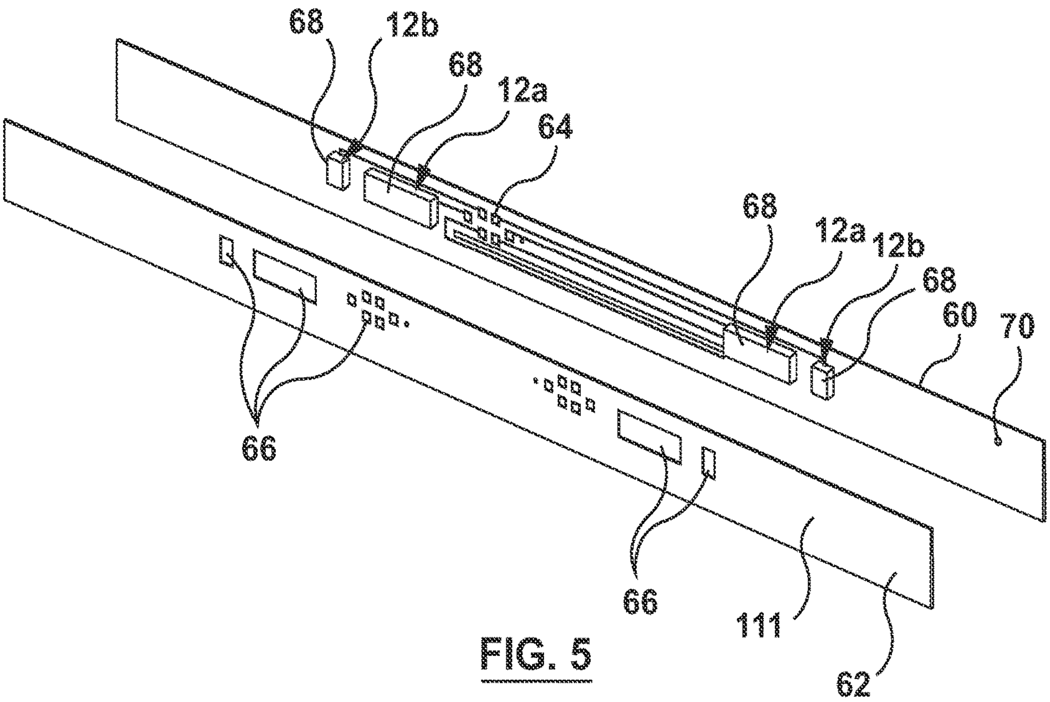


FIG. 5

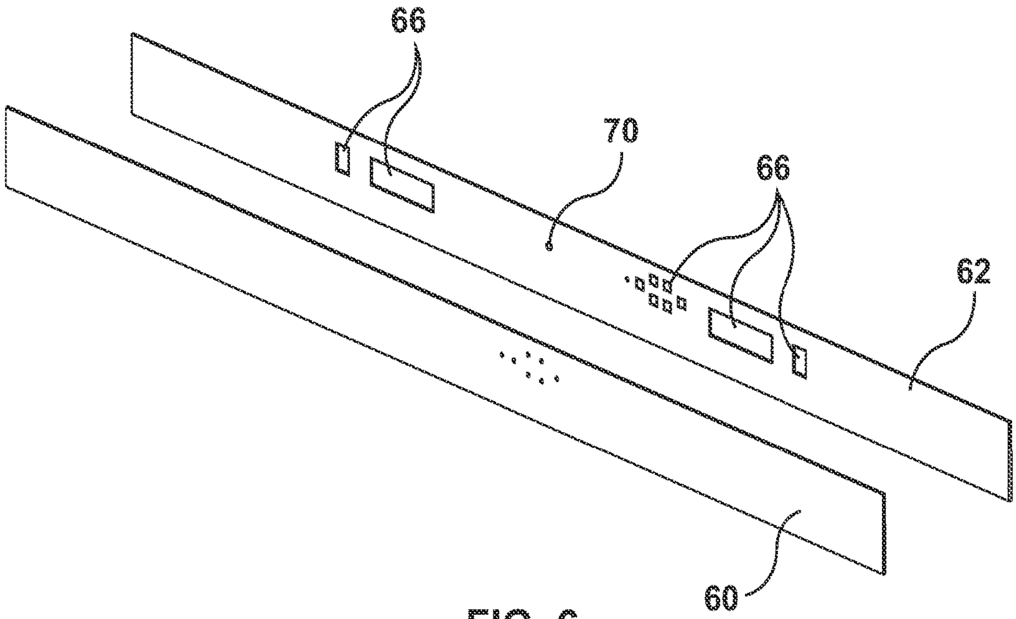


FIG. 6

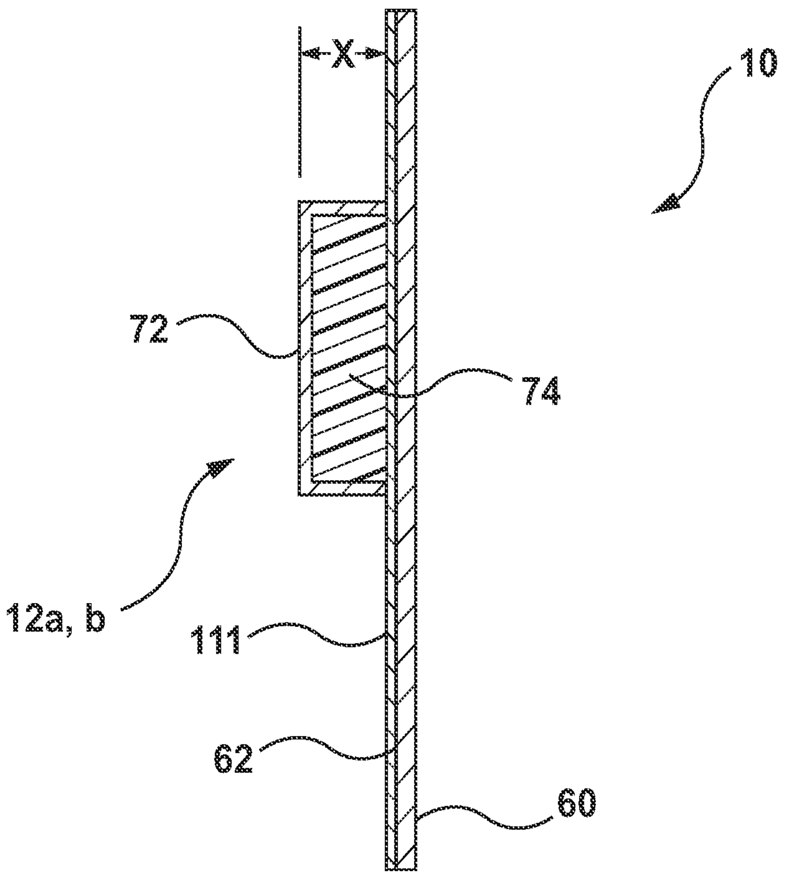


FIG. 7

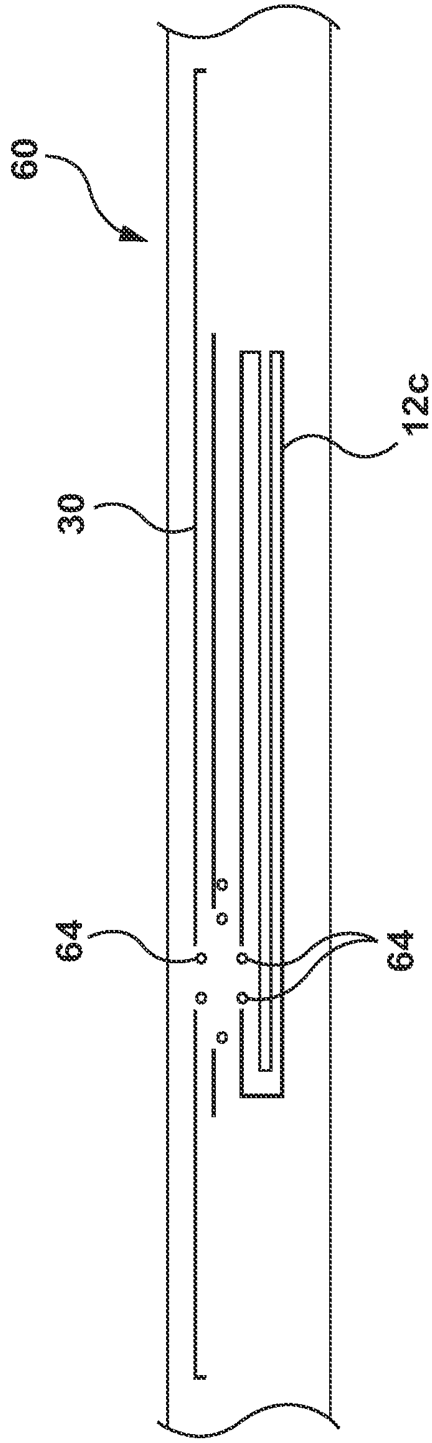


FIG. 8

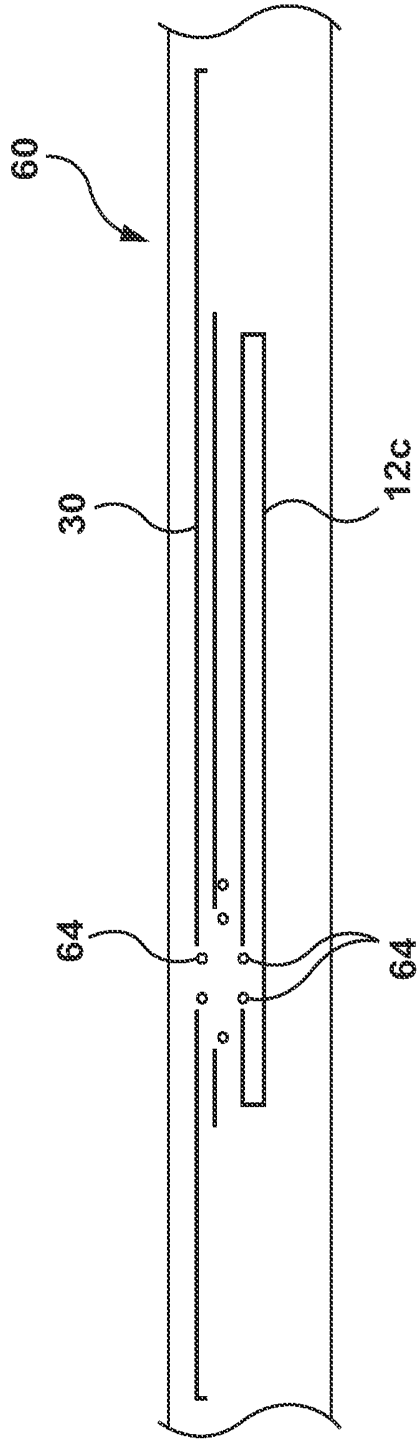


FIG. 9

SENSOR BAND FOR MULTIMODAL SENSING OF BIOMETRIC DATA

FIELD

[0001] The present disclosure relates to sensing systems for biometric data.

BACKGROUND

[0002] Sensing of biometric data in today's technological based environment is key to understanding the physical state. In particular, athletes and medical patients, among a number of other consumers, are key individuals for much needed accurate and up-to-date (i.e. real-time) biometric sensing. However, state of the art sensor arrangements can be bulky and uncomfortable for the typical wearer. Further, each physical activity and/or health condition can require a customized sensor arrangement and mode of attachment to the wearer, which can unnecessarily require multiple sensor platforms tailored to each individual/disease.

SUMMARY

[0003] It is an object of the present invention to provide a biometric sensing platform to obviate or mitigate at least one of the above presented disadvantages.

