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(54) Title: ELECTRONIC SENSOR SYSTEM FOR USE WITH FOOTWEAR

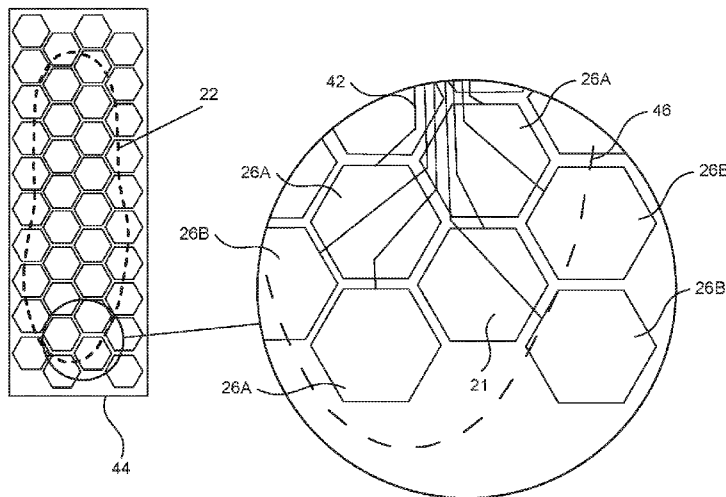


FIG. 4

(57) Abstract: The disclosed technique relates to an insert for footwear and to a composite orthotic insole comprising said insert, wherein the insert is embedded with a plurality of force (or pressure) sensors, and may be used to provide feedback on important information regarding the wearer's gait biomechanics. The layer of sensors may be used to assist in monitoring the wearer's health via foot pressure tracking. The insole can use a relative large number of sensors, which together provide broad coverage of the human foot impact area.



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ELECTRONIC SENSOR SYSTEM FOR USE WITH FOOTWEAR**CROSS-REFERENCE TO RELATED APPLICATION(S)**

5 [0001] This application claims the benefit of U.S. Provisional Application No. 62/199,818 of the same title and filed on July 31, 2015, which is incorporated by reference herein.

TECHNICAL FIELD

[0002] The technique introduced here relates to the field of electronic sensor systems for footwear.

10 **BACKGROUND**

[0003] The use of orthotic inserts in footwear to assist in the therapy and alignment of the wearer's neuromuscular and skeletal systems is known. One refinement to such orthotics contemplates their use in combination with electronic pressure sensors so that the wearer can be assessed and/or monitored.

15 **SUMMARY**

[0004] Disclosed herein is an orthotic insert configured with an improved electronic sensor layer that provides feedback on important information regarding the wearer's gait mechanics (such as the force and pressure distribution on substantially the complete footprint of the wearer) during walking and other physical activities. The layer of sensors is used to
20 assist in monitoring the wearer's health via foot pressure tracking.

[0005] Known existing sensing systems for footwear to date are limited to 8 sensors; in other words, the force/pressure signals from no more than 8 sensors (distributed around the wearer's foot) can be tracked. This is because the signals are processed through an analog-to-digital converter (ADC) device, and presently such ADC devices typically have an 8 channel
25 limit. The technique introduced here is able to utilize 9 or more (substantially more, where appropriate) sensors on the sensor layer. At least one embodiment of the disclosed system incorporates the use of one or more 32-channel analog multiplexers (or multiplexer switches) and Bluetooth 4.0 low-energy technology (the latter being used to transmit/communicate the data), to significantly increase the number of sensors that can be handled. Using a large
30 quantity of standardized sensors allows the sensor layer to be more readily customizable and robust to different foot and gait biomechanics.

[0006] Furthermore, existing sensing systems that are used with footwear are generally either impractically thick or not customizable. The manufacturing process

disclosed, coupled with the selection of suitable sensors and materials, enables sensor layers having a thickness of less than 2.6 mm to be produced.

[0007] The technique introduced here relates to an insert for footwear and to a composite orthotic insole comprising said insert, wherein the insert (or sensor layer) is embedded with a plurality of force (or pressure) sensors, and may be used to gather the wearer's foot pressure data (such as gait biomechanics) during various physical activities. The insert can include 9 or more embedded sensors, which together will provide broad coverage and precise sensing of the human foot impact area. In at least one embodiment, the insert comprises a polydimethylsiloxane (PDMS) covering to seal and protect the layer of sensors, thus providing flexibility, durability and waterproofing of the insert. The applicable data collected from the sensors will be passed to a proximally-located, battery-powered microcontroller (which may be concealed within or beneath the orthotic insole, such as in the area of the foot arch) which can use standard Bluetooth (4.0) communications technology to communicate such data to external devices.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of teachings introduced here are described below with reference to the accompanying drawings in which:

[0009] FIG. 1 is a simplified top view of the composite orthotic insole and sensor layer, illustrating the layout of the sensors in the sensor layer.

[0010] FIG. 2 is a cross-sectional view of an embodiment of an orthotic insole having multiple layers.

[0011] FIG. 3 is a schematic diagram illustrating the wiring for the sensors in the sensor layer and illustrating the multiplexer function.

[0012] FIG. 4 is a top view of the sensor sheet, along with an enlarged fragmentary view of a section thereof, illustrating the wiring of the sensors.

[0013] FIG. 5A and B are a simplified diagram (top view) of two differently sized sensor sheets, illustrating how each can be trimmed to form a sensor layer for different-sized feet.

[0014] FIG. 6 is a side view of an embodiment of an orthotic insole including a number of electronic components.

[0015] FIG. 7 is a block diagram of a system including an external user device and an application server.

[0016] FIG. 8 is a cross-sectional view of an embodiment of an orthotic insole having a support pillar in an air gap layer.

[0017] FIG. 9 is a flowchart of a method for customization of an orthotic insole.

[0018] FIG. 10 is a flowchart of a method of receipt and transmission of signals from an orthotic insert.

DETAILED DESCRIPTION

[0019] FIG. 1 is a simplified top view of the composite orthotic insole and sensor layer, illustrating the layout of the sensors in the sensor layer. A schematic top view of a smart orthotic insert 20 is shown. The orthotic insert 20 includes a number of layers. Displayed is a sensor layer 22 and a surface layer 24 which the sensor layer is placed on top of. The surface layer 24 would go around the exterior of the orthotic insert 20 and is the surface upon which users contact with their feet. The sensor layer 22 is generally in the shape of a wearer's foot, and is made up of a plurality of electronic pressure or force sensors 26 wired together in a network. The sensor 26 themselves may merely be conductive contacts

that make up a portion of a pressure sensor or switch. The surface layer 30 serves to completely seal and protect the sensor layer (among other layers), and may be made from a material such as PDMS, or other suitable plastics or gel materials which are flexible, durable and waterproof.

5 [0020] Each of the active sensors 26 is shown as having a hexagonal shape (although it should be understood that other shapes of sensors are also possible, such as circular). The general layout of the sensors 26 in relation to a wearer's foot shape is shown in Fig. 1. The number of sensors 26 and their placement/coverage around the shape of the foot is such that all important areas of the foot will be measured, regardless of the wearer's foot shape
10 specifics, as well as regardless of the wearer's gait mechanic changes during the orthotic lifetime.

