



(43) International Publication Date
9 October 2014 (09.10.2014)

- (51) International Patent Classification:
G08B 21/02 (2006.01) *G01L 1/00* (2006.01)
- (21) International Application Number:
PCT/US2014/033034
- (22) International Filing Date:
4 April 2014 (04.04.2014)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
13/858,017 6 April 2013 (06.04.2013) US
- (72) Inventor; and
- (71) Applicant : SHINOZUKA, Kenneth, Feng [US/US]; 80
Riverside Boulevard, Apt. 20D, New York, NY 10069
(US).
- (74) Agents: YIN, Bu et al.; Morrison & Foerster LLP, 12531
High Bluff Drive, Suite 100, San Diego, CA 92130-2040
(US).
- (81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME,
MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ,
OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA,
SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM,
TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM,
ZW.

- (84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ,
UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,
EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished
upon receipt of that report (Rule 48.2(g))*

(54) Title: APPARATUS AND METHOD FOR MONITORING BED-DEPARTURE AND WALKING

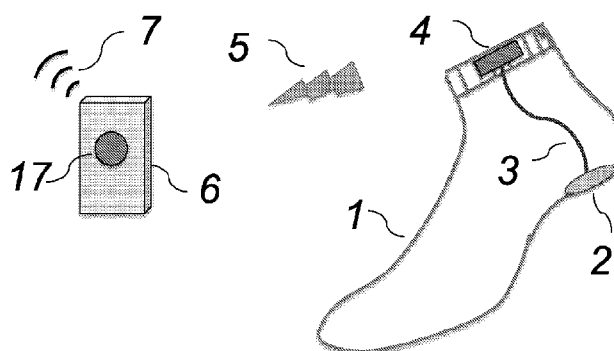


FIG. 7

(57) Abstract: In one aspect, the present disclosure relates to a method and apparatus for low-cost detection and alerting of bed-departure, which causes significant stress to caretakers of patients who often wander out of bed as a result of their dementia, Alzheimer's disease, or other medical conditions. In one aspect, the apparatus comprises a sock embedded with a pressure sensor and a battery-powered microcontroller unit with a radio frequency module. Once the user wanders out of bed and steps onto the floor, the sensor on the sock will immediately detect the pressure caused by his or her body weight and wirelessly trigger an audible sound at a caretaker's monitoring unit, which can be a smart phone, tablet, or PC. In one aspect, the sensor and the microcontroller unit can be packaged in one assembly to be mounted on an ordinary sock, slipper, or shoe. The apparatus also accurately counts steps and measures the time interval between them. In one aspect, the pressure sensor and/or the sensor/microcontroller unit assembly can adhere to a foot.



APPARATUS AND METHOD FOR MONITORING BED-DEPARTURE AND WALKING

Related Applications

[0001] This application claims priority to United States Patent Application Serial No. 13/858,017, filed on April 6, 2013, and Japanese Patent Application No. 2013-154805, filed July 25, 2013, the contents of which are incorporated by reference herein for all purposes.

Technical Field

[0002] In some embodiments, the present disclosure relates to methods and apparatuses for detecting and alerting patients' bed-departure using a pressure sensor and a microcontroller unit, for example, embedded in a sock, slipper, or shoe, or affixed to a foot, to trigger an alert on a caretaker's monitoring unit, for example, a cell phone, a smartphone, a PC, or a tablet.

Background

[0003] The population of seniors who suffer from Alzheimer's, dementia, and other medical conditions has increased in recent years. Their frequent accidents and injuries as a result of wandering out of bed, particularly when happening at night, cause significant stress to their caretakers at home as well as those in hospitals and nursing facilities. There is an increasing need for detecting and alerting of such bed departures to protect the safety of these patients and reduce the stress of their caretakers.

Summary

[0004] In one aspect, the present disclosure provides a simple method and a low-cost apparatus to detect and alert the bed-departure of wandering patients who suffer from Alzheimer's, dementia, or other medical conditions.

[0005] In one embodiment, the apparatus comprises a pressure sensor embedded in a sock, a battery-powered microcontroller unit mounted on the sock, and a separate monitoring

unit. The microcontroller unit continuously acquires an output signal from the pressure sensor at a predetermined time interval and compares the sensor signal with a predetermined threshold. Once the sock user wanders out of bed and steps onto the floor, his or her body weight will exert pressure on the sock, causing the sensor output signal to exceed the predetermined threshold. In response, the microcontroller unit immediately issues an alert by transmitting a radio-frequency signal to the caretaker's monitoring unit, such as a smartphone, a PC, a tablet, or a custom-made monitor. This signal triggers an audible sound out of the monitoring unit. The time of the alert is recorded into a database in the monitoring unit for the patent long-term health monitoring and care usages.

[0006] In another embodiment, the sensor and the microcontroller unit is packaged into one removable and re-mountable assembly to be mounted on an ordinary sock, slipper, or shoe. In other embodiments, the removable and re-mountable assembly is affixed to a foot when in use.

[0007] In one aspect, the apparatus of the present disclosure accurately counts steps and measures the time interval between them. In one aspect, the results are displayed on the microcontroller unit and/or wirelessly transmitted to a smartphone, tablet, or PC for further analysis and database purposes. This provides a simple and accurate method for monitoring and quantitative evaluation of the user's gait characteristics, an important indicator of his or her health conditions.

[0008] In certain aspects, the present disclosure offers advantages over art methods and apparatuses. In one aspect, the present method for bed-departure detection and alerting is simple and reliable. In another aspect, the present method for counting steps is accurate and reliable. In one embodiment, the cost of the present apparatus is low. In another embodiment, the present apparatus is easy to set up and operate.

[0009] These and other features and advantages of the presently disclosed methods and apparatuses will become apparent to those of ordinary skill in the art from the following description and accompanying drawings, which describe, for purposes of illustration only, embodiments of the present disclosure.

[0010] In one embodiment, disclosed herein is a method of detecting bed-departure, comprising the following steps: having a user in bed wear a sock, which is embedded or mounted with a pressure sensor in the sole, and mounted with a microcontroller unit

comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor, or placing a slipper or a shoe on the floor near a user's bed, wherein the slipper or shoe is embedded or mounted with a pressure sensor in the sole, and mounted with a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor; switching on the microcontroller unit to acquire a sensor output signal at a predetermined time interval; having the microcontroller compare the value of the sensor output signal with a predetermined threshold at the predetermined time interval; if the sensor output signal value is less than the threshold, having the microcontroller continue to acquire a new sensor output signal at the next time interval; if the sensor output signal value is equal or larger than the threshold, having the radio-frequency module transmit a radio-frequency signal to a separate monitoring unit; and having the monitoring unit generate an audible sound or a flashing light or both as an alert, once receiving the radio-frequency signal.

[0011] In one aspect, the method disclosed herein further comprises recording the time of the alert into a database in the memory of the monitoring unit. In any of the preceding embodiments, the alert can be triggered when the user wanders out of bed. In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged in one removable and re-mountable assembly, which is mounted on the sock, with the pressure sensor on the sole of the sock. In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged in one removable and re-mountable assembly, which is affixed to a foot of the user with the pressure sensor on the sole of the foot. In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged in one removable and re-mountable assembly, which is mounted on the slipper or shoe, with the pressure sensor on the insole of the slipper or on the insole of the shoe. In any of the preceding embodiments, the alert can be triggered when the user steps onto the floor, or when the user steps his or her foot into the slipper or the shoe placed on the floor.