[0004] An aspect provided is a resilient fabric band providing a sensor platform for a wearer in order to sense a plurality of biometric data, the band comprising: a pair of ECG sensors coupled to an interior surface of a body of the band, each of the pair of ECG sensors located on either side of a front to back centerline of the body; a pair of bio impedance sensors coupled to the interior surface of the body of the band, each of the pair of bio impedance sensors located on either side of the front to back centerline; a strain gauge sensor coupled to the body of the band; a computer device mounted on the body of the band via a housing, the computer device including a power source, a computer processor, a memory for storing instructions for execution by the computer processor, and a network interface for transmitting data sensed by the sensors; and a plurality of communication pathways connecting the computer device to each of the sensors, the communication pathway for sending power from the power supply to the sensors as controlled by the computer processor and for receiving sensed data from the sensors by the computer processor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The foregoing and other aspects will now be described by way of example only with reference to the attached drawings, in which:

[0006] FIG. **1** is a perspective view of a band containing a plurality of sensors;

[0007] FIG. **2** is a view of the band shown in FIG. **1** incorporated into an article of clothing;

[0008] FIG. **3** shows an embodiment of the band shown in FIG. **1** with associated electrical components;

[0009] FIG. **4** shows example applications of the biometric data combinations;

[0010] FIG. **5** shows a front perspective view of a further embodiment of the band of FIG. **1**;

[0011] FIG. **6** shows a rear perspective view of the further embodiment of FIG. **5**;

[0012] FIG. **7** shows a side view of the sensors mounted on the band of FIG. **5**; and

[0013] FIGS. **8** and **9** show further embodiments of the sensors of FIG. **1**.

DETAILED DESCRIPTION

[0014] Referring to FIG. **1**, shown is a fabric band **10**, preferable having a resilient knit type, for fitting around a body part of a wearer (not shown), in order to collect different modes/types of biometric data based on the type/number of sensors **12** positioned either on or otherwise knit/woven (e.g. embroidered) into the fabric making up the body of the band **10**. It is recognised that the body part can be such as but not limited to: waist or abdomen; limb such as a leg or arm; torso/trunk; buttocks; foot or ankle; wrist or hand; and/or head. The fabric band **10** can be provided as a stand-alone article or can be combined/combined into an article of clothing such as but not limited to: underwear **11** (see FIG. **2**—such as but not limited to any type of undergarment including jockey shorts, panties, undershirts, and bras); socks, limb bands (e.g. knee band); shirt (e.g. undershirt); etc. In terms of combined into an article of clothing (i.e. garment **11**), the band **10** can be formed as an integral component of the interlacing of the fibres making up the garment **11**. The fabric of the body of the band **10** can be comprised of interlaced resilient fibres (e.g. stretchable natural and/or synthetic material and/or a combination of stretchable and non-stretchable materials).

[0015] Referring again to FIG. **1**, provided as distributed about the band **10**, e.g. mounted on an interior surface **111** (i.e. inward facing towards the body of the wearer), are a series of sensors/electrodes **12** including ECG sensors **12***a*, bio impedance sensors **12***b*, and strain gauge sensors **12***c*. It is recognised that the sensors **12** can be composed of Electroactive polymers, or EAPs, and/or woven or knit plurality of conductive fibres constructed in a sensor/electrode configuration (e.g. a patch).

[0016] Also positioned on the band **10**, for example on, an exterior surface **13** (i.e. outward facing from the wearer), is series of electrical components **15** including a computer device **14** (see FIG. **3**) including a computer processor **16**, a memory **18** for executing stored instructions for receiving and processing of data obtained from the sensors **12**, as well as communicating via a network interface **20** with a network **22** (e.g. Wi-Fi, Bluetooth, attached wired cable, etc.) as well as sending and receiving electrical signals from the sensors **12**. The processor **16**, memory **18** and network interface **20** are mounted on a printed circuit board **26**, which is housed in a housing **24** attached to the band **10**. Also connected to the PCB **24** is a temperature sensor **12***d* for measuring a body temperature of the wearer. Also mounted in the housing is a power supply **28** (e.g. battery) for powering the various electrical components **15** within the housing **24** as well as the sensors **12***a,b,c* external to the housing **24**, connected via conductive communication pathways **30** (e.g. wires—see FIG. **1**—woven into the fabric weave/knit of the band **10** textile). The pathways **30** can be coupled to the sensors **12** via use of a conductive grommet, as desired. Also provided is a series of motion sensors **36** (e.g. accelerometer (s) and gyroscopes) for determining movements of the wearer, including posture as further described below. The sensors **12** can also be provided as speaker/microphone (e.g. for auditory signals/communication with the wearer), illumination sensors (e.g. LEDS—for visual signals/communication with the wearer) and haptic/vibrations sensors (e.g. actuators—for motion/touch signals/communication with the wearer),