[0021] An embodiment of the technique introduced here is described herein in the form of a sensor layer 22 of an orthotic insert 10. However, it should be understood that the sensor layer could instead be used in combination with a regular insole or insert, or by itself
15 as an insert for footwear.

[0022] FIG. 2 is a cross-sectional view of an embodiment of an orthotic insole having a number of layers. The sensor layer 22 interacts with a number of layers, including a pressure-sensitive resistor layer ("PSR layer") 28. The PSR 28 may comprise a layer of Velostat as manufactured by the 3M Company. Other materials are suitable so long as the
20 material used has a variable electrical resistance which is controlled by the amount of pressure applied to the material. The electrical resistance is reduced when pressure is applied. Between the sensor layer 22 and the pressure-sensitive resistor layer 28 is an air gap layer 30. The air gap layer 30 is established through the structure of the surface layer 24 which keeps the PSR layer 28 and the sensor layer 22 split apart. After the orthotic insert 20 is constructed,
25 the air pressure of the air gap layer 30 maintains the integrity of the air gap layer 30.

[0023] Below the sensor layer 22 are electronic components. The electronic components include a microcontroller 32, and a wireless communicator 34. Optionally a multiplexer 36 is connected to the microcontroller 32. The sensors 26 are connected to either the microcontroller 32 or the multiplexer 36. There is also a differential contact 38 that runs
30 between the microcontroller 32 and the PSR layer 28 that completes the circuit. The circuit is powered by a battery 40. The battery 40 may be rechargeable or replaceable.

[0024] The general functionality of the layers is as follows. The differential contact 38 carries the voltage difference from the battery 40 to the PSR layer 28. The PSR layer 28

changes its resistance when bent, compressed or is otherwise deformed by external forces (in this case, foot impact). The air gap layer 30 is placed below the PSR layer 28 to provide cushioning and support for the PSR layer 28, and therefore regulate how much pressure is required to alter the shape of the PSR layer 28. In other words, The air gap layer 30 regulates how much force or pressure is required to create the resistance difference in the circuit. Where the PSR layer 28 contacts the sensor layer 22 (the particular sensors 26) a circuit is completed. The changing resistance is measured in the microcontroller 32, and converted into digital data points for software interpretation. The recorded voltage enables calculation of the magnitude of pressure applied to the sensor as well as the timing for the applied pressure.

[0025] Based on the number of sensors 26, the orthotic insert 20 makes use of the multiplexer 36. Where the microcontroller 32 is configured to accept all of the inputs on the of the sensors 26 directly, no multiplexer 36 is required. Where the number of sensors 26 is greater than the number of sensor inputs on the microcontroller 32, a multiplexer 36 enables additional sensor input to the microcontroller 32. In at least one embodiment, the sensor coverage will be such that a minimum of nine sensors 26 providing pressure data points at all times.

[0026] In at least one embodiment, the complete pressure sensors are composed of a Velostat™ layer, an air gap layer, sensor layer and electronic components. Sensors 26 can be sized as desired, possibly in the 5mm to 40mm range. The sensors are semi-custom, in that the sensors 26 are based on a standard set of layers, and customized in terms of shape and size to fit the design of the sensor sheet. An example of a suitable off-the-shelf complete pressure sensor that utilizes a usable pressure-sensor configuration is the Tekscan™ FlexiForce™ A201.

[0027] The sensor sheet can be used in contact with a human foot and placed above an orthotic insert (which itself is preferably one that has been customized to a shape or profile to provide the wearer with specific biomechanical improvements). The sensor layer can provide gait and stride force/pressure feedback to validate these improvements, and predict future orthotic refinements. The gathered data could be used for performance analysis, performance improvement recommendation, health tracking, injury prevention, and various other biomechanical applications.

[0028] FIG. 3 is a schematic diagram illustrating the wiring for the sensors 26 in the sensor layer 22 and illustrating the multiplexer 36 function. The schematic diagram illustrates

the wiring 42 of nine separate sensors 26 and the multiplexer 36 function. To enable 9+ channels of data logging, one or more multiplexer switches 36 is used.

[0029] The sensors are wired through one or more multiplexer switch 36, which can be analog 32-channel switches, for example. From the multiplexer switch 36, the wiring 42 runs to a microcontroller 32, which is limited to 8 inputs. It may be preferable that a particular sensor sheet be made up of sensors 26 that are standardized and the same size, since this makes the sensor sheet more readily customizable and facilitates comparisons (and provides for uniformity) of the various sensor signals from the same foot or from different wearers; however, sensors 26 of differing sizes could be used.

[0030] The multiplexer 36 will switch between the sensors 26 rapidly, i.e., fast enough to ensure that any measurable pressure changes can be detected and recorded. The multiplexer 36 switches one of multiple inputs to the common output, determined by a unique binary address lines (samples are marked on each sensor 26).

[0031] For 9 - 16 sensors, a 16-channel analog multiplexer can be used, switching one of 16 inputs to one, determined by four-bit binary address lines (in this case, a 32-channel analog multiplexer could also be used). For 17 - 32 sensors, a 32-channel analog multiplexer can be used, switching one of 32 inputs to one, determined by five-bit binary address lines. Alternatively, where appropriate, two or more multiplexers 36 can be used in combination. The signal from the sensors is passed to a microcontroller 32, which can include a microcontroller and associated electronic equipment (including battery unit and communication hardware).

[0032] The above-described approach involving relatively large numbers of sensors is practical in combination with the use of electronics that consume small amounts of power (such as low-power sensors) and that require low-power for communication through the wireless communicator 34. Bluetooth 4.0 standard technology, compatible with iBeacon™, for example, can be used to conserve battery life. Other forms of wireless communicators 34 are also suitable such as WiFi or cellular (GSM, CDMA, GPRS, etc...) so long as the wireless communicator 34 is compact.

[0033] FIG. 4 is a top view of a sensor sheet 44, along with an enlarged fragmentary view of a section thereof, illustrating the wiring 42 of the sensors 26. The sensor sheet 44 itself can be designed to allow trimming and customizing for each unique footprint. The sensors 26A and peripheral sensors 26B are placed and wired in such a way that the electrical wires 42 are directed generally towards the center of the basic foot shape. This enables

adding or subtracting to the sensor sheet 44 design without disrupting the wiring 42 of the sensor 26. This also provides the advantage of being able to trim/customize each sheet to a specific foot shape, by cutting through some of the peripheral sensors 26B, without significantly affecting the functionality of the sensor layer 26 as a whole. In Fig. 4, the trim line 46 for the sensor layer 22 for a particular foot-size indicates that certain peripheral sensors 26B will be compromised by the trimming and would not function; other active sensors 26A; however would continue to be able to record pressure data.

[0034] The production process can start with a set of standard sensor sheets 44. In some embodiments these sensor sheets 44 are categorized for one or more shoe sizes. In some embodiments, the sensor sheets 44 are suitably large to be used for all shoe sizes. The customization of the orthotic inserts 20 begins with the sizing of the sensor sheet 44. Where customized foot sized data is received by the manufacturer, a very particular foot shape may be cut into the sensor sheet 44 matching foot of the intended user as accurately as possible. This is technique is highly customizable, in part, as a result of the repeating, pattern of the sensors 26 on the sensor sheet 44, and that the wiring 42 for each of the sensors 26 is routed towards the center of the sensor sheet 44. Routing the wiring 42 to the center of the sensor sheet 44 enables large variation in the foot size cut 46 into the sensor sheet 44 while still enabling the wiring 42 to function for all remaining sensors 26.