[0012] In another aspect, disclosed herein is an apparatus for detecting bed-departure, comprising: a pressure sensor embedded in or mounted on the sole of a sock worn by a user in bed, or a pressure sensor embedded in or mounted on the insole of a slipper or a shoe

placed on the floor near a user's bed; a microcontroller unit mounted on the sock or the slipper or shoe, the microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor; and a monitoring unit, which can be for example, a smartphone, a tablet, a PC, or a custom-made monitor, the monitoring unit comprising a radio-frequency module and a speaker and/or an indicator light, wherein the microcontroller is configured to be switched on to acquire an output signal from the pressure sensor at a predetermined time interval, wherein the microcontroller compares the sensor signal with a predetermined threshold at the predetermined time interval and, when the sensor output signal value is equal or larger than the threshold, commands the radio-frequency module to transmit a radio-frequency signal to trigger an audible sound and/or a flashing light signal out of the monitoring unit.

[0013] In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged into a removable and re-mountable assembly, which is mounted on the slipper or shoe, with the pressure sensor on the insole of the slipper or shoe. In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged into a removable and re-mountable assembly, which is mounted on the sock, with the pressure sensor on the sole of the sock. In any of the preceding embodiments, the monitoring unit can be a caretaker's monitoring unit. In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged into a removable and re-mountable assembly, which is affixed to the foot, with the pressure sensor on the sole of the foot.

[0014] In yet another aspect, a method of counting steps and measuring time intervals between steps is provided, the method comprising: having a user wear a sock or a shoe, which is embedded or mounted with a pressure sensor in the sole of the sock or in the insole of the shoe, and mounted with a microcontroller unit, the microcontroller unit comprising a battery, a radio-frequency module, a display screen, and a microcontroller connected to the pressure sensor; when the user begins to walk and/or run, turning on a switch in the microcontroller unit to acquire an output signal of the pressure sensor at a predetermined time interval; storing the values of the signal and time to the memory of the microcontroller at each predetermined time interval, thereby providing pressure time history data stored in the

memory; turning off the switch to stop sensor signal acquisition; having the microcontroller count the number of steps and the average time interval between the steps at the end of a user-specified monitoring period, in accordance with a preprogramed algorithm using the pressure time history data stored in the memory; and displaying the number of steps and the average time interval between the steps in the display screen.

[0015] In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged in one removable and re-mountable assembly, which is mounted on the sock or shoe, with the pressure sensor on the sole of the sock or the insole of the shoe.

[0016] In any of the preceding embodiments, the method can further comprise: comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold; and counting the number of the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold, wherein the number of steps in the user-specified monitoring period is identified as the double of the number of the intersections.

[0017] In any of the preceding embodiments, the method can further comprise transmitting the number of steps, the average time interval between the steps, and/or the pressure time history data to a smartphone, tablet, PC, or other suitable monitoring and/or data processing unit, via the radio-frequency module for further analysis and database purposes.

[0018] In any of the preceding embodiments, the method can further comprise: comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold; identifying the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold; and measuring the average time duration between every two adjacent the intersections over the user-specified monitoring period, wherein the average time interval between steps in the user-specified monitoring period is identified as the half of the measured average time duration.

[0019] In some embodiments, provided herein is an apparatus for counting steps and measuring time intervals between steps, comprising: a pressure sensor embedded in or mounted on the sole of a sock or the insole of a shoe; a microcontroller unit mounted on the

sock, the microcontroller unit comprising a battery, a radio-frequency module, a display, and a microcontroller connected to the pressure sensor; and a smartphone or a PC, wherein the microcontroller acquires an output signal from the pressure sensor, stores the values of the signal and time to the memory of the microcontroller at each predetermined time interval to provide pressure time history data stored in the memory, counts the number of steps and the average time interval between the steps in accordance with a preprogramed algorithm using the pressure time history data stored in the memory, and displays the number of steps and the average time interval between the steps in the display screen.

[0020] In any of the preceding embodiments, the pressure sensor and the microcontroller unit can be packaged into a removable and re-mountable assembly, which is mounted on the sock or shoe, wherein the pressure sensor is on the sole of the sock or on the insole of the shoe. In any of the preceding embodiments, the microcontroller can command the radio-frequency module to transmit the number of steps, the average time interval between the steps, and/or the pressure time history data to the smartphone or PC for further analysis and database purposes.

[0021] In other aspects, a method of detecting bed-departure is provided, the method comprising: affixing to a foot of a user in bed a pressure sensor and a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor; switching on the microcontroller unit to acquire a sensor output signal at a predetermined time interval; having the microcontroller compare the value of the sensor output signal with a predetermined threshold at the predetermined time interval; if the sensor output signal value is less than the threshold, having the microcontroller continue to acquire a new sensor output signal at the next time interval; if the sensor output signal value is equal or larger than the threshold, having the radio-frequency module transmit a radio-frequency signal to a separate monitoring unit; and having the monitoring unit generate an audible sound or a flashing light or both as an alert, once receiving the radio-frequency signal.

[0022] In any of the preceding embodiments, the pressure sensor can be affixed to the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot. In any of the preceding embodiments, the microcontroller unit can be affixed to the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, the upper foot, or the instep of the foot.

[0023] In any of the preceding embodiments, the method can further comprise recording the time of the alert into a database in the memory of the monitoring unit. In some aspects, the alert is triggered when the user wanders out of bed.

[0024] In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged in one removable and re-mountable assembly. In any of the preceding embodiments, the alert can be triggered when the user steps onto the floor, and/or when the user steps his or her foot into a slipper or a shoe placed on the floor near the bed.

[0025] In yet another aspect, disclosed herein is an apparatus for detecting bed-departure, comprising: a pressure sensor affixed to a foot of a user in bed; a microcontroller unit affixed to the foot, the microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor; and a monitoring unit, which is a smartphone, a PC, or a custom-made monitor, the monitoring unit comprising a radio-frequency module and a speaker and/or an indicator light, wherein the microcontroller is configured to be switched on to acquire an output signal from the pressure sensor at a predetermined time interval, wherein the microcontroller compares the sensor signal with a predetermined threshold at the predetermined time interval and, when the sensor output signal value is equal or larger than the threshold, commands the radio-frequency module to transmit a radio-frequency signal to trigger an audible sound and/or a flashing light signal out of the monitoring unit.

[0026] In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged into a removable and re-mountable assembly. In any of the preceding embodiments, the pressure sensor can be configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot. In any of the preceding embodiments, the microcontroller unit can be configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, the upper foot, or the instep of the foot.

[0027] In any of the preceding embodiments, the monitoring unit can be a caretaker's monitoring unit.

[0028] In additional embodiments, provided herein is a method of counting steps and measuring time intervals between steps, comprising the following steps: affixing to a foot of

a user a pressure sensor and a microcontroller unit, the microcontroller unit comprising a battery, a radio-frequency module, a display screen, and a microcontroller connected to the pressure sensor; when the user begins to walk and/or run, turning on a switch in the microcontroller unit to acquire an output signal of the pressure sensor at a predetermined time interval; storing the values of the signal and time to the memory of the microcontroller at each predetermined time interval, thereby providing pressure time history data stored in the memory; turning off the switch to stop sensor signal acquisition; having the microcontroller count the number of steps and the average time interval between the steps at the end of a user-specified monitoring period, in accordance with a preprogramed algorithm using the pressure time history data stored in the memory; and displaying the number of steps and the average time interval between the steps in the display screen.

[0029] In any of the preceding embodiments, the pressure sensor and the microcontroller unit connected to the pressure sensor can be packaged in one removable and re-mountable assembly. In any of the preceding embodiments, the pressure sensor can be affixed to the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot. In any of the preceding embodiments, the microcontroller unit can be affixed to the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, the upper foot, or the instep of the foot.

[0030] In any of the preceding embodiments, the method can further comprise: comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold; and counting the number of the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold, wherein the number of steps in the user-specified monitoring period is identified as the double of the number of the intersections.

[0031] In any of the preceding embodiments, the method can further comprise transmitting the number of steps, the average time interval between the steps, and/or the pressure time history data to a smartphone or a PC via the radio-frequency module for further analysis and database purposes.

