US007311675B2

US 7,311,675 B2

(12) **United States Patent**
Peifer et al.

(10) **Patent No.:** US 7,311,675 B2
(45) **Date of Patent:** Dec. 25, 2007

(54) **SYSTEMS AND METHODS FOR MOBILE ACTIVITY MONITORING**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 327 days.

(21) Appl. No.: **10/732,078**

(22) Filed: **Dec. 10, 2003**

(65) **Prior Publication Data**

US 2005/0131318 A1 Jun. 16, 2005

(51) **Int. Cl.**
A61B 5/103 (2006.01)
A61B 5/117 (2006.01)
(52) **U.S. Cl.** **600/587**; 600/595
(58) **Field of Classification Search** 600/587, 600/595, 300; 128/903
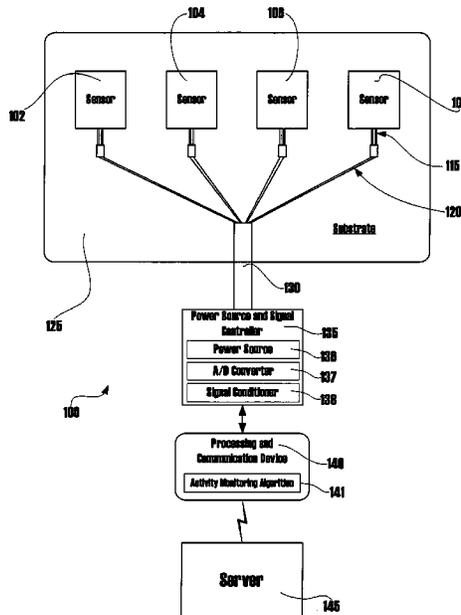See application file for complete search history.