[0035] This is illustrated in **FIG. 5A and 5B**, which show two differently sized sensor sheets 44A and 44B, and illustrate how each could be trimmed to be formed into a sensor layer for two different-sized feet (in this case, sensor sheet 44A for a relatively larger foot, and sensor sheet 44B for a relatively smaller foot). It also may be preferable that the sensor sheet 44 be made relatively thin - in practice, a thickness of less than about 2.6mm may be considered optimal.

[0036] The optimal sized sheet is chosen, then trimmed/customized along the trim lines 46A and 46B respectively for the individual foot shape. Each standard sheet size could be produced in bulk using a packaging machine, or produced using additive manufacturing with a modified 3D printer. It also may be preferred to determine sensor spacing based on foot size. For example, relatively smaller foot sizes may require less spacing between sensors than larger sizes. In cases where a standardized sensor sheet 44 is used, there is a positive correlation between a number of sensors 26 to the foot size trim lines 46. Further, in those embodiments there is a static density of sensors 26 despite variance to the foot size trim lines 46.

[0037] FIG. 6 is a side view of an embodiment of an orthotic insole including a number of electronic components. In addition to a set of pressure sensors 26, additional instruments 48 can be inserted in the orthotic insert 20 to provide data. The additional instruments 48 may include, for example: a geolocation sensor (such as a GPS), a thermometer, an accelerometer, an ultrasonic sensor, a heartbeat sensor and/or a gyroscope. More than one of the additional instruments 48 may be placed within the orthotic insert 20. The additional instruments feed collected data to the microcontroller 32 which in turn feeds data to the wireless communicator 34 for transmission. The additional instruments 48 provide additional data that help shape the machine understood story of the travel a foot, a pair of feet, or even a whole body take.

[0038] In some embodiments, the additional instruments 48 are socketed into an insole without the pressure sensors. Rather than use a layered pressure sensor, the additional instruments 48 are inserted into sockets in the surface layer 24. Between the sockets wiring connects the microcontroller 32 and the wireless communicator 34 and the battery 40.

[0039] FIG. 7 is a block diagram of a system including an external user device and an application server. The orthotic insert 20 uses the internal wireless communicator 34 to transmit data and signals 49 collected and processed by the microcontroller 32 to an external device 50. The external device 50, may be a number of devices including but not limited to a smart phone, a tablet, a laptop or desktop computer, a virtual reality interface, a augmented reality interface, and a suitable control module known in the art.

[0040] Processed data and signals 49 are either used directly by the external device 50, or forwarded to an applications server 52. The external device 50 may be connected to the application server 52 through wireless, network, or wired connections. In some embodiments, the processed data and signals 49 are used to construct analytical models of the wearer's gait, physical stresses, and body health.

[0041] Another possible application for the disclosed system is for entertainment purposes. For example, the foot pressure on the wearer may be tracked through the layer of sensors and used as inputs to a connected user-interactive processing device (such as a video game system or a virtual reality hardware device). The wearer can provide instructions to or otherwise control the processing device, at least in part, via the foot pressure communicated (e.g. the wearer may represent/simulate actions such as jumping, walking, hopping, balancing, etc.).

[0042] FIG. 8 is a cross-sectional view of an embodiment of an orthotic insole 20 having a support pillar 54 in an air gap layer 30. In order to increase the resistance of the air layer 30 beyond air pressure, one or more collapsible support pillars 54 or substrate may be affixed within the air gap layer 30 increasing the amount of pressure required upon the PSR layer 38 in order to make contact with the sensor layer 22.

[0043] FIG. 9 is a flowchart of a method for customization of an orthotic insole. In step 902, a insole manufacturing station receives foot size parameters. The scope of insole manufacturing station is general. Included examples of a insole manufacturing station are a corporate entity with the purpose of manufacturing insoles, a 3D printer, a single machine that assembles insoles, or a group of machines that assemble insoles. The foot size parameters pertain to the size of a customer's foot as measured by an external method. In step 904, the insole manufacturing station determines the correct sensor sheet 44 to use for the particular customer's foot size parameter.

[0044] In step 906, the insole manufacturing station cuts the sensor sheet to the foot size parameter. In doing so, extraneous sensors 26B and wiring 42 for those sensors are stripped away leaving only the sensors 26A which will remain in the sensor layer 22. In step 908, the remainder of the sensor matrix is completed: the PSR layer 28 and the air gap layer 30 are formed. The electronic components (microcontroller 32, multiplexer 36, and wireless communicator 34) are connected to the wiring 42 and the differential contact 38 is connected to the PSR layer 28.

[0045] In step 910, any additional instruments 48 are added as suitable. In step 912, the layers, including the surface layer 24 are fixed into position and a completed custom orthotic insert 20 is ready to ship to the customer.

[0046] FIG. 10 is a flowchart of a method of receipt and transmission of signals from an orthotic insert. In step 1002, the orthotic insert 20 receives a footfall, the footfall imparting pressure upon the insert 20. In step 1004, the imparted pressure increasing the conductivity of the PSR layer 28 of the insole 20. In step 1006, the imparted pressure further causes the air gap layer 30 to at least partially collapse. The collapse of the air gap layer 30 causes the PSR layer 28 to contact one or more sensors 26 on a sensors layer 22 of the insert 20.

[0047] In step 1008, the orthotic insert 20 completes one or more circuits between the one or more sensors 26 and the PSR layer 28. In step 1010, each completed circuit delivers a signal to a microcontroller 32, each signal including a unique identifier associated with each of the one or more sensors that complete the one or more circuits. In inserts 20 with a

multiplexer 36 the unique identifier is determined by a binary code corresponding to the input on the multiplexer 36. In inserts 20 without a multiplexer, the unique identifier is indicated by the input used on the microcontroller 32.

5 [0048] In step 1012, the microcontroller 32 processes the received signals. In step 1014, the microcontroller 32 delivers the processed signals to the wireless communicator 34 for transmission. In step 1016, the signals are analyzed with a measured voltage to determine the magnitude of the pressure supplied by the footfall across each sensor 26 receiving pressure. Step 1016 may be performed either by the microcontroller 32 prior to step 1014, or after step 1014 by an external device 50 or an application server 52.

10 [0049] Depending on how the transmitted data is to be used by the external device 50 or application server 52, the method proceeds to step 1018 or 1020. In step 1018, the external device 50 or application server 52 uses the transmitted signals to develop analytical models of footfalls. In step 1020, the transmitted signals provide user input to an entertainment apparatus such as a game system or virtual/augmented reality apparatus.

15 [0050] The embodiments described herein are not, and are not intended to be, limiting in any sense. One of ordinary skill in the art will recognize that the disclosed technique(s) may be practiced with various modifications and alterations, such as structural and logical modifications. Although particular features of the disclosed technique(s) may be described with reference to one or more particular embodiments and/or drawings, it should be
20 understood that such features are not limited to usage in the one or more particular embodiments or drawings with reference to which they are described, unless expressly specified otherwise.