[0032] In any of the preceding embodiments, the method can further comprise: comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold; identifying the intersections where the value of the output signal of the pressure sensor increases with time

and exceeds the threshold; and measuring the average time duration between every two adjacent the intersections over the user-specified monitoring period, wherein the average time interval between steps in the user-specified monitoring period is identified as the half of the measured average time duration.

[0033] In still another aspect, disclosed herein is an apparatus for counting steps and measuring time intervals between steps, comprising: a pressure sensor affixed to a foot of a user; a microcontroller unit affixed to the foot, the microcontroller unit comprising a battery, a radio-frequency module, a display, and a microcontroller connected to the pressure sensor; and a smartphone or a PC, wherein the microcontroller acquires an output signal from the pressure sensor, stores the values of the signal and time to the memory of the microcontroller at each predetermined time interval to provide pressure time history data stored in the memory, counts the number of steps and the average time interval between the steps in accordance with a preprogramed algorithm using the pressure time history data stored in the memory, and displays the number of steps and the average time interval between the steps in the display screen.

[0034] In any of the preceding embodiments, the pressure sensor and the microcontroller unit can be packaged into a removable and re-mountable assembly. In any of the preceding embodiments, the pressure sensor and the microcontroller unit can be packaged into a removable and re-mountable assembly, wherein the pressure sensor can be configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot. In any of the preceding embodiments, the microcontroller unit can be configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, or upper foot of the foot.

[0035] In any of the preceding embodiments, the microcontroller can command the radio-frequency module to transmit the number of steps, the average time interval between the steps, and/or the pressure time history data to the smartphone or PC for further analysis and database purposes.

Brief Description of the Figures

[0036] FIG.1 is a schematic view, showing an apparatus for detecting bed-departure in accordance with an embodiment of the present disclosure.

[0037] FIG. 2 is a schematic view, showing a microcontroller unit according to an embodiment of the present disclosure.

[0038] FIG. 3 is a schematic view, showing a sensor-microprocessor assembly according to an embodiment of the present disclosure.

[0039] FIG. 4 is a schematic view of a plot of pressure time history measured during walking or running, showing how steps are counted and the time intervals measured, according to an embodiment of the present disclosure.

[0040] FIG. 5 is a schematic of an apparatus for detecting bed-departure according to an embodiment of the present disclosure.

[0041] FIG. 6 is a schematic of an apparatus for detecting bed-departure according to an embodiment of the present disclosure.

[0042] FIG. 7 is a schematic view, showing an apparatus for detecting bed-departure in accordance with an embodiment of the present disclosure.

[0043] FIG. 8 is a schematic of an apparatus adhering to a foot of a user, according to an embodiment of the present disclosure.

Detailed Description

[0044] Unless otherwise defined, all terms of art, notations and other scientific terms or terminology used herein are intended to have the meanings commonly understood by those of skill in the art to which this disclosure pertains. In some cases, terms with commonly understood meanings are defined herein for clarity and/or for ready reference, and the inclusion of such definitions herein should not necessarily be construed to represent a substantial difference over what is generally understood in the art. Many of the techniques and procedures described or referenced herein are well understood and commonly employed using conventional methodology by those skilled in the art.

[0045] All publications, including patent documents, articles and webpages, referred to in this application are incorporated by reference in their entireties for all purposes to the same extent as if each individual publication were individually incorporated by reference. If a definition set forth herein is contrary to or otherwise inconsistent with a definition set forth in the patents, patent applications, published applications or other publications that are herein incorporated by reference, the definition set forth herein prevails over the definition that is

incorporated herein by reference. Citation of the publications or documents is not intended as an admission that any of them is pertinent prior art, nor does it constitute any admission as to the contents or date of these publications or documents.

[0046] All headings are for the convenience of the reader and should not be used to limit the meaning of the text that follows the heading, unless so specified.

[0047] As used herein and in the appended claims, the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. For example, “a” or “an” means “at least one” or “one or more.” Thus, reference to “the method” includes reference to equivalent steps and methods disclosed herein and/or known to those skilled in the art, and so forth.

[0048] Throughout this disclosure, various aspects of this disclosure are presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the present disclosure. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

[0049] In the following description of certain embodiments provided here, reference is made to the accompanying drawings which form a part hereof, and in which it is shown by way of illustration specific embodiments in which the present disclosure can be practiced. It is to be understood that other embodiments can be used and structural changes can be made without departing from the scope of the present disclosure.

[0050] In certain aspects, load sensors can be installed on a patient's bed to detect his or her bed departure. Japanese Laid-Open Patent Application No. 2-280733 uses weight information to determine whether a user is still on the bed or has left the bed. Other methods of calculating the center of gravity from the weight information of four points on the bed, and using the center-of-gravity position information to monitor the movement of a user in bed, are disclosed in Japanese Patent No. 3093745, Japanese Patent No. 3322632, U.S. Patent No. 5,276,432, and U.S. Patent Application No. 2009/0260158. In certain cases, the associated

costs and cumbersome set-up prevent the wide applications of specialized beds installed with load sensors in homes as well as in nursing facilities and hospitals.

[0051] Shoes and socks embedded with sensors are known. For example, pressure sensors are used on athletic shoes to measure strides length, running speed and other stride characteristics for sport training purposes, as disclosed in U.S. Patent No. 4,736,312, U.S. Patent No. 5,221,088, U.S. Patent No. 5,343,445, U.S. Patent No. 5,452,269, U.S. Patent No. 5,471,405, and U.S. Patent No. 8,280,681. In other examples, strain sensors are used on a shoe to monitor patient force during rehabilitation, for example, as disclosed in U.S. Patent No. 6,122,846. In some aspects, force sensors are used on a shoe insole for remote gait analysis, as disclosed in U.S. Patent No. 6,360,597. In yet other aspects, a sensor sock can be used for measuring plantar pressure in the diagnosis of peripheral neuropathy, as disclosed in “Sensor Sock: measuring your sole,” dated 2 July 2010, updated 14 October 2011, available at www.CSIRO.au.

[0052] In one aspect, the apparatus according to the present disclosure comprises a pressure sensor embedded in the sole of a sock, a battery-powered microcontroller unit mounted on the same sock, and a separate monitoring unit to generate an audible sound, once wirelessly triggered by the microcontroller unit. This is illustrated in FIG. 1.

[0053] In FIG. 1, the sock is denoted by numeral 1, the pressure sensor by numeral 2, electrical wires by numeral 3, the microcontroller unit by numeral 4. Numeral 5 represents the wireless radio-frequency signal. Numeral 6 is the monitoring unit, which can be a smartphone, a PC, or a custom-made monitor. Monitoring unit 6 has a radio-frequency module and a speaker. Numeral 7 represents the audible sound from the speaker of monitoring unit 6.

[0054] In another embodiment, an apparatus for detecting bed-departure is shown in FIG. 7, wherein the sock is denoted by numeral 1, the pressure sensor by numeral 2, electrical wires by numeral 3, the microcontroller unit by numeral 4. Numeral 5 represents the wireless radio-frequency signal. Numeral 6 is the monitoring unit, and numeral 7 represents the audible sound from the speaker of monitoring unit 6. Numeral 17 represents an indicator light which can send a flashing light signal.

[0055] FIG. 2 is a schematic view of a preferred embodiment of microcontroller unit 4, comprising a battery cell denoted by numeral 8, a microcontroller denoted by numeral 9, a radio-frequency module denoted by numeral 10, and sensor output signal by numeral 11.