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(57) **ABSTRACT**

Weight-shift activity is measured by small, flat, low-cost pressure sensors placed under the cushion in the seat of the wheelchair. A wireless communications device such as a Blackberry™ page processes data received from the pressure sensors and transfers the electronic records to a central database periodically or in near real-time. The information about activity and weight shift exercises is stored at the central database where it may be accessed and viewed by Internet users. Historical records of an individual's activity may be presented to the individual and authorized caregivers through secure web pages. This activity information will encourage the wheelchair user to perform regular weight shift exercises and will allow caregivers to intervene when high-risk periods of inactivity are detected.
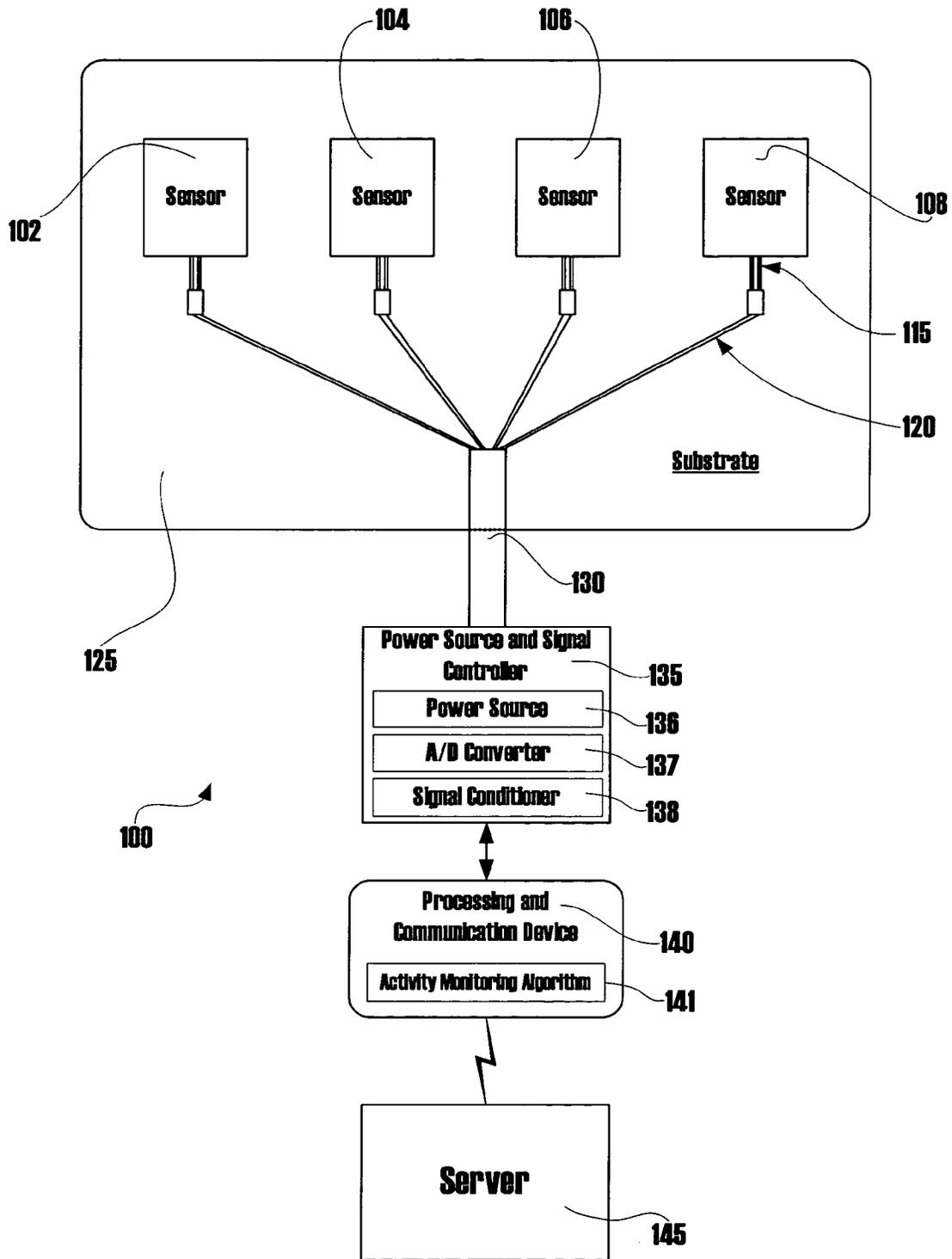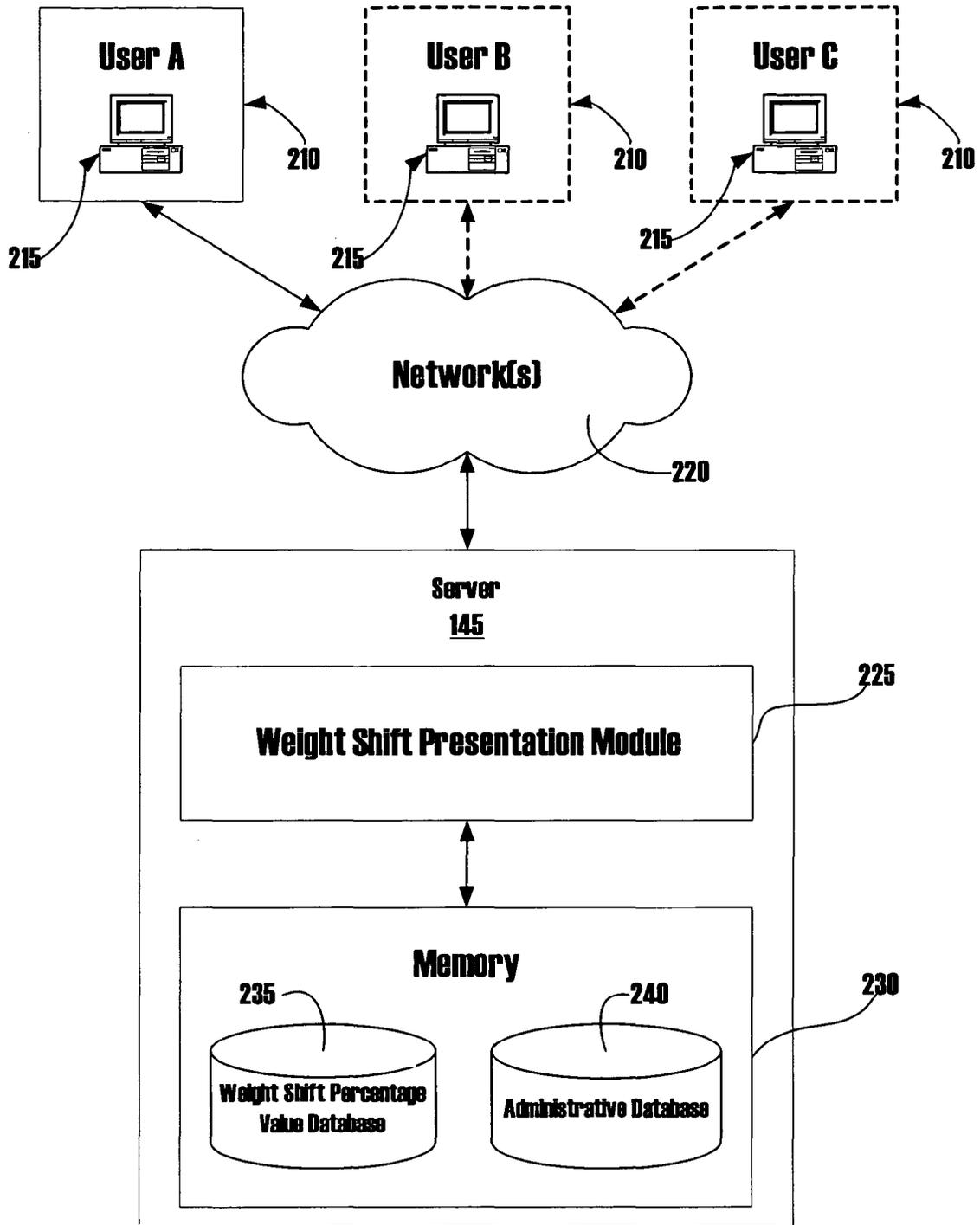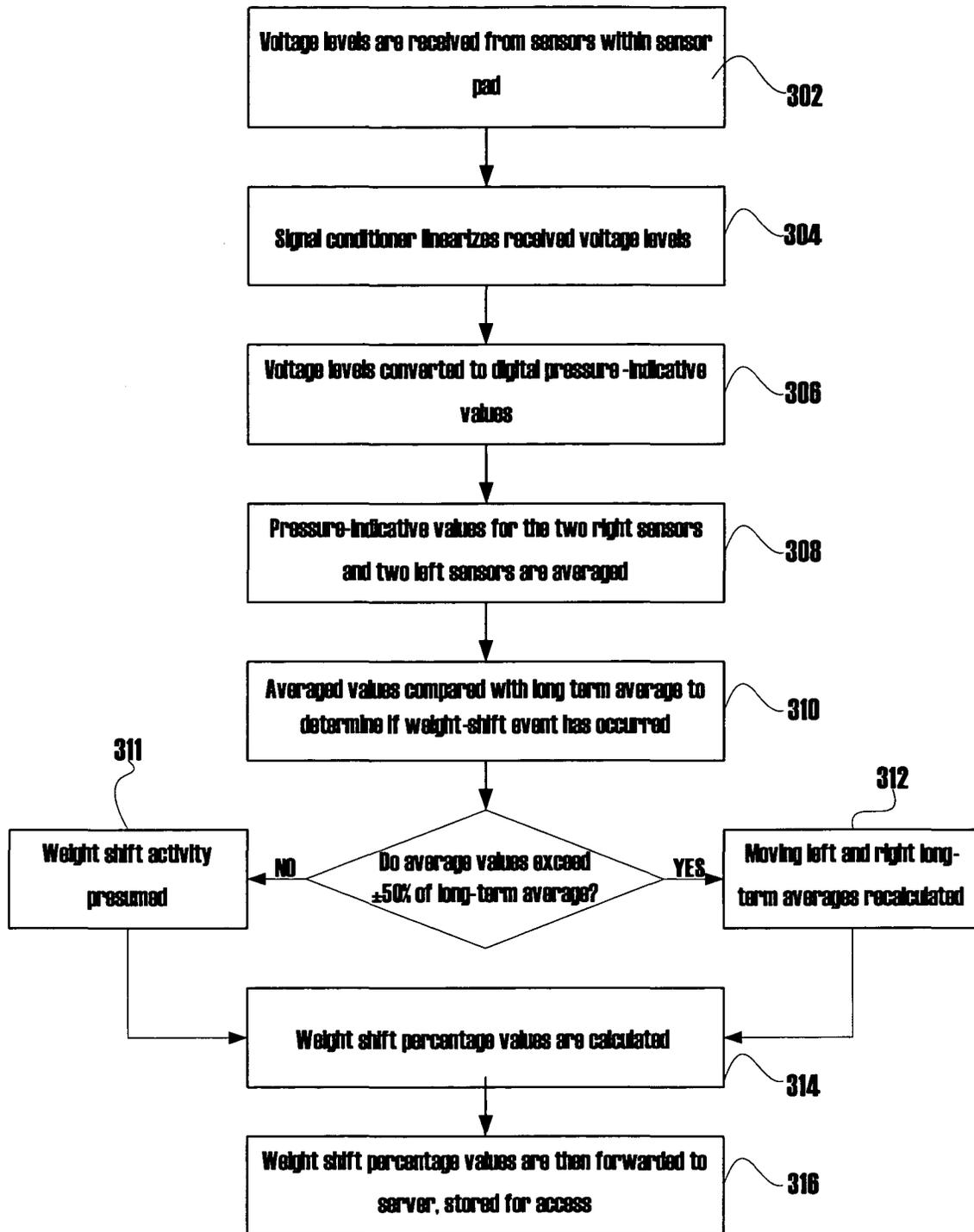
19 Claims, 6 Drawing Sheets