Sensor Examples

[0017] The sensors **12** can be composed of Electroactive polymers, or EAPs, which are polymers that exhibit a change in size or shape when stimulated by an electric field. EAPS could also exhibit a change in electrical field if stimulated by mechanical deformation. The most common applications of this type of material are in actuators and sensors. A typical characteristic property of an EAP is that they will undergo deformation while sustaining forces. For example, EPDM rubber containing various additives for optimum conductivity, flexibility and ease of fabrication can be used as a sensor **12** material for measuring electrode impedance measured on human skin of the wearer. Further, EAPs may be used to measure ECG as well as measuring deformation (i.e. expansion of the waist and therefore breathing can be inferred from EAPs). ECG can be measured using surface electrodes, textile or polymer, as desired.

[0018] These electrodes **12** can be capable of recording biopotential signals such as ECG while for low-amplitude signals such as EEG, as coupled via pathways **30** with an active circuit of the electrical components **15** within the housing **24**. The ECG sensors **12***a* can be used to collect and transmit signals to the computer processor **1** reflective of the heart rate of the wearer. AS such, it is recognized that the electrodes as sensors **12** can be composed of conductive yarn/fibres (e.g. knitted, woven, embroidery using conductive fibres—e.g. silver wire/threads) of the band **10**, as desired.

[0019] In terms of bioelectrical impedance, these sensors **12***a,b* and their measurements can be used in analysis (BIA) via the processor **16** and memory **18** instructions for estimating body composition, and in particular body fat. In terms of estimating body fat, BIA actually determines the electrical impedance, or opposition to the flow of an electric current through body tissues of the wearer interposed between the sensors **12** (e.g. **12***a,b*), which can then be used to estimate total body water (TBW), which can be used to estimate fat-free body mass and, by difference with body weight, body fat.

[0020] In terms of strain sensing, these sensors **12***c* can be operated as a strain gauge to take advantage of the physical property of electrical conductance and its dependence on the conductors geometry. When the electrical conductor **12***c* is stretched within the limits of its elasticity such that it does not break or permanently deform, the sensor **12***c* will become narrower and longer, changes that increase its electrical resistance end-to-end. Conversely, when the sensor **12***c* is compressed such that it does not buckle, the sensor **12***c* will broaden and shorten, changes that decrease its electrical resistance end-to-end. From the measured electrical resistance of the strain gauge, via the power **28** that is administered to the sensors **12** via the computer processor **16** acting on stored **18** instructions, the amount of induced stress can be inferred. For example, a strain gauge **12***c* arranged as a long, thin conductive fibres in a zig-zag pattern of parallel lines such that a small amount of stress in the direction of the orientation of the parallel lines results in a multiplicatively larger strain measurement over the effective length of the conductor surfaces in the array of conductive lines—and hence a multiplicatively larger change in resistance—than would be observed with a single straight-line conductive wire. In terms of location/structure of the strain gauge **12***c,* the strain gauge can be located around the circumference of the band **10**. A further embodiment is where the strain gauge **12***c* is located in a portion of the circumference, for example in a serpentine arrangement, positioned in a front **52** portion (positioned adjacent to the front of the wearer) of the band **10**. The strain gauge **12***c* can be configured for sensing in the k Ohm range.

[0021] In terms of temperature sensor **12***d,* this sensor is used to measure the dynamic body temperature of the wear. For example, the temperature sensor **12***d* can be a thermistor type sensor, which is a thermally sensitive resistors whose prime function is to exhibit a large, predictable and precise change in electrical resistance when subjected to a corresponding change in body temperature. Examples cam include Negative Temperature Coefficient (NTC) thermistors exhibiting a decrease in electrical resistance when subjected to an increase in body temperature and Positive Temperature Coefficient (PTC) thermistors exhibiting an increase in electrical resistance when subjected to an increase in body temperature. Other temperature sensor types can include thermocouples, resistance thermometers and/or silicon bandgap temperature sensors as desired. It is also recognized that the sensors **12** can include haptic feedback sensors that can be actuated via the computer processor **16** in response to sensed data **44** processed onboard by the processor **16** and/or instructions received from a third party device **60** or the wearer (operator of the computer device **40**) via an interface **20**. Another example of temperature sensors **12***d* is where thermocouples could be knitted into the band **10** fabric using textile and coupled directly to the body of the wearer through close proximity/contact in order to get more accurate temperature readings.