[0056] Pressure sensor 2 is embedded in the sole of sock 1, connected by electrical wires 3 to microprocessor unit 4, which is mounted on sock 1. When the sock user is in bed, microcontroller 9 continuously acquires output signal 11 from sensor 2 and compares the signal with a predetermined threshold at each predetermined time interval. If the value of the sensor signal is less than the threshold, microcontroller 9 will continue acquiring a sensor output signal at the next time interval. Once the user wanders out of bed and steps onto the floor, his or her body weight will exert pressure on the sock, causing the sensor signal to exceed the predetermined threshold. The microcontroller will then command the radio-frequency module 10 to immediately transmit a radio-frequency signal 5 to the separate monitoring unit 6. Signal 5 will trigger an audible sound out of the monitoring unit 6 to alert a caretaker. The monitoring unit can be a smartphone, a PC, or a custom-made monitor, each comprising a radio-frequency module and a speaker.

[0057] The time of the alert is recorded into a database in the monitoring unit for the patient health monitoring and care usages.

[0058] Pressure sensor 2 can be any pressure sensor that can be embedded in the sole of a sock and is thin and soft enough not to affect walking.

[0059] Instead of a sock, pressure sensor 2 can be embedded in the insole of a slipper or the insole of a shoe, and microcontroller unit 4 is also mounted on the same slipper or the same shoe. A slipper 15 is illustrated in FIG. 5, and a shoe 16 is illustrated in FIG. 6. When a user in bed gets out of bed and steps his or her foot into the slipper or shoe on the floor, radio-frequency module in microcontroller 4 will immediately send a radio-frequency signal to trigger an audible sound out of monitoring unit 6 to alert the caretaker.

[0060] In another embodiment of the apparatus as illustrated in FIG. 3, pressure sensor 2 and microcontroller unit 4, connected by electrical wires 3, are packaged into one assembly, which can be conveniently mounted on any ordinary sock, slipper, or shoe, with pressure sensor 2 in contact with the sole of a user's foot when in use. The advantage of this removable and re-mountable assembly is in its flexibility to be mounted on any ordinary footwear.

[0061] FIG. 8 is a schematic of the apparatus adhering to a foot, according to an embodiment of the present disclosure, wherein 18 denotes a foot of a user. Pressure sensor 2 is affixed to foot 18, wherein the pressure sensor is connected by electrical wires 3 to microprocessor unit 4. In some aspects, the pressure sensor is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot. In other aspects, the microcontroller unit is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, or upper foot of the foot. The pressure sensor and the microcontroller unit or components thereof can be affixed separately to the foot, or packaged or assembled into a removable and re-mountable assembly, wherein the assembly is affixed to the foot.

[0062] By adding a simple display screen to microcontroller unit 4, and programming an algorithm into microcontroller 9, the apparatus of the present disclosure for bed-departure detection becomes a pedometer, which accurately counts the number of steps taken in a given time period, measures the time interval between steps, and displays the results. The user may wear sock 1 embedded with pressure sensor 2 or any ordinary sock or shoe mounted with the sensor-microcontroller assembly shown in FIG 3. Once microcontroller unit 4 is turned on, output signal 11 from pressure sensor 2 is continuously recorded into the memory of microcontroller 9 at each time interval for a given period of time. In the end of the period, the number of total steps and the average time interval between steps are computed in the microcontroller 9 and displayed in the display screen.

[0063] To demonstrate how steps are counted and the time interval between them are measured, FIG. 4 schematically plots a pressure time history measured on one foot during walking or running. In FIG. 4, the horizontal axis is time and the vertical axis is pressure measured by the pressure sensor. One cycle represents the change of pressure on the single foot during one step, where the minimum pressure value occurs when the foot is off the ground and the maximum value occurs when the foot is stepping on the ground. Numeral 12 denotes a pressure value at a time instant, numeral 13 denotes a predetermined threshold, and numeral 14 denotes an intersection where pressure output signal 12 increases and exceeds threshold 13. Because the plot is the pressure time history on a single foot, each time when sensor output signal 12 increases and exceeds threshold 13 at intersection 14, two steps are counted. The time duration between two adjacent the intersections is a half of the time

interval between steps. An average time interval of steps for the entire monitoring period may be computed by averaging each of the measured time intervals.

[0064] When needed, the recorded pressure time history data, as well as the number of steps and the average time interval between steps are transmitted to a smartphone or a PC via radio-frequency module 10 for further analysis and database purposes. These data can be analyzed and made into a database, useful for monitoring and quantitative evaluation of the user's gait characteristics, as they reveal important information about his or her health conditions.

[0065] In some aspects, the methods and apparatuses of the present disclosure offer significant advantages over art methods and apparatuses. The method for bed-departure detection is simple and reliable. The cost of the apparatus is low. It is easy to set up and operate the apparatus. The method for counting steps and measuring the time interval between steps is more accurate and reliable, compared to widely available pedometers, which are inaccurate because they use accelerometers to measure hip motion to count steps, rather than measuring the steps themselves.

[0066] In any of the preceding embodiments, the microcontroller unit or any component thereof can be affixed on the side of the foot, sock, slipper, or shoe.

[0067] In any of the preceding embodiments, an algorithm can be used to prevent false triggering due to, for example, the user kicking the bed, which causes the pressure detected by the pressure sensor to exceed the threshold. In one embodiment, the algorithm compares the sensor output signal with the threshold at a number of consecutive sampling time instances, rather than only once at one sampling time instance. If the sensor output signal only exceeds the threshold at one sampling time instance, but not at a pre-determined number of subsequent consecutive time instance(s), the alert will not be triggered. In another aspect, if the sensor output signal exceeds the threshold at one sampling time instance, as well as at a pre-determined number of subsequent consecutive time instance(s), the alert will be triggered.

[0068] In certain embodiments, the method or apparatus compares the sensor output signal with the threshold at at least 2, 3, 4, 5, 6, 7, 8, 9, 10, between about 10 and about 15, between about 15 and about 20, or more than about 20 consecutive sampling time instances, in order to prevent false triggering. For example, in one aspect, if the sensor output signal

only exceeds the threshold at one sampling time instance, but not at the subsequent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, between about 10 and about 15, between about 15 and about 20, or more than about 20 consecutive time instance(s), the alert will not be triggered, and/or there is indicated that triggering of the alarm is a false positive. In another aspect, if the sensor output signal exceeds the threshold at one sampling time instance, as well as at the subsequent 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, between about 10 and about 15, between about 15 and about 20, or more than about 20 consecutive time instance(s), the alert will be triggered, and triggering of the alarm is a true positive signal. In any of the preceding embodiments, the sampling frequency can be about 0.0001 Hz, about 0.001 Hz, about 0.01 Hz, about 0.1 Hz, about 0.5 Hz, about 1 Hz, about 2 Hz, about 3 Hz, about 4 Hz, about 5 Hz, about 6 Hz, about 7 Hz, about 8 Hz, about 9 Hz, about 10 Hz, about 20 Hz, about 50 Hz, about 100 Hz, or more than about 100 Hz. Any suitable combination of the sampling frequency and the number of consecutive sampling time instance can be used. For example, sampling at the frequency of three times every second (3 Hz) for 6 consecutive sampling time instances (each 1/3 second in length) can be used. Alternatively, sampling at the frequency of once every second (1 Hz) for 2 consecutive sampling time instances (each 1 second in length) can be used. In another example, sampling at the frequency of twice every second (2 Hz) for 6 consecutive sampling time instances (each 1/2 second in length) can be used. Alternatively, sampling at the frequency of once every second (1 Hz) for 3 consecutive sampling time instances (each 1 second in length) can be used.

[0069] The present disclosure is further illustrated by the following exemplary embodiments. Embodiment 1 is a method of detecting bed-departure, comprising the following steps: having a user in bed wear a sock, which is embedded with a pressure sensor in the sole, and mounted with a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor; switching on the microcontroller unit to acquire a sensor output signal at a predetermined time interval; having the microcontroller compare the value of the sensor signal with a predetermined threshold at the time interval; if the sensor signal value is less than the threshold, having the microcontroller continue to acquire a new sensor output signal at the next time interval; if the sensor signal value is equal or larger than the threshold, i.e., the user has left bed and stepped onto floor, having the radio-frequency module transmit a radio-frequency signal to a separate

monitoring unit; and having the monitoring unit generate an audible sound as an alert, once receiving the radio-frequency signal.