104

106

Sensor

Sensor

Sensor

Sensor

102

108

115

120

Substrate

125

130

Power Source and Signal Controller 135

Power Source	136
A/D Converter	137
Signal Conditioner	138

100

Processing and Communication Device 140

| Activity Monitoring Algorithm | 141 |

Server 145

FIG. 1

FIG. 2

Voltage levels are received from sensors within sensor pad — 302

Signal conditioner linearizes received voltage levels — 304

Voltage levels converted to digital pressure-indicative values — 306

Pressure-indicative values for the two right sensors and two left sensors are averaged — 308

Averaged values compared with long term average to determine if weight-shift event has occurred — 310

311

Weight shift activity presumed

312

Moving left and right long-term averages recalculated

NO ← Do average values exceed ±50% of long-term average? → YES

Weight shift percentage values are calculated — 314

Weight shift percentage values are then forwarded to server, stored for access — 316

FIG. 3

FIG. 4

FIG. 5

12

9

3

620

6

610

600

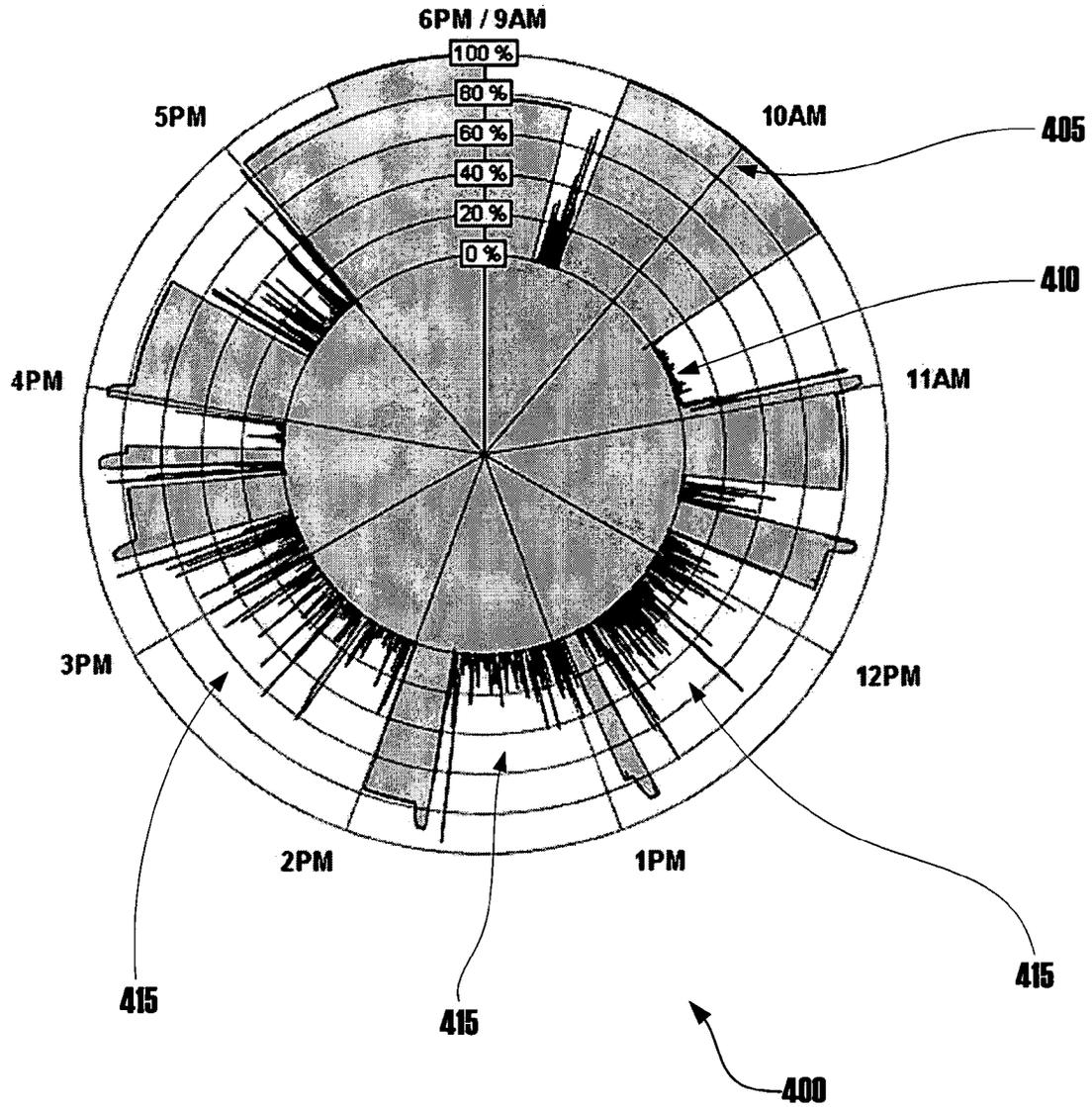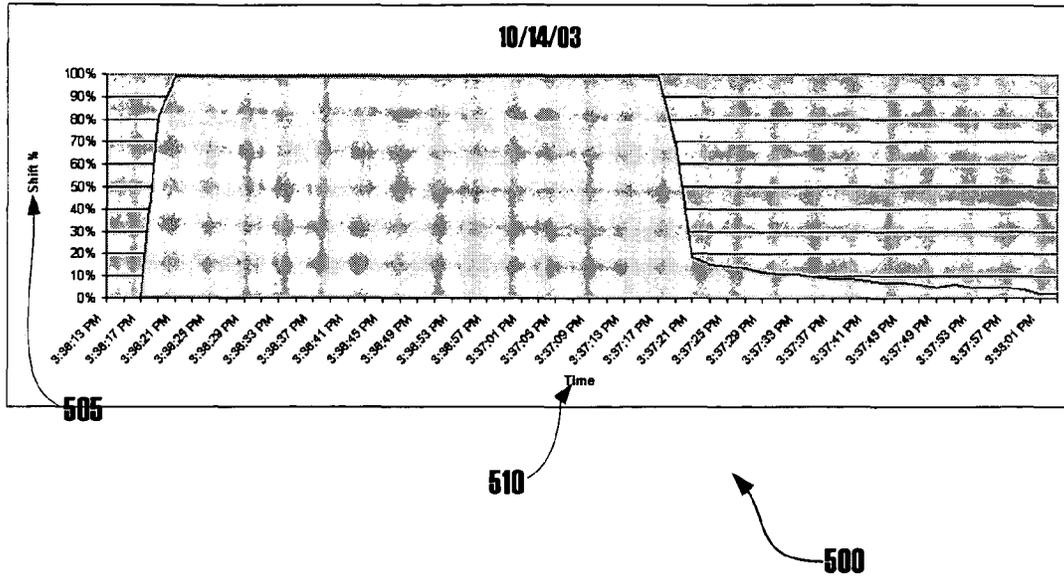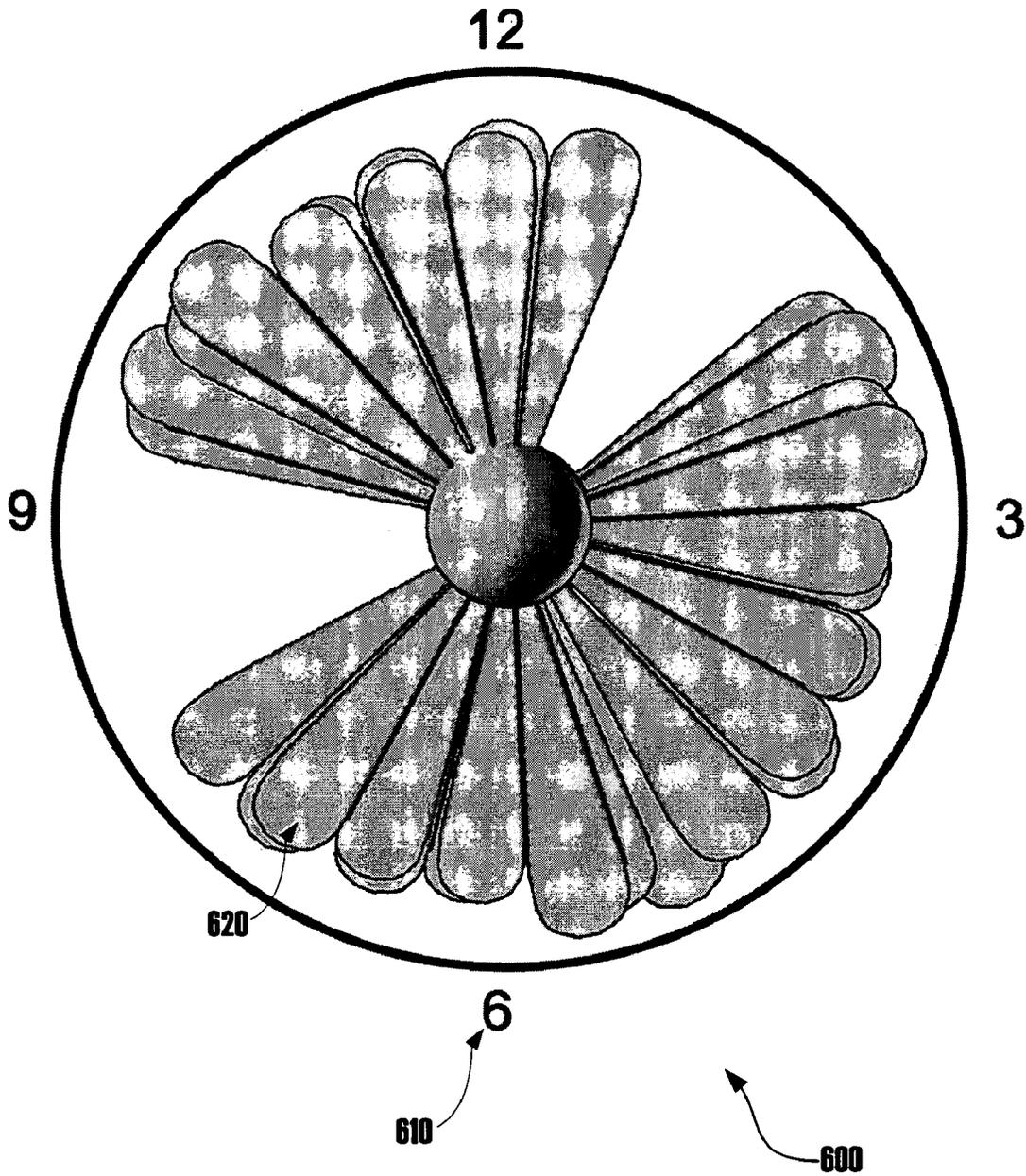**FIG. 6**