Sensed Data and Processing

[0022] Referring again to FIGS. **2** and **3**, the processor **16** (acting on stored **18** instructions) can transmit the collected data **44** (in raw format and/or in preprocessed format from the sensors **12**) to an external computer device **40** (e.g. smartphone or other desktop application) for viewing and/or further processing of the sense data. For example, the device **40** application can display the sensed data **44** in a dashboard type format **46** on a display **42** (or other type of GUI interface) for viewing by the wearer (or by another person other than the wearer that has been provided access to the data **44**). For example, the sensed data **44** can be provided in a dashboard format indicating real-time (or other selected dynamic periodic frequency) of: body temperature for indicating fluctuations in skin temperature; gyroscope/accelerometer measurements for indicating amount/degree of physical activity (i.e. via sensed motion) of the wearer as well as contributing via gyroscope readings of wearer posture (for example in the case where the band **10** is positioned at the waist of the wearer) as well as determined calculation of number of calories expended; strain gauge measurements (e.g. via conductive yarn) in order to indicate real-time breathing of the wearer as the band **10** expands and contracts as well as the ability to differentiate strain degree contributing to posture angle (i.e. band and associated strain sensor **12***c* with change in length as the posture of the wearer changes due to bending at the waist—in the case of the underwear **11** example of FIG. **2**); real-time heart rate measurements based on sensed ECG data using the sensors

12*a;* and real-time hydration/body fat measurements based on galvanic sensing using the sensors **12***b* (and optionally **12***a* as further described below).

[0023] It is recognised that multiple sources of sensed data (e.g. temperature sensor **12***d* with activity/motion sensors **36** can be used in an algorithm stored in memory **18** to calculate calories expended based on activity combined with body temperature). Other combinations of sensed data types can include combinations such as but not limited to: heart rate with activity data; heart rate with activity data with temperature; activity data with bio impedance data; strain gauge for breathing rate data determination with activity data and heart rate data for determination of exertion levels; etc. It is also realized that combinations of sensor type readings can be used by the computer processor **16** to determine exercise activity type being performed by the wearer, based on computer models of activity type with typical sensor data, for example gradual changes in body posture with detected lower levels of heart rate and breathing could be indicative of a wearer practicing yoga. A further type of multiple sensed data usage can be for accelerometer and gyroscope data, such that both can be used or one can be used and the other discounted during determination of a selected metric of the dashboard **46**. For example, in the case of the band **10** being situated at the waist of an overweight person, the "off-vertical" reading of the gyroscope would not be indicative of a bent posture (from the vertical), rather due to the folded waistband due to body composition. As such, the degree of gyroscope readings would be discounted from the calculation of the posture determination.

[0024] Referring again to FIG. **1**, the location of the sensors **12***a,b* are such that they are positioned in pairs on either side of a centerline **50**, in order to position an appropriate amount of body mass between the sensors **12***a,b* as well as, providing an appropriate conductive path through the body of the wearer (e.g. cross body measurement). It is also recognised that placement of the sensors **12***a,b* are preferred in body regions where muscle noise (actions of muscles can introduce signal noise into the adjacent sensors **12**) is minimized. As such, the sensors **12***a,b* can be positioned in the band **10** in a location for positioning adjacent to the hip and/or the kidney of the wearer in the case where the band **10** is positioned at the waist. It is recognised that positioning the sensors **12***a,b* in the band **10** in order to be adjacent to either hip of the wearer, i.e. both sensors **12***a,b* of the pair to one side of the centerline **56** of the band **10**, would provide for a lower signal amplitude/quality when wearer activity is subdued (e.g. resting) however would also advantageously provide an increases signal quality when the wearer is active (as the presence of utilized muscle mass adjacent to the hip region is minimal as compared to other regions about the waist).