CLAIMS

1. A flexible, multi-layered insole for footwear, the insole comprising:

a surface layer that binds the insole together and arranged to contact a foot of a user;

5 a pressure-sensitive resistor layer that becomes more conductive as pressure is applied;

a sensor layer including a plurality of sensors arranged laterally across the insole, each sensor having a unique identifier;

10 an air gap layer between the pressure-sensitive resistor layer and the sensor layer, the air gap layer configured to collapse at least partially when the insole receives a footfall to thereby cause contact between the pressure-sensitive resistor layer and one or more of the sensors and cause each said one or more of the sensor pads to output a respective signal; and
a microcontroller coupled to receive and process the signals received from the sensor pads.

15 2. The insole of claim 1, further comprising:

a wireless communicator communicatively coupled with the microcontroller and configured to transmit processed signals from the microcontroller to external devices.

3. The insole of claim 1, further comprising:

20 a multiplexer to receive the signals from the sensors and selectively output a subset of the signal to the microcontroller.

4. The insole of claim 1, wherein each of the sensors of the sensor layer includes a contact that directs the corresponding to a central location on the insole.

5. The insole of claim 4, wherein the central location is an arch section of the insole.

25 6. The insole of claim 1, wherein the sensors are arranged in a repeating pattern across the sensor layer.

7. The insole of claim 6, wherein the sensor layer contains a positive correlation between a number of sensors to a foot size of insole, and a static density of sensors despite variance in the foot size of insole.

8. The insole of claim 1, further comprising:

30 a load column affixed between the pressure-sensitive resistor layer and the sensor layer in the air gap layer that increases the amount of pressure required to collapse the air gap layer.

9. The insole of claim 1, further comprising one or more of:

a geolocation sensor;
a thermometer;
an accelerometer;
an ultrasonic sensor;
5 a heartbeat sensor; or
a gyroscope.

10. A footwear insert system comprising:

a plurality of pressure switches arranged on a flexible substantially planar member,
each of the pressure switches including a variable resistor that varies based on a magnitude of
10 pressure applied; and

a footwear insert shell that includes an internal volume containing the plurality of
pressure switches.

11. The insert system of claim 10, further comprising:

a microcontroller which receives and processes signals from the plurality of pressure
15 switches; and

a wireless communicator communicatively coupled with the microcontroller and
configured to transmit processed signals from the microcontroller to an external device.

12. The insert system of claim 11, further comprising:

a multiplexer to receive the signals from the pressure switches and selectively output
20 a subset of the signal to the microcontroller.

13. The insert system of claim 11, wherein each of the pressure switches include a contact
that directs the respective signals to a central or arch location on the insert.

14. The insert system of claim 13, wherein the central location is an arch section of the insert.

15. The insert system of claim 10, wherein the pressure switches are arranged in a repeating
25 pattern across the flexible substantially planar member.

16. The insert system of claim 15, wherein there is a positive correlation between a
number of pressure switches to a size of the footwear insert shell, and a static density of
pressure switches despite variance in the size of footwear insert shell.

17. The insert system of claim 10, wherein the plurality of pressure switches on the flexible
30 substantially planar member are constructed including:

a pressure-sensitive resistor layer that becomes more conductive as pressure is
applied;

a sensor layer including a plurality of sensors, each of the sensors having a unique identifier and upon contact with the pressure-sensitive resistor layer close a pressure switch; and

an air gap layer between the pressure-sensitive resistor layer and the sensor layer, the
5 air gap layer configured to collapse at least partially when the insert receives a footfall to thereby cause contact between the pressure-sensitive resistor layer and one or more of the sensors and cause each said one or more of the sensor pads to output a respective signal.

18. The insert system of claim 15, further comprising:

10 a load column affixed between the pressure-sensitive resistor layer and the sensor layer in the air gap layer that increases the amount of pressure required to collapse the air gap layer.

19. The insert system of claim 11, further comprising one or more of the following sensors:

15 a geolocation sensor;
a thermometer;
an accelerometer;
an ultrasonic sensor;
a heartbeat sensor; or
a gyroscope.

20. The insert system of claim 11, further comprising:

20 application software resident on the external device, the application software including instructions to receive signals transmitted from the wireless communicator and develop analytical footfall models to report to a user.

21. The insert system of claim 11, further comprising:

25 application software resident on the external device, wherein the external device is a gaming apparatus, and the application software including instructions to receive signals transmitted from the wireless communicator and provide user inputs to the gaming apparatus thereby influencing virtual reality simulations.

22. A method comprising:

30 receiving a footfall on a flexible, multi-layered insole for footwear, the footfall imparting pressure upon the insole;
the imparted pressure increasing the conductivity of a pressure sensitive resistor layer of the insole;

causing the pressure-sensitive resistor layer to at least partially collapse an air gap layer and contact one or more sensors on a sensors layer of the insole; and

completing one or more circuits between the one or more sensors and the pressure sensitive resistor layer, each completed circuit delivering a signal to a microcontroller, each
5 signal including a unique identifier associated with each of the one or more sensors that complete the one or more circuits.

23. The method of claim 22, further comprising:

transmitting, by a wireless communicator, processed signals from the microcontroller to an external device.

10 24. The insole system of claim 22, further comprising:

cutting the sensor layer to a custom insole size from a sheet of sensors having a repeating pattern of sensors, each of the sensors including a contact directed to the center of the sheet of sensors such that contacts meet at a location on the sensor sheet which is included in every cut sensor layer despite variance in insole size.

15 25. The method of claim 24, wherein the sensor layer contains a positive correlation between a number of sensors to a foot size of insole, and a static density of sensors despite variance in the foot size of insole.

26. The method of claim 23, wherein the transmitting step further includes transmitting data from integrated sensors, integrated sensors further comprising one or more of the following

20 sensors:

a geolocation sensor;

a thermometer;

an accelerometer;

an ultrasonic sensor;

25 a heartbeat sensor; or

a gyroscope.

27. The method of claim 23, further comprising:

receiving, by application software resident on the external device, signals transmitted from the wireless communicator; and

30 developing analytical footfall models to report to a user.

28. The method of claim 23, further comprising:

receiving, by application software resident on the external device, signals transmitted from the wireless communicator, wherein the external device is an entertainment apparatus; and

5 providing user inputs to the entertainment apparatus thereby influencing virtual reality simulations.

29. A flexible, sensor-equipped insole for footwear, the insole comprising:

an insole body;

one or more sensors from the list:

10 a geolocation sensor;

a thermometer;

an accelerometer;

an ultrasonic sensor;

a heartbeat sensor; or

15 a gyroscope.

a microcontroller that receives and processes output of the one or more sensors; and

a wireless communicator that receives microcontroller outputs and subsequently transmits said microcontroller outputs to external devices.