SYSTEMS AND METHODS FOR MOBILE ACTIVITY MONITORING

FIELD OF THE INVENTION

The present invention relates generally to systems and methods for mobile activity monitoring, and more particularly, to systems and methods for remotely monitoring weight-shift activity of a person seated in a wheelchair.

BACKGROUND OF THE INVENTION

When sitting for long periods of time, people must occasionally shift their weight to allow blood flow in compressed posterior tissues. Without adequate blood flow, skin problems and pressure sores can develop that lead to serious health complications. Because of their limited mobility, wheelchair users are at a greater risk to develop such sores.

One such problem, pressure ulcers, are a major public health concern that can lead to painful, life-threatening, and expensive medical complications. If severe, pressure ulcers may result in a person becoming bed-ridden. For wheelchair users, pressure ulcers can be directly attributable to the failure of a user to perform regular weight shift exercises. Weight shift exercises enable unrestricted capillary blood flow in compressed posterior tissues, and are often effective at preventing pressure ulcers and other skin problems resulting from inactivity. Unfortunately, a wheelchair user often does not realize if he or she has been stationary for extended periods of time, which may lead to sores and skin problems.

What is needed are systems and methods to enable the activity monitoring of a person seated for extended periods of time, such as wheelchair users. It would also be advantageous if such systems and methods permitted not only the wheelchair user to monitor his or her activity, but also other persons, such as physical therapists, to remotely monitor the wheelchair user's activity.

SUMMARY OF THE INVENTION

Activity monitoring systems and methods of the present invention promote healthy skin by monitoring and encouraging weight shift activity. The systems and methods of the present invention perform continuous activity measurements and use wireless data communications to provide feedback to both the wheelchair user and skin care specialists through a web-based interface.

Weight-shift activity is measured by small, flat, low-cost pressure sensors placed under the cushion in the seat of the wheelchair. A wireless communications device such as a Blackberry™ page processes data received from the pressure sensors and transfers the electronic records to a central database periodically or in near real-time. The information about activity and weight shift exercises is stored at the central database where it may be accessed and viewed by Internet users. Historical records of an individual's activity may be presented to the individual and authorized caregivers through secure web pages. This activity information encourages the wheelchair user to perform regular weight shift exercises and allows caregivers to intervene when high-risk periods of inactivity are detected.