[0070] Embodiment 2 is a method of Embodiment 1, further comprising recording the time of the alert into a database in the memory of the monitoring unit. Embodiment 3 is a method of Embodiment 1 or 2, wherein instead of the sock, a slipper or a shoe embedded with the pressure sensor in the insole and mounted with the microcontroller unit is placed on the floor near a user's bed; and the alert is triggered when the user wonders out of bed and steps his or her foot into the slipper or the shoe on the floor. Embodiment 4 is a method of Embodiment 1 or 2, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly which is mounted on an ordinary sock, with the pressure sensor on the sole of the sock; a user in bed wears the sock; and the alert is triggered when the user wonders out of bed and steps onto the floor. Embodiment 5 is a method of any one of Embodiments 1, 2, and 3, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on an ordinary slipper or an ordinary shoe, with the pressure sensor on the insole of the slipper or on the insole of the shoe; the slipper or the shoe is placed on the floor near a user's bed; and the alert is triggered when the user wonders out of bed and steps his or her foot into the slipper or the shoe on the floor.

[0071] Embodiment 6 is an apparatus for detecting bed-departure, comprising: a pressure sensor embedded in the sole of a sock, wherein the sensor is any type of pressure sensor that is thin and soft enough not to affect walking, a microcontroller unit mounted on the sock, further comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor, and a monitoring unit, which is a smartphone, a PC, or a custom-made monitor further comprising a radio-frequency module and a speaker, wherein the microcontroller acquires an output signal from the pressure sensor, compares the sensor signal with a predetermined threshold at a predetermined time interval and, when the sensor signal value is equal or larger than the threshold, commands the radio-frequency module to transmit a radio-frequency signal to trigger an audible sound out of the monitoring unit.

[0072] Embodiment 7 is an apparatus of Embodiment 6, wherein instead of the sock, the pressure sensor is embedded in the insole of a slipper or the insole of a shoe, and the

microcontroller unit is also mounted on the slipper or the shoe. Embodiment 8 is an apparatus of Embodiment 6 or 7, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, which is mounted on an ordinary sock, an ordinary slipper, or an ordinary shoe, with the pressure sensor on the sole of the sock, on the insole of the slipper, or on the insole of the shoe.

[0073] Embodiment 9 is a method of counting steps and measuring time intervals between steps, comprising the following steps: having a user wear a sock or a shoe, which is embedded with a pressure sensor in the sole of the sock or in the insole of the shoe, and mounted with a microcontroller unit further comprising a battery, a radio-frequency module, a display screen, and a microcontroller connected to the pressure sensor; when the user begins to walk and/or run, turning on a switch in the microcontroller unit to acquire an output signal of the pressure sensor and to store the values of the signal and time to the memory of the microcontroller at each predetermined time interval; turning off the switch to stop sensor signal acquisition, and to have the microcontroller count the number of steps and the average time interval between the steps in the end of a user-specified monitoring period, in accordance with a preprogramed algorithm using the pressure time history data recorded in the memory; displaying the number of steps and the average time interval between the steps in the display screen; and when needed, transmitting the number of steps, the average time interval between the steps, and/or the pressure time history data to a smartphone or a PC via the radio-frequency module for further analysis and database purposes.

[0074] Embodiment 10 is a method of Embodiment 9, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on an ordinary sock or an ordinary shoe with the pressure sensor on the sole of the sock or the insole of the shoe, and a user wears the sock or the shoe. Embodiment 11 is a method of Embodiment 9 or 10, comprising an algorithm preprogramed in the microcontroller for counting steps and measuring time interval between steps using the pressure time history data measured on a single foot, which algorithm comprises: comparing the pressure sensor signal value at each time interval with a predetermined threshold; identifying the intersections where the sensor signal value increases and exceeds the threshold; doubling the number of the intersections resulting in the number

of steps, given that the pressure time history data are measured on one foot, and measuring the time duration between every two adjacent the intersections, taking an average over the entire measurement period, and dividing the average in half resulting in the average time interval between steps, given that the pressure time history data are measured on one foot.

[0075] Embodiment 12 is an apparatus for counting steps and measuring time intervals between steps, comprising: a pressure sensor embedded in the sole of a sock or the insole of a shoe, wherein the sensor is any type of pressure sensor that is thin and soft enough not to affect walking, a microcontroller unit mounted on the sock, further comprising a battery, a radio-frequency module, a display, and a microcontroller connected to the pressure sensor, and a smartphone or a PC, wherein the microcontroller acquires an output signal from the pressure sensor, stores the values of the signal and time to the memory of the microcontroller at each predetermined time interval, counts the number of steps and the average time interval between the steps in accordance with a preprogramed algorithm, displays the number of steps and the average time interval between the steps in the display screen and, when needed, commands the radio-frequency module to transmit the number of steps, the average time interval between the steps, and/or the pressure time history data to the smartphone or PC for further analysis and database purposes.

[0076] Embodiment 13 is an apparatus of Embodiment 12, wherein the pressure sensor and the microcontroller unit are packaged into a removable and re-mountable assembly, which is mounted on an ordinary sock or an ordinary shoe, wherein the pressure sensor is on the sole of the sock or on the insole of the shoe.

[0077] Embodiment 14 is a method of detecting bed-departure, comprising the following steps:

having a user in bed wear a sock, which is embedded or mounted with a pressure sensor in the sole, and mounted with a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor, or placing a slipper or a shoe on the floor near a user's bed, wherein the slipper or shoe is embedded or mounted with a pressure sensor in the sole, and mounted with a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor;

switching on the microcontroller unit to acquire a sensor output signal at a

predetermined time interval; having the microcontroller compare the value of the sensor output signal with a predetermined threshold at the predetermined time interval;

if the sensor output signal value is less than the threshold, having the microcontroller continue to acquire a new sensor output signal at the next time interval;

if the sensor output signal value is equal or larger than the threshold, having the radio-frequency module transmit a radio-frequency signal to a separate monitoring unit; and

having the monitoring unit generate an alert, for example, an audible sound or a flashing light or both, once receiving the radio-frequency signal.

[0078] Embodiment 15 is the method of Embodiment 14, further comprising recording the time of the alert into a database in the memory of the monitoring unit.

[0079] Embodiment 16 is the method of Embodiment 14 or Embodiment 15, wherein the alert is triggered when the user wanders out of bed.

[0080] Embodiment 17 is the method of any one of Embodiments 14-16, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on the sock, with the pressure sensor on the sole of the sock.

[0081] Embodiment 18 is the method of any one of Embodiments 14-17, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on the slipper or shoe, with the pressure sensor on the insole of the slipper or on the insole of the shoe.

[0082] Embodiment 19 is the method of any one of Embodiments 14-18, wherein the alert is triggered when the user steps onto the floor.

[0083] Embodiment 20 is the method of any one of Embodiments 14-19, wherein the alert is triggered when the user steps his or her foot into the slipper or the shoe placed on the floor.

[0084] Embodiment 21 is an apparatus for detecting bed-departure, comprising:

a pressure sensor embedded in or mounted on the sole of a sock worn by a user in bed, or a pressure sensor embedded in or mounted on the insole of a slipper or a shoe placed on the floor near a user's bed;

a microcontroller unit mounted on the sock or the slipper or shoe, the microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the

pressure sensor; and

a monitoring unit, for example, a monitoring unit comprising a smartphone, a PC, or a custom-made monitor, the monitoring unit comprising a radio-frequency module and a signaling module, for example, a signaling module comprising a speaker and/or an indicator light,

wherein the microcontroller is configured to be switched on to acquire an output signal from the pressure sensor at a predetermined time interval, wherein the microcontroller compares the sensor signal with a predetermined threshold at the predetermined time interval and, when the sensor output signal value is equal or larger than the threshold, commands the radio-frequency module to transmit a radio-frequency signal to trigger an alert, for example, an audible sound and/or a flashing light or both, out of the monitoring unit.