[0025] It is also recognised that location of the sensors **12***a,b* can be positioned to either side of the centerline **60** running front to back rather than to either side of the centerline **56** running side to side (of the wearer), as the separation distance for the typical wearer is greater side to side rather than front to back (i.e. wider between hips verses between spine and belly button).

[0026] Further, one example option for the sensor configuration is a 4-electrode ECG sensor configuration. Cost of such an ECG design can be, a factors however the design could potentially give better signal performance. The theory behind the four sensor ECG design is that the processor **16** can switch between each sensor pair (of the multiple pair ECG sensor configuration) to find the one with the best signal quality and use that one during sensed movement of the wearer.

[0027] Referring again to FIG. **3**, the processor **16** and associated stored **18** instructions can be used to determine (based on received sensor **12** readings) bio impedance values by utilizing both of the ECG sensors **12***a* and the sensors **12***b* at the same time. This is advantageous as EGG sensing (using sensors **12***a*) cannot occur at the same time as bio impedance sensing (using sensors **12***b*), as signal amplitude generated by the sensors **12***b* oversaturates the EGG sensors **12***a*. As such, it is recognised that the processor **16** cycles between ECG readings and bio impedance readings (i.e. these readings are done sequentially rather than in parallel). As such, the processor instructs power to both the sensors **12***a,b* on one side of the centerline **50** as drivers and both the sensors **12***a,b* on the other side of the centerline **50** as collectors during taking of bio impedance readings. As such, it is recognised that the positioning of the sensor pair **12***a* and the sensor pair **12***b* can be symmetrical about the centerline(s) **50**,**56**.

[0028] Referring to FIGS. **3** and **4**, the computer device **14** can be used to send the sensed data **44** to the off band computer device **40**, which can then use its own customized applications **43** to process the sensed data **44** to inform the wearer of their physical/mental state on potential adaptations/changes that can be actively done by the wearer. For example, the application **43** can report sensed data **44** pertaining to a combination of temperature and activity over time as an indicator of the quality of sleep of the wearer. Further, the application **43** can notify the wearer of a determined emotional state of the wearer (e.g. based on a combination of breathing data and activity data—with optional ECG data) as well as continued monitoring of the data combination to inform the wearer whether steps taken by the wearer are positively influencing the determined emotional state. Further, the application **43** can track and report on the degree as well as quality/nature of the wearer's activity, for example based on a combination of strain gauge data and activity data. Further, the application can interact with other external computer networked devices **60** (see FIG. **3**) such as but not limited to music systems, heating system, lighting systems, etc in response to a determined mood and/or temperature of the wearer based on a combination of sensed data (e.g. activity, heartrate, etc.).

[0029] Referring to FIGS. **5** and **6**, shown is an alternative embodiment of the band **10**, in exploded view. In particular, the band **10** is composed of a front band portion **60** and a back band portion **62**, such that the portion **60** has sensors **12***a,b* with communication pathways **30** electrically connecting the sensors **12***a,b* to respective connectors **64** (which connect to respective connector portions of the PCB **26** (see FIG. **3**), in order to electrically couple the sensors **12***a,b* to the network interface **20**). The band portion **62** has cutouts **66** in order for the sensors **12***a,b* to be received in the cutouts **66** when the band portions **60**,**62** are assembled with one another (e.g. coupled together for example by stitching via adjacently places surfaces **70**), thus providing for surfaces **68** of the sensors **12***a,b* to become in contact with the skin of the wearer, as the surface **111** is for contact with the skin. It is recognized that the electrically conductive pathways **30**

can be electrically conductive fibres interlaced with electrically insulative fibres comprising the material of the band portion **60**.

[0030] Referring to FIG. **7**, shown is an example side view of one of the sensors **12***a,b,* such that the portions **60**,**62** are assembled and the sensors **12***a,b* are received in the cutouts **66** (see FIGS. **5**,**6**). It is important to note that the sensors **12***a,b* themselves extend from the skin contact surface **111** by a distance X, thus providing for improved contact with the skin of the wearer. In particular, the sensors **12***a,b* can have a conductive portion **72** of the surface **68** (i.e. coupled to the communication pathways **30** extending through backing material **74**) as well as the raised backing material **74** to provide for the respective extension of the conductive portion **72** of the sensors **12***a,b* from the surface **111**. For example, the backing material **74** can be comprised of electrically insulative interlaced fibres interleaved with the textile fibres incorporating the material (i.e. electrically insulative fibres) of the band portion **62**.