BRIEF DESCRIPTION OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

FIG. 1 is a block diagram illustrating an exemplary system in accordance with certain exemplary embodiments of the present invention.

FIG. 2 is a block diagram of one or more users in communication with a mobile activity monitoring module, according to one embodiment of the present invention.

FIG. 3 is a block diagram flowchart showing a mobile activity reporting process, according to one embodiment of the present invention.

FIG. 4 is a polar plot illustrating the weight shift percentage of a person during various times of a day, according to an illustrative example of one embodiment of the present invention.

FIG. 5 is a graph showing a maximum shift percentage of a person during various times of a day, according to an illustrative example of one embodiment of the present invention.

FIG. 6 is a daisy plot illustrating the weight shift percentage of a person during various times of a day, according to an illustrative example of one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. The present invention may be adapted for use in a wide variety of applications and is suitable for any environment in which mobile activity monitoring is desired. By way of illustration and not by way of limitation, unless indicated otherwise, the preferred embodiment is presented in the context of a system and method in which weight-shift activity of a person seated in a wheelchair is monitored. This invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

FIG. 1 shows a block diagram illustrating an exemplary system 100 in accordance with certain exemplary embodiments of the present invention. As shown, the system 100 includes a substrate 125, a power source and signal controller 135, a processing and communication device 140, and a server 145. Attached to the substrate 125 are a plurality of sensors 102, 104, 106, 108 forming a sensor array. The sensors 102, 104, 106, 108 are each operable to transmit signals that indicate the pressure or force applied to each sensor 102, 104, 106, 108, as is known in the art. According to one aspect of the present invention, the sensors 102, 104, 106, 108 are placed in the seat, or within a cushion, underneath a seated person to monitor the amount of movement or activity of that person.

According to a preferred embodiment of the present invention, the sensors 102, 104, 106, 108 may be force sensing resistors (FSRs) that are polymer-thick film (PTF) devices that exhibit a decrease in resistance with an increase in the force applied to the active surface. When pressure is applied to the sensors 102, 104, 106, 108, the output voltage of the sensors 102, 104, 106, 108 increases due to the decrease in resistance of the FSRs with the application of pressure. Therefore, the monitoring of the voltage output of the sensors 102, 104, 106, 108 permits the system to effectively monitor the pressure applied to the respective sensors 102, 104, 106, 108. It should be appreciated that

although FSRs are preferred and used as the sensors **102**, **104**, **106**, **108** in the embodiments described herein, the sensors **102**, **104**, **106**, **108** may also be capacitive sensors or piezoelectric pressure sensors, as are known in the art.

As illustrated in FIG. **1**, each sensor **102**, **104**, **106**, **108** may include two leads **115**, which are in respective communication with two wires **120** in electrical communication with the power source and signal controller **135** for providing a continuous, low voltage source to each sensor **102**, **104**, **106**, **108**. According to one embodiment of the present invention, the sensors **102**, **104**, **106**, **108** are Series **400** FSRs manufactured by Interlink™ having an active sensor area of 1.5" by 1.5" and a thickness of less than 0.5 mm. It will be appreciated that the FSRs may not provide a precise measure of force and variations between sensors may be as much as ±5 to 25%. A variety of external factors, such as bending and temperature, may also contribute to variability in FSR measurements.

To reduce variances in due to external factors such as bending and temperature fluctuations, the sensors **102**, **104**, **106**, **108** are mounted on a flat substrate **125**. The substrate **125** is preferably semi-rigid or rigid so as to prevent bending of the sensors **102**, **104**, **106**, **108**. According to one aspect of the invention, the substrate **125** is constructed of plastic and can lay flat in the seat of a wheelchair underneath the wheelchair's cushion. It will be appreciated that although the substrate **125** may reduce some variability in the sensors' measurements, some variability may remain. However, the variability will have little effect on the present invention, as precise pressures are unnecessary to measure activity resulting from short-term (e.g., seconds and minutes) changes in pressure, as will be explained in further detail below.

As shown in the embodiment of FIG. **1**, the four sensors **102**, **104**, **106**, **108** are mounted in a line on the substrate **125** having a approximate dimensions of 8.5 inches by 14 inches, where the sensors **102**, **104**, **106**, **108** are mounted 1.5" from the back edge of the substrate **125** and are evenly spaced along the length of the substrate **125**. According to one aspect of the invention, the semi-rigid substrate **125** may be encased between two layers of rubber sheeting (not illustrated) approximately 0.5 mm thick, where the relatively thin rubber sheeting protects the wires **120** connected to the sensors **102**, **104**, **106**, **108** and provides the sensors **102**, **104**, **106**, **108** protection from moisture, abrasion and sharp impacts. Other materials may be used for the encasing, including, e.g., plastic or metal.

Collectively, the sensors **102**, **104**, **106**, **108** (including respective leads **115** and wires **120**), substrate **125**, and encasing materials are referred to hereinafter as a sensor pad. According to one embodiment of the present invention, the sensor pad is completely sealed except for a ribbon cable **130** that connects the sensors **102**, **104**, **106**, **108** and substrate **125** to the power source and signal controller **135**. According to one aspect of the invention, the bottom of the sensor pad may include Velcro™ or a double sided adhesive material to allow the sensor pad to be attached to or integrated with the seats of a variety of different wheelchairs.

The sensor configuration illustrated in FIG. **1** may be suited for placement in air cushions as well as foam cushions that are flexible. It will be appreciated that cushions having a rigid base may require a different sensor configuration that sits between the rigid basin and a gel cushion. Nevertheless, the sensor pad should generally be positioned in the center of a wheelchair below the ischial tuburosities of the wheelchair user. It should also be appreciated that the system **100** is designed to accommodate a variety of sensor configura-

tions so as to provide for accurate measurements of pressure over a variety of geometries. For instance, where the system **100** of the present invention is used to monitor the activity of a person seated in a wheelchair, additional sensors may be used to more accurately monitor a person's activity. As an example, additional sensors, such as eight sensors in a 4 by 2 grid, may be advantageous for large seating areas. Other configurations, as appreciated by those of skill in the art, may also be possible.

Referring once again to FIG. **1**, the system **100** is powered by the power source and signal controller **135**, and more particularly, the power source **136**, which provides power to the sensors **102**, **104**, **106**, **108** and to the A/D converter **137** and signal conditioner **138** within the power source and signal controller **135**. According to one embodiment of the invention, the power source **136** may comprise a stack of twelve (12) 1.5 Volt C cell batteries providing approximately 1 mA of current, although other power sources, such as batteries, known to those of skill in the art may also be used. It is preferred that the power source **136** provide power to the system **100** components for extended periods of time to reduce the need to recharge or change the power source **136**.