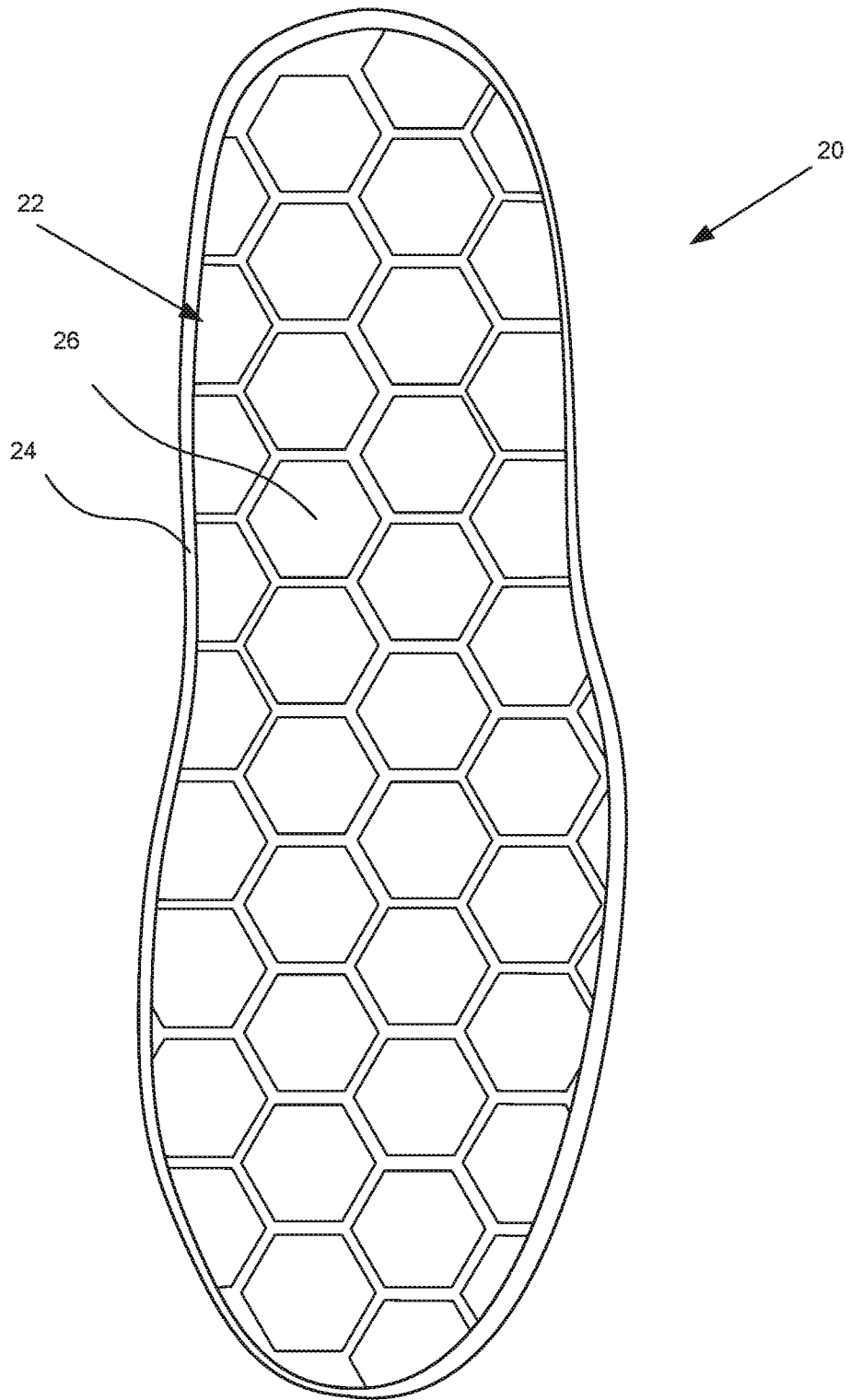


FIG. 1

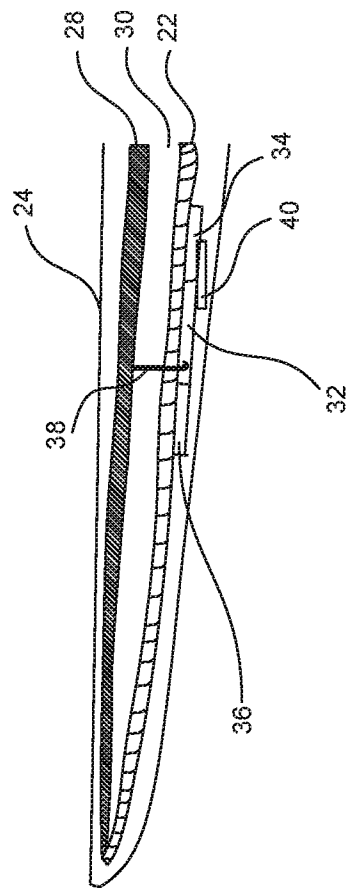


FIG. 2

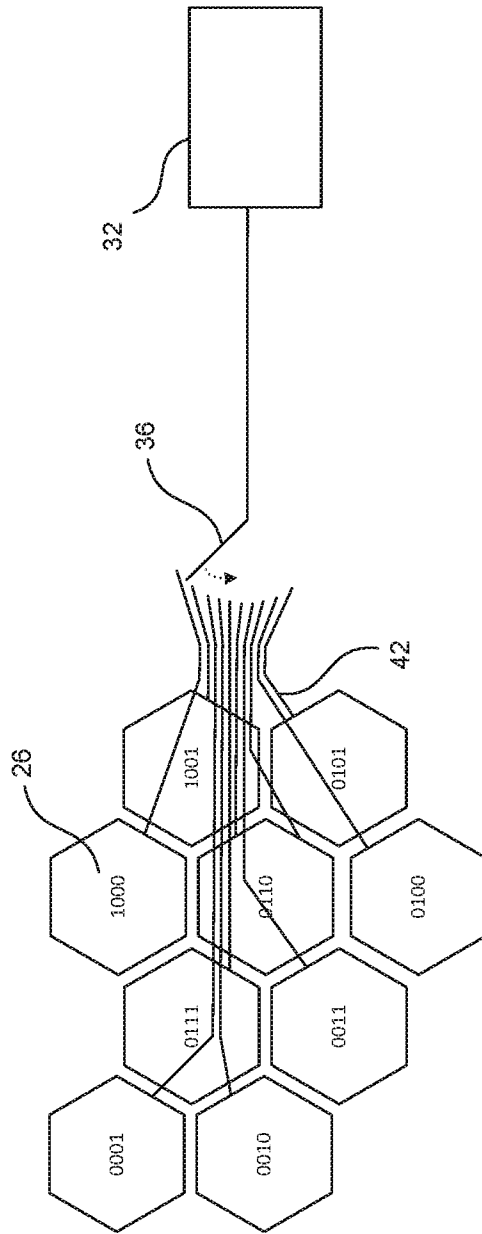


FIG. 3