[0085] Embodiment 22 is the apparatus of Embodiment 21, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, which is mounted on the slipper or shoe, with the pressure sensor on the insole of the slipper or shoe.

[0086] Embodiment 23 is the apparatus of Embodiment 21 or Embodiment 22, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, which is mounted on the sock, with the pressure sensor on the sole of the sock.

[0087] Embodiment 24 is the apparatus of any one of Embodiments 21-23, wherein the monitoring unit is a caretaker's monitoring unit.

[0088] Embodiment 25 is a method of counting steps and measuring time intervals between steps, comprising the following steps:

having a user wear a sock or a shoe, which is embedded or mounted with a pressure sensor in the sole of the sock or in the insole of the shoe, and mounted with a microcontroller unit, the microcontroller unit comprising a battery, a radio-frequency module, a display screen, and a microcontroller connected to the pressure sensor;

when the user begins to walk and/or run, turning on a switch in the microcontroller unit to acquire an output signal of the pressure sensor at a predetermined time interval;

storing the values of the signal and time to the memory of the microcontroller at each

predetermined time interval, thereby providing pressure time history data stored in the memory;

turning off the switch to stop sensor signal acquisition;

having the microcontroller count the number of steps and the average time interval between the steps at the end of a user-specified monitoring period, in accordance with a preprogrammed algorithm using the pressure time history data stored in the memory; and

displaying the number of steps and the average time interval between the steps in the display screen.

[0089] Embodiment 26 is the method of Embodiment 25, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on the sock or shoe, with the pressure sensor on the sole of the sock or the insole of the shoe.

[0090] Embodiment 27 is the method of Embodiment 25 or Embodiment 26, further comprising:

comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold; and

counting the number of the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold,

wherein the number of steps in the user-specified monitoring period is identified as the double of the number of the intersections.

[0091] Embodiment 28 is the method of any one of Embodiments 25-27, further comprising transmitting the number of steps, the average time interval between the steps, and/or the pressure time history data to a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, via the radio-frequency module for further analysis and database purposes.

[0092] Embodiment 29 is the method of any one of Embodiments 25-28, further comprising:

comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold;

identifying the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold; and

measuring the average time duration between every two adjacent the intersections over the user-specified monitoring period,

wherein the average time interval between steps in the user-specified monitoring period is identified as the half of the measured average time duration.

[0093] Embodiment 30 is an apparatus for counting steps and measuring time intervals between steps, comprising:

a pressure sensor embedded in or mounted on the sole of a sock or the insole of a shoe;

a microcontroller unit mounted on the sock, the microcontroller unit comprising a battery, a radio-frequency module, a display, and a microcontroller connected to the pressure sensor; and

a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, wherein the microcontroller acquires an output signal from the pressure sensor, stores the values of the signal and time to the memory of the microcontroller at each predetermined time interval to provide pressure time history data stored in the memory, counts the number of steps and the average time interval between the steps in accordance with a preprogramed algorithm using the pressure time history data stored in the memory, and displays the number of steps and the average time interval between the steps in the display screen.

[0094] Embodiment 31 is the apparatus of Embodiment 30, wherein the pressure sensor and the microcontroller unit are packaged into a removable and re-mountable assembly, which is mounted on the sock or shoe, wherein the pressure sensor is on the sole of the sock or on the insole of the shoe.

[0095] Embodiment 32 is the apparatus of Embodiment 30 or 31, wherein the microcontroller commands the radio-frequency module to transmit the number of steps, the average time interval between the steps, and/or the pressure time history data to a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, for further analysis and database purposes.

[0096] Embodiment 33 is a method of detecting bed-departure, comprising the following steps:

affixing to a foot of a user in bed a pressure sensor and a microcontroller unit

comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor;

switching on the microcontroller unit to acquire a sensor output signal at a predetermined time interval;

having the microcontroller compare the value of the sensor output signal with a predetermined threshold at the predetermined time interval;

if the sensor output signal value is less than the threshold, having the microcontroller continue to acquire a new sensor output signal at the next time interval;

if the sensor output signal value is equal or larger than the threshold, having the radio-frequency module transmit a radio-frequency signal to a separate monitoring unit; and

having the monitoring unit generate an alert, for example, an audible sound or a flashing light or both, once receiving the radio-frequency signal.

[0097] Embodiment 34 is the method of Embodiment 33, wherein the pressure sensor is affixed to the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot.

[0098] Embodiment 35 is the method of Embodiment 33 or 34, wherein the microcontroller unit is affixed to the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, or upper foot of the foot.

[0099] Embodiment 36 is the method of any one of Embodiments 33-35, further comprising recording the time of the alert into a database in the memory of the monitoring unit.

[00100] Embodiment 37 is the method of any one of Embodiments 33-36, wherein the alert is triggered when the user wanders out of bed.

[00101] Embodiment 38 is the method of any one of Embodiments 33-37, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly.

[00102] Embodiment 39 is the method of any one of Embodiments 33-38, wherein the alert is triggered when the user steps onto the floor.

[00103] Embodiment 40 is the method of any one of Embodiments 33-38, wherein the alert is triggered when the user steps his or her foot into a slipper or a shoe placed on the floor near the bed.

[00104] Embodiment 41 is an apparatus for detecting bed-departure, comprising:

a pressure sensor affixed to a foot of a user in bed;
a microcontroller unit affixed to the foot, the microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor;
and

a monitoring unit, for example, a monitoring unit comprising a smartphone, a PC, or a custom-made monitor, the monitoring unit comprising a radio-frequency module and a signaling module, for example, a speaker and/or an indicator light,

wherein the microcontroller is configured to be switched on to acquire an output signal from the pressure sensor at a predetermined time interval, wherein the microcontroller compares the sensor signal with a predetermined threshold at the predetermined time interval and, when the sensor output signal value is equal or larger than the threshold, commands the radio-frequency module to transmit a radio-frequency signal to trigger an alert, for example, an audible sound and/or a flashing light, out of the monitoring unit.

[00105] Embodiment 42 is the apparatus of Embodiment 41, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly.

[00106] Embodiment 43 is the apparatus of Embodiment 41 or 42, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, wherein the pressure sensor is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot.

[00107] Embodiment 44 is the apparatus of any one of Embodiments 41-43, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, wherein the microcontroller unit is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, or upper foot of the foot.

[00108] Embodiment 45 is the apparatus of any one of Embodiments 41-44, wherein the monitoring unit is a caretaker's monitoring unit.

[00109] Embodiment 46 is a method of counting steps and measuring time intervals between steps, comprising the following steps:

affixing to a foot of a user a pressure sensor and a microcontroller unit, the microcontroller unit comprising a battery, a radio-frequency module, a display screen, and a

microcontroller connected to the pressure sensor;

when the user begins to walk and/or run, turning on a switch in the microcontroller unit to acquire an output signal of the pressure sensor at a predetermined time interval;

storing the values of the signal and time to the memory of the microcontroller at each predetermined time interval, thereby providing pressure time history data stored in the memory;

turning off the switch to stop sensor signal acquisition;

having the microcontroller count the number of steps and the average time interval between the steps at the end of a user-specified monitoring period, in accordance with a preprogrammed algorithm using the pressure time history data stored in the memory; and

displaying the number of steps and the average time interval between the steps in the display screen.

[00110] Embodiment 47 is the method of Embodiment 46, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly.

[00111] Embodiment 48 is the method of Embodiment 46 or 47, wherein the pressure sensor is affixed to the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot.

[00112] Embodiment 49 is the method of any one of Embodiments 46-48, wherein the microcontroller unit is affixed to the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, or upper foot of the foot.