According to one aspect of the invention, one or more voltage regulators (not illustrated) may also be placed within the power source and signal controller **135**, such as in the signal conditioner **138**, where the voltage regulators are operable to reduce power supplies to appropriate levels (e.g., to +1.25 VDC, −1.25 VDC) to keep a relatively low current level through the sensors **102**, **104**, **106**, **108**. For instance, where FSRs are used, one or more voltage regulators may be necessary to reduce power supplies to appropriate levels when the resistance of the FSRs decrease as a result of the application of force to the FSRs.

The A/D converter **137** receives analog voltage signals from each of the sensors **102**, **104**, **106**, **108** and converts them to digital form. The resulting digital signals are digital pressure-indicative values. As described above, because the resistance of the sensors **102**, **104**, **106**, **108** drops with applied pressure, for instance, from a seated person's posterior, lower resistance will result in lower voltages. Therefore, the analog values converted by the A/D converter **137** may be a measure of the voltage of each sensor, which indicates the pressure placed on each sensor where the input voltage remains constant. Prior to digitization, the measure of voltage may undergo a linearization operation, as is explained below. It will be appreciated that other related analog values, such as resistance, may also be used by the system **100** as analog pressure-indicative signals to determine the relative pressure placed on each sensor at anytime.

According to one embodiment of the present invention, the A/D converter **137** may be a DATAQ™ serial 8-bit A/D converter that requires +9 VDC and −9 VDC for operation. This power may be supplied by the power source **136**. Additionally, the signal conditioner **138** may include signal conditioning electronics that include a circuit board having op-amp linearization circuitry, as is known to those of skill in the art. This may be advantageous where the sensors, such as FSRs, have non-linear response to pressure. The linearization therefore allows the resulting digitized pressure-indicative values to be linear rather than correcting a non-linear sensor response elsewhere in the system **100**. Nevertheless, it will be appreciated that the linearization of analog measurements of digitized values may occur elsewhere in the system **100**.

The digital pressure-indicative values are collected by the system **100** and forwarded by the power source **136** and signal controller **135** to the processing and communication

device **140** at a rate of approximately four samples per second, where a sample includes a pressure-indicative value for each of the four sensors **102**, **104**, **106**, **108**. The processing and communication device **140** may include a wireless page, such as a Blackberry™ device, which is operable to communicate wirelessly with the server **145**. According to an alternative embodiment of the present invention, the processing and communication device **140** may also comprise a laptop, tablet PC, personal digital assistant, or mobile phone. The processing and communication device **140** is preferably operable to process the pressure-indicative values received from the A/D converter **137** according to an activity monitoring algorithm **141** stored thereon. The activity monitoring algorithm **141** is operable to identify weight shift events based on the pressure-indicative values received from the power source and signal controller **135**.

The activity monitoring algorithm **141** includes computer program instructions may be loaded onto the processing and communication device **140**, which may be a general purpose computer, special purpose computer, or other programmable data processing apparatus, where the instructions which execute on the computers or other programmable data processing apparatus create means for implementing the functions described herein. Such computer program instructions may also be stored in a computer-readable memory that can direct the processing and communication device **140** to function in a particular manner. Further, the methods described herein may be embodied as a data processing system or a computer program product on a computer-readable storage medium having computer-readable program code means embodied in the storage medium. Any suitable computer-readable storage medium may be utilized including hard disks, CD-ROMs, DVDs, optical storage devices, or magnetic storage devices. Accordingly, the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment combining software and hardware aspects, such as firmware. According to a preferred embodiment, the methods described herein are implemented by a wireless processing and communication device **140** embodied as a Blackberry™ page.

According to one embodiment of the present invention, the activity monitoring algorithm **141** averages the two left sensor pressure-indicative values (e.g., from sensors **102**, **104**) for each sample. The two right sensor pressure-indicative values (e.g., from sensors **106**, **108**) for each sample are also averaged together by the activity monitoring algorithm **141**. The left and right averages are collected and stored by the processing and communication device **140** in a memory (not illustrated).

The right and left averaged pressure-indicative values are used to calculate a long term moving average used to estimate the pressure state in which an individual is seated normally without performing a shift. It will be appreciated that because a seated individual can adjust weight distribution through a wide range of movements that may or may not be associated with a weight shift event (also referred herein to a weight shift activity), it is difficult to detect what should be considered an upright and still state in all situations and environments. Therefore, the upright and still state is measured by pressure-indicative values taken in situations where the individual is seated (i.e., exerting pressure on the sensor pad) but not moving enough to register as a weight shift activity. The activity monitoring algorithm **141** therefore uses the long-term moving average as a means of approximately tracking the user's weight in a normal sitting posi-

tion. This average is then used by the activity monitoring algorithm **141** to compare against continuously measured pressure-indicative values to determine when a weight shift event has taken place.

According to methods of the present invention, the system **100** attempts to detect weight shift events so that pressure-indicative values during these events can be excluded from the normal sitting long-term average. For instance, if a user executes a full shift in body weight, the activity monitoring algorithm **141** will detect a significant change in pressure for more than, e.g., a few seconds, and will not include sensor data during that event in the long-term moving average. Therefore, by using a long-term moving average, the system **100** accommodates for sensor drift and slowly changing seating posture.

For instance, if the activity monitoring algorithm **141** detects a relative change in either the left or right moving average of 50% or greater then the algorithm **141** may halt updates to the long term moving average of both the left and right pressure-indicative values. Other percentages may be used to signify a weight shift activity, although 50% or approximately 50% is preferred. It will be appreciated that a very gradual change in sensor values over the course of an hour will not trigger a 50% shift. Therefore, the halting of updates, which may also be referred to as a shift trigger, allows a seated individual to complete an activity such as a weight shift and then return to their resting seating behavior without skewing the long-term averages. A time limit of, e.g., 90 seconds is placed on the duration in which moving average updates may be halted. After this period of time, the algorithm **141** will begin to allow moving average updates. This approach allows the algorithm **141** to recover from borderline conditions that might keep the algorithm **141** in a state that consistently overestimates weight shift percentage values.