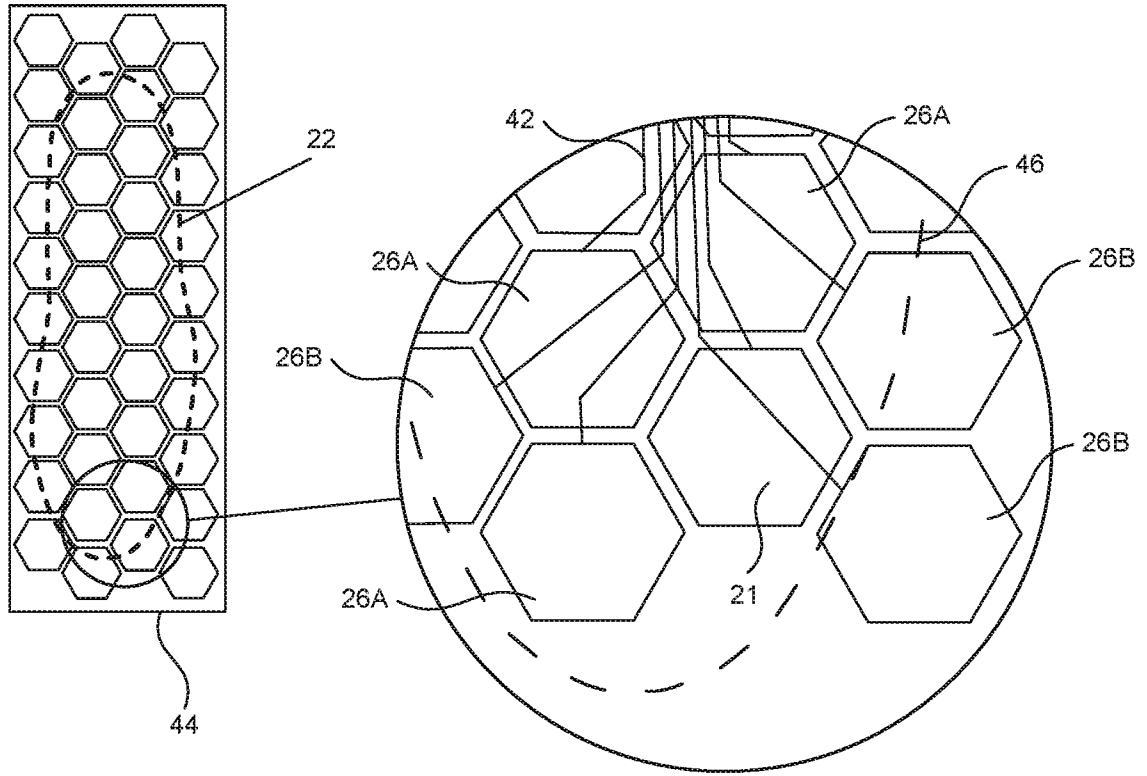


FIG. 4

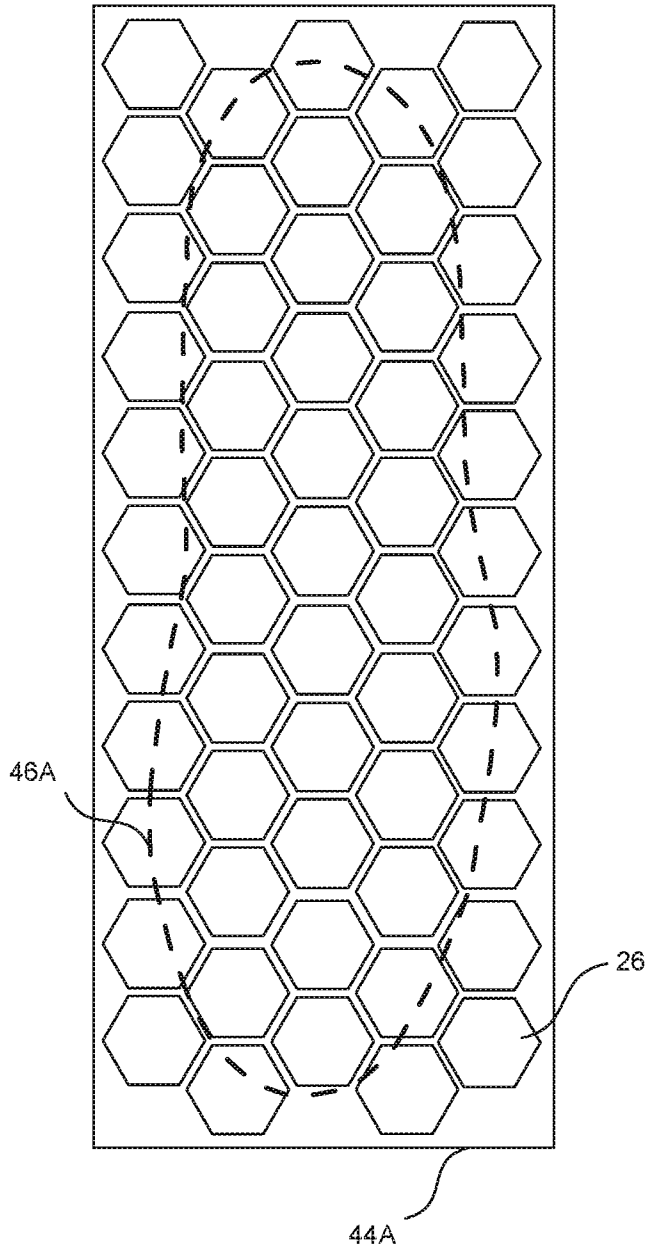


FIG. 5A

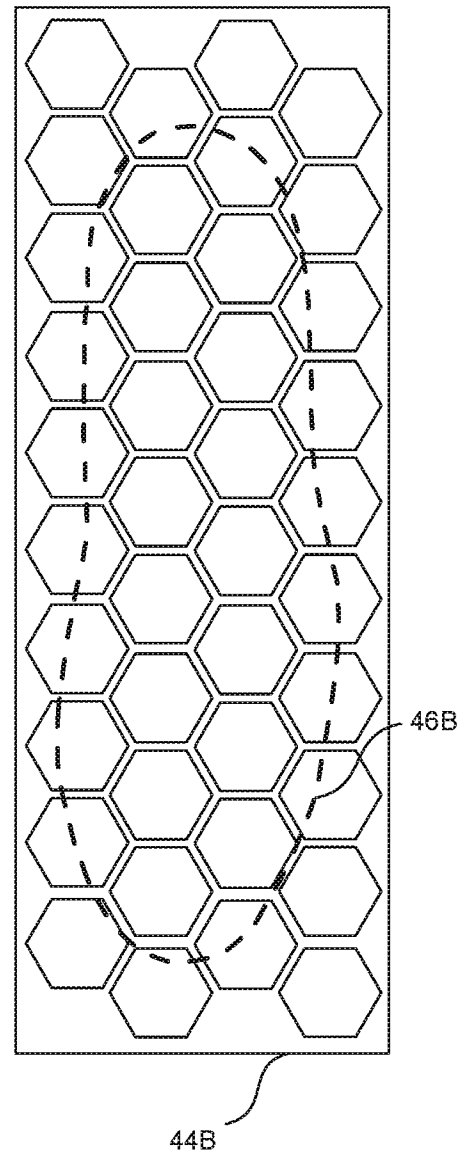
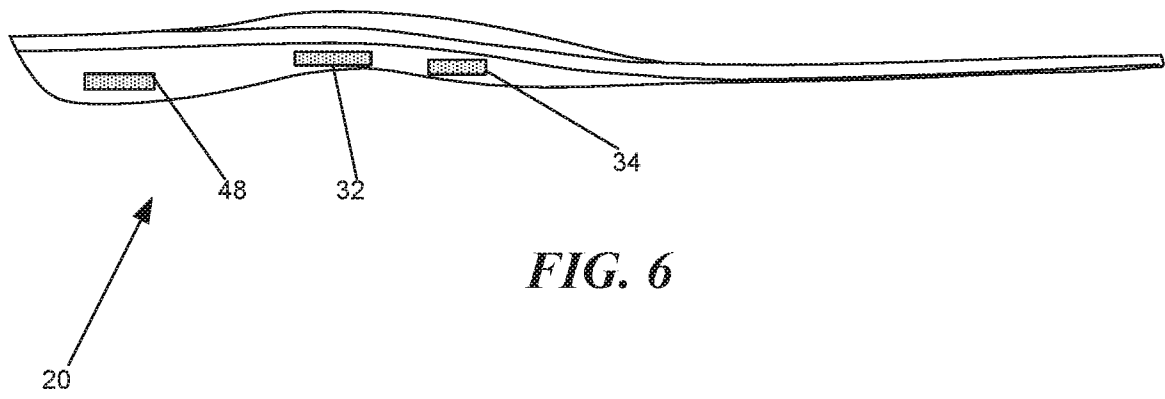