[00113] Embodiment 50 is the method of any one of Embodiments 46-49, further comprising:

comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold; and

counting the number of the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold,

wherein the number of steps in the user-specified monitoring period is identified as the double of the number of the intersections.

[00114] Embodiment 51 is the method of any one of Embodiments 46-50, further comprising transmitting the number of steps, the average time interval between the steps,

and/or the pressure time history data to a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, via the radio-frequency module for further analysis and database purposes.

[00115] Embodiment 52 is the method of any one of Embodiments 46-51, further comprising:

- comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold;

- identifying the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold; and

- measuring the average time duration between every two adjacent the intersections over the user-specified monitoring period,

- wherein the average time interval between steps in the user-specified monitoring period is identified as the half of the measured average time duration.

[00116] Embodiment 53 is an apparatus for counting steps and measuring time intervals between steps, comprising:

- a pressure sensor affixed to a foot of a user;

- a microcontroller unit affixed to the foot, the microcontroller unit comprising a battery, a radio-frequency module, a display, and a microcontroller connected to the pressure sensor; and

- a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC,

- wherein the microcontroller acquires an output signal from the pressure sensor, stores the values of the signal and time to the memory of the microcontroller at each predetermined time interval to provide pressure time history data stored in the memory, counts the number of steps and the average time interval between the steps in accordance with a preprogramed algorithm using the pressure time history data stored in the memory, and displays the number of steps and the average time interval between the steps in the display screen.

[00117] Embodiment 54 is the apparatus of Embodiment 53, wherein the pressure sensor and the microcontroller unit are packaged into a removable and re-mountable assembly.

[00118] Embodiment 55 is the apparatus of Embodiment 53 or 54, wherein the pressure sensor and the microcontroller unit are packaged into a removable and re-mountable

assembly, wherein the pressure sensor is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot.

[00119] Embodiment 56 is the apparatus of any one of Embodiments 53-55, wherein the pressure sensor and the microcontroller unit are packaged into a removable and re-mountable assembly, wherein the microcontroller unit is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, or upper foot of the foot.

[00120] Embodiment 57 is the apparatus of any one of Embodiments 53-56, wherein the microcontroller commands the radio-frequency module to transmit the number of steps, the average time interval between the steps, and/or the pressure time history data to a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, for further analysis and database purposes.

[00121] Alterations and modifications may be made by those having ordinary skill in the art without departing from the spirit and scope of the present disclosure. Therefore, it must be understood that the illustrated embodiment has been set forth only for the purposes of example and that it should not be taken as limiting the present disclosure.

[00122] The words used in this specification to describe the present disclosure and its various embodiments are to be understood not only in the sense of their commonly defined meanings, but to include by special definition in this specification structure, material or acts beyond the scope of the commonly defined meanings. Thus if an element can be understood in the context of this specification as including more than one meaning, then its use in a claim must be understood as being generic to all possible meanings supported by the specification and by the word itself.

[00123] The definitions of the words or elements of the following claims are, therefore, defined in this specification to include not only the combination of elements which are literally set forth, but all equivalent elements or acts for performing substantially the same function in substantially the same way to obtain substantially the same result. In this sense it is therefore contemplated that an equivalent substitution of two or more elements may be made for any one of the elements in the claims below or that a single element may be substituted for two or more elements in a claim.

[00124] Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, now known or later devised, are expressly contemplated as being

equivalently within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are within the scope of the present disclosure.

[00125] The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptually equivalent, what can be obviously substituted and also what essentially incorporates the essential idea of the present disclosure.

[00126] It will be appreciated that, for clarity purposes, the above description has described embodiments of the present disclosure with reference to different functional units and/or modules of the device. However, it will be apparent that any suitable distribution of functionality between different functional units, modules or domains may be used without detracting from the present disclosure. For example, functionality illustrated to be performed by separate modules may be performed by the same module. Hence, references to specific functional units are only to be seen as references to suitable means for providing the described functionality, rather than indicative of a strict logical or physical structure or organization.

[00127] Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term “including” should be read as meaning “including, without limitation” or the like; the term “example” is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; and adjectives such as “conventional,” “traditional,” “normal,” “standard,” “known,” and terms of similar meaning, should not be construed as limiting the item described to a given time period, or to an item available as of a given time. But instead these terms should be read to encompass conventional, traditional, normal, or standard technologies that may be available, known now, or at any time in the future. Likewise, a group of items linked with the conjunction “and” should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as “and/or” unless expressly stated otherwise. Similarly, a group of items linked with the conjunction “or” should not be read as requiring mutual exclusivity among that group, but rather should also be read as “and/or” unless expressly stated otherwise. Furthermore, although items, elements or components of the disclosure may be described or claimed in the singular, the plural is contemplated to be within the scope thereof unless limitation to the singular is explicitly stated. For example, “a” device includes one or more devices. The

presence of broadening words and phrases such as “one or more,” “at least,” “but not limited to”, or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent.

[00128] While various embodiments of the present disclosure have been described above, it should be understood that they have been presented by way of example only, and not by way of limitation. Likewise, the various diagrams may depict an example architectural or other configuration for the disclosure, which is done to aid in understanding the features and functionality that can be included in the disclosure. The disclosure is not restricted to the illustrated example architectures or configurations, but can be implemented using a variety of alternative architectures and configurations. Additionally, although the disclosure is described above in terms of various exemplary embodiments and implementations, it should be understood that the various features and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described. They instead can, be applied, alone or in some combination, to one or more of the other embodiments of the disclosure, whether or not such embodiments are described, and whether or not such features are presented as being a part of a described embodiment. Thus the breadth and scope of the present disclosure should not be limited by any of the above-described exemplary embodiments.

CLAIMS

1. A method of detecting bed-departure, comprising the following steps:
 - having a user in bed wear a sock, which is embedded or mounted with a pressure sensor in the sole, and mounted with a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor, or placing a slipper or a shoe on the floor near a user's bed, wherein the slipper or shoe is embedded or mounted with a pressure sensor in the sole, and mounted with a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor, or affixing to a foot of a user in bed a pressure sensor and a microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor;
 - switching on the microcontroller unit to acquire a sensor output signal at a predetermined time interval;
 - having the microcontroller compare the value of the sensor output signal with a predetermined threshold at the predetermined time interval;
 - if the sensor output signal value is less than the threshold, having the microcontroller continue to acquire a new sensor output signal at the next time interval;
 - if the sensor output signal value is equal or larger than the threshold, having the radio-frequency module transmit a radio-frequency signal to a separate monitoring unit; and
 - having the monitoring unit generate an alert, for example, an audible sound or a flashing light or both, once receiving the radio-frequency signal.
2. The method of claim 1, further comprising recording the time of the alert into a database in the memory of the monitoring unit.
3. The method of claim 1 or 2, wherein the alert is triggered when the user wanders out of bed.
4. The method of any one of claims 1-3, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on the sock, with the pressure sensor on the sole of the sock.

5. The method of any one of claims 1-4, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on the slipper or shoe, with the pressure sensor on the insole of the slipper or on the insole of the shoe.
6. The method of any one of claims 1-5, wherein the alert is triggered when the user steps onto the floor.
7. The method of any one of claims 1-6, wherein the alert is triggered when the user steps his or her foot into the slipper or the shoe placed on the floor.
8. An apparatus for detecting bed-departure, comprising:
 - a pressure sensor embedded in or mounted on the sole of a sock worn by a user in bed, or a pressure sensor embedded in or mounted on the insole of a slipper or a shoe placed on the floor near a user's bed, and a microcontroller unit mounted on the sock or the slipper or shoe, the microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor; or
 - a pressure sensor affixed to a foot of a user in bed, and a microcontroller unit affixed to the foot, the microcontroller unit comprising a battery, a radio-frequency module, and a microcontroller connected to the pressure sensor; and
 - a monitoring unit, for example, a monitoring unit comprising a smartphone, a PC, or a custom-made monitor, the monitoring unit comprising a radio-frequency module and a signaling module, for example, a signaling module comprising a speaker and/or an indicator light,wherein the microcontroller is configured to be switched on to acquire an output signal from the pressure sensor at a predetermined time interval, wherein the microcontroller compares the sensor signal with a predetermined threshold at the predetermined time interval and, when the sensor output signal value is equal or larger than the threshold, commands the radio-frequency module to transmit a radio-frequency signal to trigger an alert, for example, an audible sound and/or a flashing light or both, out of the monitoring unit.
9. The apparatus of claim 8, wherein the pressure sensor and the microcontroller unit

connected to the pressure sensor are packaged into a removable and re-mountable assembly, which is mounted on the slipper or shoe, with the pressure sensor on the insole of the slipper or shoe.