The activity monitoring algorithm **141** constantly examines recently measured left and right average pressure-indicative values to identify relative changes in those values to identify potential weight shift events. The average pressure-indicative values for each side, right and left, are continuously monitored for changes, and are compared to the corresponding long-term moving averages for each side by the algorithm **141**. More specifically, the algorithm **141** calculates the difference between the average pressure-indicative value for each side by the moving average for each respective side. The algorithm **141** then normalizes the results of these comparisons to create weight shift percentage values ranging from 0 to 100%. To normalize the changes in average pressure-indicative values for each side, the algorithm **141** divides the computed differences by the difference between long-term moving average (representing full weight on the sensors during normal sitting) and the maximum observed sensor value (representing no weight on the sensors). Therefore, the normalization process maps sensor values to a 0 to 1 scale, where the sensor values when no weight is placed on a monitored chair represent one end of the scale, and the long-term sensor average with full weight in the normal sitting position represent the other end of the scale.

Because the algorithm **141** normalizes the left and right average pressure-indicative values, weight shift percentage values may be computed and reported as activity, where the weight shift percentage values represent a ratio of the pressure-indicative values to the long term moving average. This may occur in real-time, or routinely, such that weight shift percentage values for each previous ten-minute span are reported together. According to another aspect of the

invention, weight shift percentage values may only be reported where there is a change in the weight shift percentage values.

Specifically, the weight shift percentage values describe the degree to which force is added or removed from the sensors related to weight changes in the seat. A weight shift percentage value of 0% describes a condition where the user is sitting stationary, and a weight shift percentage value of 100% describes the condition where the user is fully removed from the seat or shifts his or her weight fully off of one side of the seat. Although the moving average can occasionally produce weight shift percentage values above 100 and below 0, the reported shift percentage values may be held by the activity monitoring algorithm **141** to a floor and ceiling of 0% and 100% respectively.

As noted above, the activity monitoring algorithm **141** is executed on the processing and communication device **140**, where a preferred processing and communication device **140** is a wireless Blackberry™ page. Because the processing and communication device **140** is operable to transmit information wirelessly, the processing and communication device **140** can wirelessly transmit weight shift percentages to a remote location. According to the preferred embodiment the page may package the algorithm-generated weight-shift percentage values into emails sent to the server **145**, after which the server **145** may parse the email and insert the weight shift percentage values into a Structured Query Language (SQL) database that may be accessed by authorized users over the Internet. It will be appreciated that each weight-shift percentage value is recorded and emailed with a time stamp indicating when the weight-shift percentage value was recorded. Additionally, the server **145** may send a receipt to the page to notify that the data has been successfully received so that upon receipt of the notification the page can delete old data. If the notification receipt is not received in a timely fashion, the page may resend the data after a predetermined amount of time, such as 5 minutes. This technique ensures that no data is lost except in the case of filling up all memory on the processing and communication device **140** or a general hardware failure.

It will be appreciated that although the processing and communication device **140** is illustrated as a single component in FIG. **1**, the activity monitoring algorithm **141** and associated processing hardware may be located external to the device. For instance, the activity monitoring algorithm **141** may be positioned in the power source and signal controller **135**, such that the processing and communication device only functions to forward weight shift percentage values to a remote location. Similarly, the power source **136**, A/D converter **137** and signal conditioner **138** may be independent hardware components that are not local to each other or disposed within a single device such as the power source and signal controller **135**.

It will be appreciated that the system **100** of the present invention does not need to measure actual seat pressures in known units of force. The system only uses the pressure-indicative values received from the power source and signal controller **135** to determine weight shift percentage values, which are reported as activity. As a result, the system **100** does not need to be calibrated to an individual seating condition (weight, position, posture). Furthermore, the variations of different cushions in which the sensor pad may be placed will have no affect on the system and method of the present invention, although differing cushions and locations of the sensor pad may result in varying degrees of spreading and absorbing of the forces exerted by the user's weight. The advantage of the normalizing approach is that

the system **100** will effectively identify weight shift activity in a variety of conditions including variability in the cushions, actual user weight and weight distribution, ambient temperature, barometric pressure, battery voltage, etc. The system **100** can detect both long periods of inactivity, and any type of movement reported as an activity.

Using the systems and methods of the present invention both wheelchair users and caregivers can monitor the activity data. FIG. **2** shows a plurality of users **210** in communication with the server **145** via one or more networks **220**, such as a LAN, or a WAN such as the Internet. The users communicate with the server **145** via a computer **215** associated with each user. Therefore, the users **210** may monitor the weight shift activity of a person remotely, and in the preferred embodiment, from any computer with Internet access to the server **145**. According to one aspect of the present invention, the users may be the person whose activity is being monitored, a physical therapist, doctor, family member, or any other individual who may wish to monitor the weight shift activity of a seated person.

As noted above, weight shift percentage values are stored by the server **145**, such as in a weight shift percentage values database **235** within the server's memory **230**. This database **235** may be a SQL database, as is known in the art, and may store the weight shift percentage values for a length of time, such as a week or month, such that historical weight shift activity data is maintained. The users **210** may view the weight shift percentage values within the database **235** using the weight shift presentation module **225**, which is a program that permits the uses **210** to access and view a graphical display of the weight shift percentage values for a monitored person over a period of time such as a day. Like the activity monitoring algorithm **141**, the weight shift presentation module **225** may be implemented by computer program instructions executed in conjunction with a processor and computer program instructions of the server **145**.

As described with respect to FIGS. **4** and **5** below, the weight shift presentation module **225** of the present invention may present the weight shift percentage values for a particular monitored person using one or more graphical presentations, including activity graphs in polar, bar and/or line form. These values may also be presented in non-graphical form, such as in a table of values. Because each weight-shift percentage value is received from the processing and communication device **140** with a time and date stamp identifying the time and date the values were calculated, the weight shift presentation module **225** can provide detailed information on a person's activity during specific times of a day.

According to another aspect of the invention, access to the weight shift percentage values may be permitted by the weight shift presentation module **225** only after a user **210** has logged in using an established user-id and password, to prevent unauthorized access to the weight shift percentage values of a particular person. Furthermore, each user may have varying rights to view data. For instance, a person being monitored may only be able to view graphs representing recent weight shift activity, whereas a physical therapist or system administrator may be able to access all historical weight shift percentage values for a particular monitored person. Furthermore, the user-id and password may be used to identify persons with rights to access an administrative database **240**, which may be used to store user accounts and other administrative information for operating the server **145**.