FIG. 5B



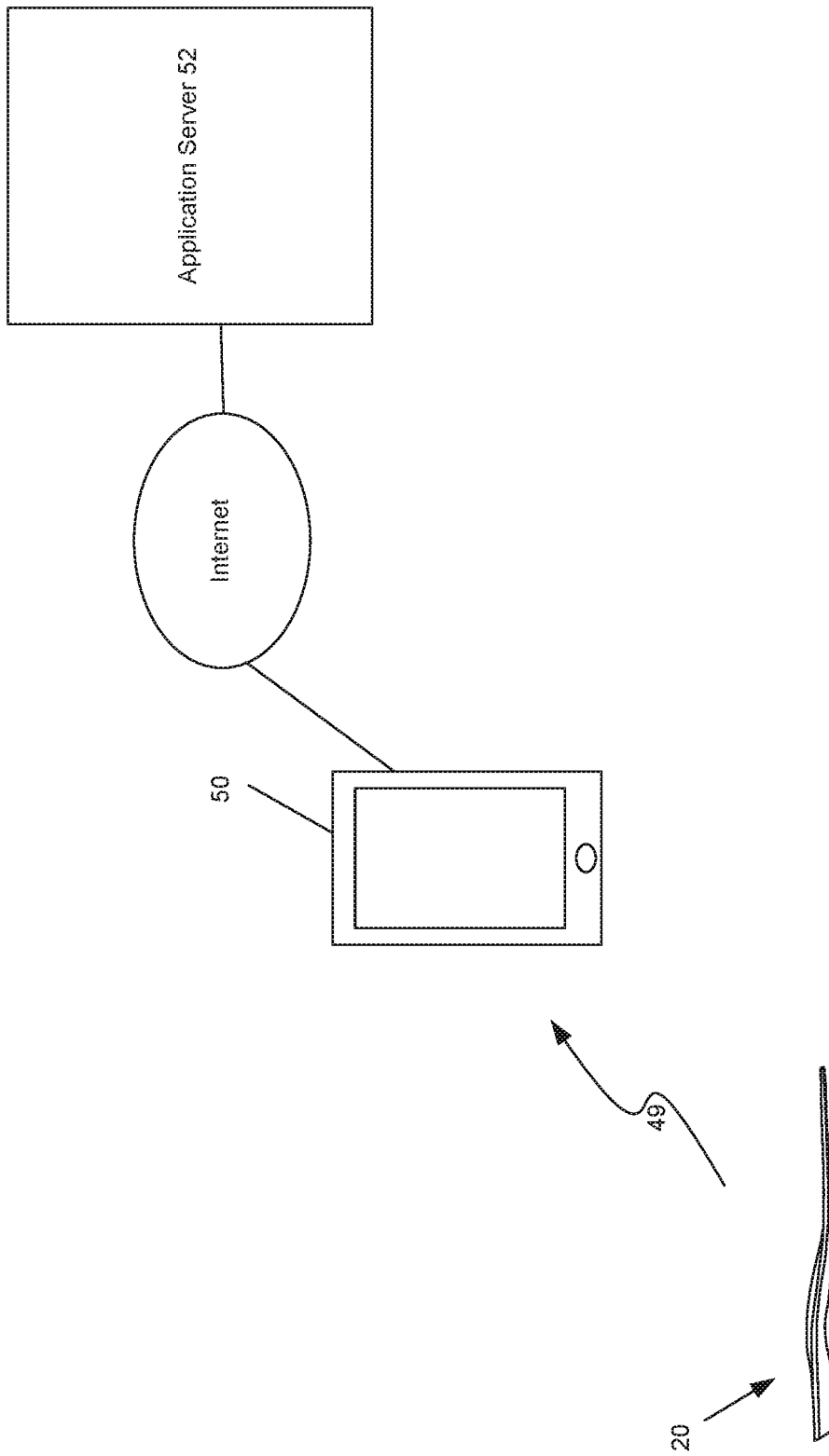


FIG. 7

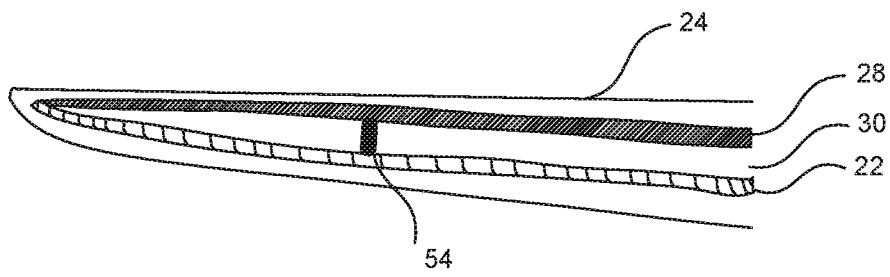


FIG. 8

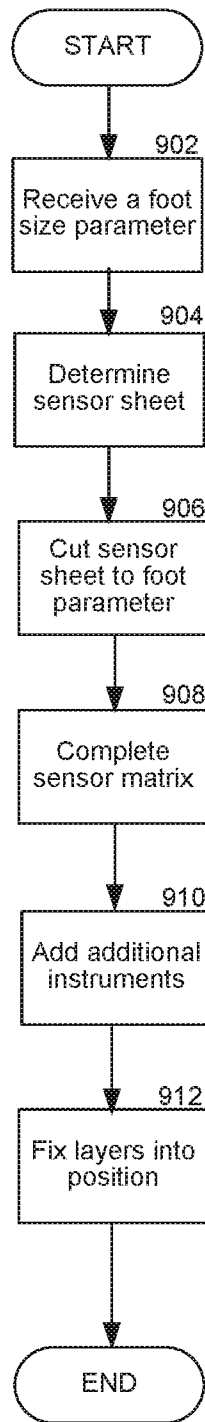


FIG. 9

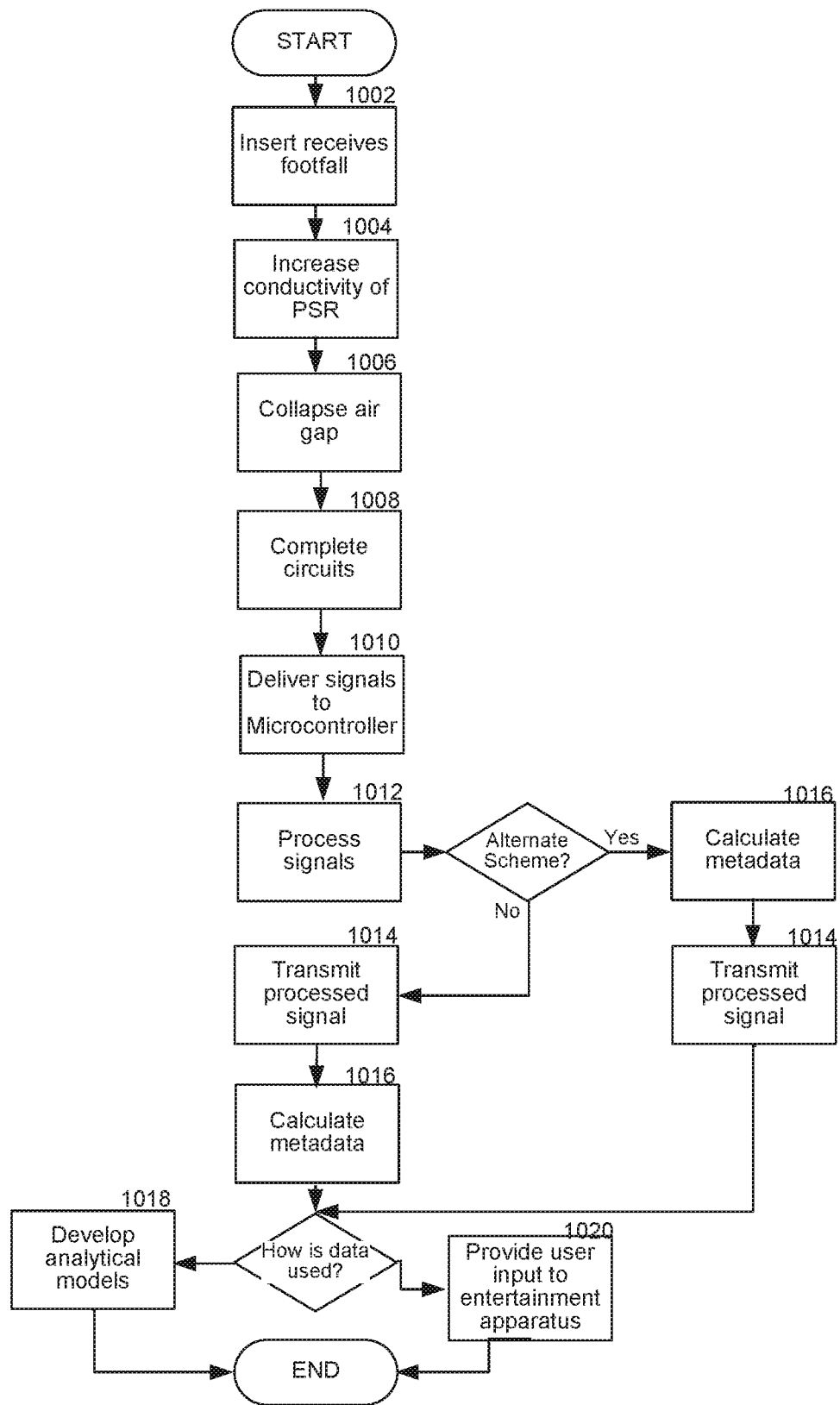


FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/045047

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
See supplemental page

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-9

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2016/045047

A. CLASSIFICATION OF SUBJECT MATTER IPC(8) - A43B 3/00; A43B 13/12; A43B 13/14; A43B 17/00; A43B 17/03; G01L 1/22 (2016.01) CPC - A43B 3/0005; A43B 13/12; A43B 13/14; A43B 17/006; A43B 17/03; G01L 1/22 (2016.11) According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC - A43B 3/00; A43B 13/12; A43B 13/14; A43B 17/00; A43B 17/03; G01L 1/22 CPC - A43B 3/00; A43B 3/0005; A43B 13/12; A43B 13/14; A43B 17/006; A43B 17/03; G01L 1/22; G01L 1/2287 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched USPC - 36/43; 36/136; 73/172; 73/862.041; 73/862.045; 340/573.100; 600/592 (keyword delimited) Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) Orbit, Google Patents, Google Scholar Search terms used: shoe, foot, insert, insole, flexible, layer, sensor, pressure, air, gap, pressure, identify, arch, multiplexer, select, load, column, select, wireless,		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	WO 2013/126751 A1 (NIKE INTERNATIONAL LTD.) 29 August 2013 (29.08.2013) entire document	1, 2, 4-9 --- 3
Y	US 5,505,072 A (OREPER) 09 April 1996 (09.04.1996) entire document	3
A	US 2002/0121146 A1 (MANARESI et al) 05 September 2002 (05.09.2002) entire document	1-9
A	US 2001/0011496 A1 (MISHIMA et al) 09 August 2001 (09.08.2001) entire document	1-9
A	US 6,195,921 B1 (TRUONG) 06 March 2001 (06.03.2001) entire document	1-9
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 11 November 2016		Date of mailing of the international search report 08 DEC 2016
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300		Authorized officer Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Continued from Box No. III Observations where unity of invention is lacking

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-9, drawn to a flexible, multi-layered insole for footwear.

Group II, claims 10-21, drawn to a footwear insert system.

Group III, claims 22-28, drawn to a method comprising: receiving a footfall on a flexible, multi-layered insole for footwear.