[0031] Referring to FIG. **8**, shown is a further embodiment of the band portion **80** showing the strain gauge sensor **12***c* woven/knit in a serpentine fashion with other insulative fibres comprising the material of the band portion **60**. As such, as shown in FIG. **7**, it is recognized that once assembled, the band portion **62** would cover the strain gauge sensor **12***c* and thus insulate the skin of the wearer from direct contact with the electrically conductive fibres of the strain sensor **12***c*. FIG. **9** shows a further geometrical configuration of the strain sensor **12***c*.

[0032] Referring to FIGS. **5** to **8**, it is recognized that they contain example geometrical layouts of the communication pathways **30** (e.g. traces) and the strain sensor **12***c* itself. The shown construction of the sensors **12***a,b,c* and band portions **60**,**62** are advantageous, as the entire pattern (of pathways **30** and sensor(s) **12***c*) is actually contained within covering portions **60**,**62** as one assembled (e.g. interlaced) layer of fabric, however the traces (of pathways **30** and sensor(s) **12***c*) are knitting inside the knit pattern and therefore as a consequence of that are insulated, therefore inhibiting any necessity of external insulation (glues, laminates, etc), in order to inhibit undesirably application of electrical charge from the traces to the skin of the wearer. Further, the 3D shape (e.g. extension from the surface **111**) of the sensors **12***a,b* themselves can improves the sensors **12***a,b* contact with the skin and can provide for the collection of biometric data across a variety of skin conditions, dry or wet.

We claim:

1. A resilient fabric band providing a sensor platform for a wearer in order to sense a plurality of biometric data, the band comprising:

a pair of ECG sensors coupled to an interior, surface of a body of the band, each of the pair of ECG sensors located on either side of a front to back centerline of the body;

a pair of bio impedance sensors coupled to the interior surface of the body of the band, each of the pair of bio impedance sensors located on either side of the front to back centerline;

a strain gauge sensor coupled to the body of the band;

a computer device mounted on the body of the band via a housing, the computer device including a power source, a computer processor, a memory for storing instructions for execution by the computer processor, and a network interface for transmitting data sensed by the sensors; and

a plurality of communication pathways connecting the computer device to each of the sensors, the communication pathway for sending power from the power supply to the sensors as controlled by the computer processor and for receiving sensed data from the sensors by the computer processor.

2. The band of claim **1** further comprising a temperature sensor mounted in or external to the housing and facing the interior surface of the body.

3. The band of claim **1** further comprising the band incorporate as a component of an article of clothing.

4. The band of claim **3**, wherein the article of clothing is underwear and the band is positioned at a waist of the underwear.

5. The band of claim **1** further comprising motion sensors selected from the group consisting of accelerometer and gyroscope.

6. The band of claim **1**, wherein the strain gauge sensor is interlaced into fabric of the body of the band as a plurality of conductive fibres.

7. The band of claim **1**, wherein the both the bio impedance sensors and the ECG sensors are positioned on one side of a side to side centerline of the body.

8. The band of claim **1**, wherein the communication pathways are conductive fibres interlaced in the fabric of the body of the band.

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专利名称(译)	用于生物识别数据的多模态感测的传感器带
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摘要(译)

弹性织物带为佩戴者提供传感器平台以便感测多个生物识别数据，该带包括：耦合到该带的主体的内表面的一对ECG传感器，所述一对ECG传感器中的每一个位于身体前后中心线的两侧;一对生物阻抗传感器，耦合到带体的内表面，每对生物阻抗传感器位于前后中心线的两侧;应变仪传感器耦合到带体;通过外壳安装在带体上的计算机设备，该计算机设备包括电源，计算机处理器，用于存储由计算机处理器执行的指令的存储器，以及用于传输由传感器感测的数据的网络接口;多个通信路径将计算机设备连接到每个传感器，该通信路径用于在计算机处理器的控制下从电源向传感器发送电力，并且用于通过计算机处理器从传感器接收感测数据。