Next, FIG. **3** shows a block diagram flowchart showing a mobile activity reporting process, according to an illustra-

tive embodiment of the present invention. First, voltage levels are received (block **302**) from the sensors **102**, **104**, **106**, **108** within the sensor pad, which is placed within a cushion on which a person is seated. The signal conditioner **138** may then linearize the voltage levels (block **304**), which are then converted to digital pressure-indicative values by the A/D converter **137** (block **306**). The pressure-indicative values for the two right sensors and two left sensors are averaged (block **308**), respectively, and are then compared the long term average of these values to determine if a weight-shift event has occurred (block **310**). If the newly measured average values represent a relative change in either the left or right moving average of 50%, a weight shift activity is presumed to have taken place and the newly measured average values are not used to recalculate the moving average (block **311**). On the other hand, if the newly measured average values do not represent a significant change, the values are used to recalculate the moving left and right long-term averages (block **312**). Next, weight shift percentage values are calculated using the long-term average (block **314**). The weight shift percentage values are then forwarded to the server, where they are stored for access by one or more users via graphical interfaces (block **316**).

FIG. **4** shows a polar plot **400** illustrating the weight shift activity of a person during various times of a day, according to an illustrative example of one embodiment of the present invention. The polar plot **400** may be generated by the weight shift presentation module **225** illustrated in FIG. **2**, and may be presented to one or more users in remote or local communication with the server **145**. Therefore, the polar plot **400** may be made available to both wheelchair users and caregivers. According to one embodiment of the invention, the monitored time presented on the plot **400** may be configurable by viewers using simple and intuitive user interfaces.

The polar plot **400** is intended to present a quick overview of seating activity over the course of a day. As illustrated in the polar plot in FIG. **4**, long periods of inactivity and the times at which these occur can be easily identified. For instance, at approximately 10 am **405**, the person is removed from his or her seat, where as at approximately 10:45 am **410** the user is in the seat and not moving. The spikes in the polar graph **415** illustrate times when the weight shift percentage values fluctuate, illustrating movement or activity of the person in the seat.

The weight shift presentation module **225** may also present a caregiver a more detailed look at the weight shift activity in the form of spreadsheet-formatted data, which may permit the caregiver to examine subtler changes weight shift activity. For instance, as shown in FIG. **5**, weight shift percentage values **505** graphed with respect to time **510**, such as every 4 seconds, may be monitored by a caregiver using a shaded line graph **500**.

Yet another graphical display of weight shift activity generated by the weight shift presentation module **225** is illustrated in FIG. **6**, according to an illustrative example of the present invention. FIG. **6** shows a daisy plot **600**, which is a simple graphical display that allows a user to quickly ascertain periods of inactivity. The daisy plot **600** includes a plurality of the petals **620** having various petal lengths, where the petals **620** represent activity and the petal lengths represent the amount of weight shift activity, or the weight shift percentage value, for a particular time of day. Missing petals represent inactivity. The daisy plot **600** preferably includes times **610** to identify when periods of activity and inactivity take place, and the daisy plot **600** may correspond to a 12 hour time period or a 24 hour day.

A healthy daisy plot would show full petals throughout the day. When petals are short or missing, a user can tell at a glance when period of low activity are occurring. Because of the simple nature of the daisy plot **600**, it may be advantageous for presenting to a non-technical wheelchair user to quickly identify healthy activity patterns and at risk periods of inactivity. Therefore, in viewing the daisy plot **600** the wheelchair user can receive feedback on his or her weight shift activity to encourage regular weight shifts.

Additional features of the present invention may include the reporting and monitoring of individual sensors, rather than composite weight shift percentage values. Furthermore, the present invention may be used to monitor other activity, such as activities of infants in an ICU, patients in a hospital or nursing home bed, or other environments in which activity monitoring may be useful.

Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

That which is claimed:

1. A system for activity monitoring, comprising:
   a sensor array comprising at least one sensor, wherein the sensor array transmits at least one analog signal indicative of the pressure applied to the at least one sensor;
   an analog-to-digital (A/D) converter, wherein the A/D converter receives the at least one analog signal and generates at least one digital signal indicative of the pressure applied to the at least one sensor;
   a processing device, in communication with the A/D converter, wherein the processing device:
      receives the at least one digital signal indicative of the pressure applied to the at least one sensor;
      converts the at least one digital signal into at least one pressure-indicative value;
      determines if a weight shift occurs at least in part by determining a difference between the at least one pressure-indicative value and at least one moving average of pressure-indicative values; and
      generates a weight shift percentage value, wherein the weight shift percentage value is based at least in part on the determined difference; and
      communicates the weight shift percentage value to a server in wireless communication with the processing device.

2. The system of claim **1**, wherein the server presents the weight shift percentage value to at least one user via a graphical display.

3. The system of claim **1**, wherein the processing device communicates the weight shift percentage value to the server via email.

4. The system of claim **1**, wherein the processing device is a wireless page.

5. The system of claim **1**, wherein the processing device generates the weight shift percentage value based at least in part on a normalization of the determined difference.

6. The system of claim **1**, wherein the processing device recalculates the at least one moving average of pressure-indicative values using the at least one pressure-indicative value.

7. The system of claim **6**, wherein the processing device does not recalculate the at least one moving average of pressure-indicative values if a weight shift occurs.

8. The system of claim **1**, wherein the sensor array is placed on a semi-rigid sensor substrate.

9. The system of claim **8**, wherein the semi-rigid sensor substrate is encased in at least two layers of encasing material.

10. The system of claim **9**, wherein the encasing material comprises rubber.

11. A system for activity monitoring, comprising:

a sensor array comprising at least one sensor, wherein the sensor array transmits at least one analog signal indicative of the pressure applied to the at least one sensor;

an analog-to-digital (A/D) converter, wherein the A/D converter receives the at least one analog signal and generates at least one digital signal indicative of the pressure applied to the at least one sensor;

a processing device, in communication with the A/D converter, wherein the processing device:

receives the at least one digital signal indicative of the pressure applied to the at least one sensor;

converts the at least one digital signal into at least one pressure-indicative value;

determines if a weight shift occurs at least in part by determining a difference between the at least one pressure-indicative value and at least one moving average of pressure-indicative values; and

generates a weight shift percentage value, wherein the weight shift percentage value is calculated at least in part by a normalization of the determined difference; and

a communication device in wireless communication with a server, wherein the communication device communicates the weight shift percentage value to the server.

12. The system of claim **11**, wherein the server presents the weight shift percentage value to at least one user via a graphical display.

13. The system of claim **11**, wherein the processing device communicates the weight shift percentage value to the server via email.

14. The system of claim **11**, wherein the processing device is a wireless page.

15. The system of claim **11**, wherein the processing device recalculates the at least one moving average of pressure-indicative values using the at least one pressure-indicative value.

16. The system of claim **15**, wherein the processing device does not recalculate the at least one moving average of pressure-indicative values if a weight shift occurs.

17. The system of claim **11**, wherein the sensor array is placed on a semi-rigid sensor substrate.

18. The system of claim **17**, wherein the semi-rigid sensor substrate is encased in at least two layers of encasing material.

19. The system of claim **18**, wherein the encasing material comprises rubber.

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