Group IV, claim 29, drawn to a flexible, sensor-equipped insole for footwear.

The inventions listed as Groups I, II, III or IV do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: a surface layer that binds the insole together and arranged to contact a foot of a user; cause each said one or more of the sensor pads to output a respective signal; and a microcontroller coupled to receive and process the signals received from the sensor pads as claimed therein is not present in the invention of Groups II, III or IV. The special technical feature of the Group II invention: a footwear insert shell that includes an internal volume containing the plurality of pressure switches as claimed therein is not present in the invention of Groups I, III or IV. The special technical feature of the Group III invention: completing one or more circuits between the one or more sensors and the pressure sensitive resistor layer, each completed circuit delivering a signal to a microcontroller, each signal including a unique identifier associated with each of the one or more sensors that complete the one or more circuits as claimed therein is not present in the invention of Groups I, II or IV. The special technical feature of the Group IV invention: a wireless communicator that receives microcontroller outputs and subsequently transmits said microcontroller outputs to external devices as claimed therein is not present in the invention of Groups I, II or III.

Groups I, II, III, and IV lack unity of invention because even though the inventions of these groups require the technical feature of sensor equipped footwear; a sensor layer including a plurality of sensors arranged laterally across the insole, each sensor having a unique identifier an air gap layer; pressure-sensitive resistor layer; the air gap layer configured to collapse, this technical feature is not a special technical feature as it does not make a contribution over the prior art.

Specifically, US 2001/0011496 A1 (MISHIMA et al) 09 August 2001 (09.08.2001) teaches sensor equipped footwear (Paras. 17-18); a sensor layer including a plurality of sensors arranged laterally across the insole, each sensor having a unique identifier an air gap layer (Paras. 63 and 73); pressure-sensitive resistor layer (Para. 67); the air gap layer configured to collapse (Para. 73).

Since none of the special technical features of the Group I, II, III, or IV inventions are found in more than one of the inventions, unity of invention is lacking.