10. The apparatus of claim 8 or 9, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, which is mounted on the sock, with the pressure sensor on the sole of the sock.

11. The apparatus of any one of claims 8-10, wherein the monitoring unit is a caretaker's monitoring unit.

12. A method of counting steps and measuring time intervals between steps, comprising the following steps:

having a user wear a sock or a shoe, which is embedded or mounted with a pressure sensor in the sole of the sock or in the insole of the shoe, and mounted with a microcontroller unit, the microcontroller unit comprising a battery, a radio-frequency module, a display screen, and a microcontroller connected to the pressure sensor, or affixing to a foot of a user a pressure sensor and a microcontroller unit, the microcontroller unit comprising a battery, a radio-frequency module, a display screen, and a microcontroller connected to the pressure sensor;

when the user begins to walk and/or run, turning on a switch in the microcontroller unit to acquire an output signal of the pressure sensor at a predetermined time interval;

storing the values of the signal and time to the memory of the microcontroller at each predetermined time interval, thereby providing pressure time history data stored in the memory;

turning off the switch to stop sensor signal acquisition;

having the microcontroller count the number of steps and the average time interval between the steps at the end of a user-specified monitoring period, in accordance with a preprogrammed algorithm using the pressure time history data stored in the memory; and

displaying the number of steps and the average time interval between the steps in the display screen.

13. The method of claim 12, wherein the pressure sensor and the microcontroller unit

connected to the pressure sensor are packaged in one removable and re-mountable assembly, which is mounted on the sock or shoe, with the pressure sensor on the sole of the sock or the insole of the shoe.

14. The method of claim 12 or 13, further comprising:
comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold; and
counting the number of the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold,
wherein the number of steps in the user-specified monitoring period is identified as the double of the number of the intersections.

15. The method of any one of claims 12-14, further comprising transmitting the number of steps, the average time interval between the steps, and/or the pressure time history data to a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, via the radio-frequency module for further analysis and database purposes.

16. The method of any one of claims 12-15, further comprising:
comparing the value of the output signal of the pressure sensor measured on one foot of the user at each predetermined time interval with a predetermined threshold;
identifying the intersections where the value of the output signal of the pressure sensor increases with time and exceeds the threshold; and
measuring the average time duration between every two adjacent the intersections over the user-specified monitoring period,
wherein the average time interval between steps in the user-specified monitoring period is identified as the half of the measured average time duration.

17. An apparatus for counting steps and measuring time intervals between steps, comprising:
a pressure sensor embedded in or mounted on the sole of a sock or the insole of a shoe, and a microcontroller unit mounted on the sock, the microcontroller unit comprising a battery, a radio-frequency module, a display, and a microcontroller connected to the pressure sensor; or

a pressure sensor affixed to a foot of a user, and a microcontroller unit affixed to the foot, the microcontroller unit comprising a battery, a radio-frequency module, a display, and a microcontroller connected to the pressure sensor; and

a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, wherein the microcontroller acquires an output signal from the pressure sensor, stores the values of the signal and time to the memory of the microcontroller at each predetermined time interval to provide pressure time history data stored in the memory, counts the number of steps and the average time interval between the steps in accordance with a preprogramed algorithm using the pressure time history data stored in the memory, and displays the number of steps and the average time interval between the steps in the display screen.

18. The apparatus of claim 17, wherein the pressure sensor and the microcontroller unit are packaged into a removable and re-mountable assembly, which is mounted on the sock or shoe, wherein the pressure sensor is on the sole of the sock or on the insole of the shoe.

19. The apparatus of claim 17 or 18, wherein the microcontroller commands the radio-frequency module to transmit the number of steps, the average time interval between the steps, and/or the pressure time history data to a monitoring unit, for example, a monitoring unit comprising a smartphone or a PC, for further analysis and database purposes.

20. The method of claim 1 or 12, wherein the pressure sensor is affixed to the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot.

21. The method of any one of claims 1, 12, and 20, wherein the microcontroller unit is affixed to the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, or upper foot of the foot.

22. The apparatus of claim 6 or 17, wherein the pressure sensor and the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, wherein the pressure sensor is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, or a toe of the foot.

23. The apparatus of any one of claims 6, 17, and 22, wherein the pressure sensor and

the microcontroller unit connected to the pressure sensor are packaged into a removable and re-mountable assembly, wherein the microcontroller unit is configured to conform to a region of the sole of the foot, on or near the heel, the ball, the arch, a toe, the ankle, the upper foot, or the instep of the foot.

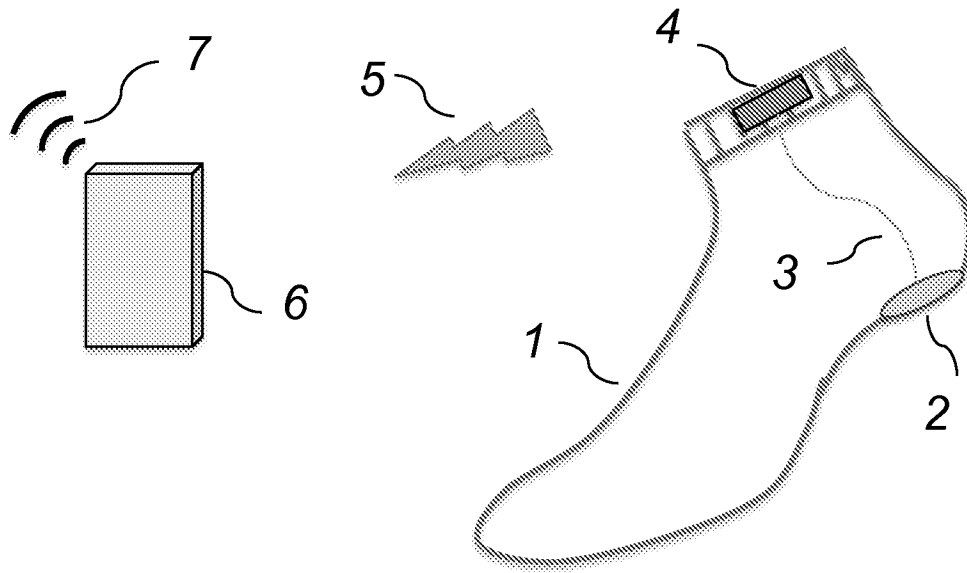


FIG. 1

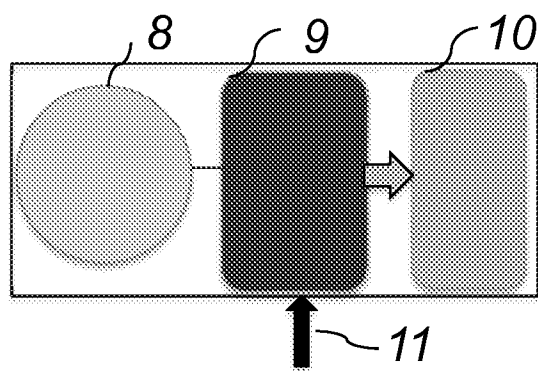


FIG. 2

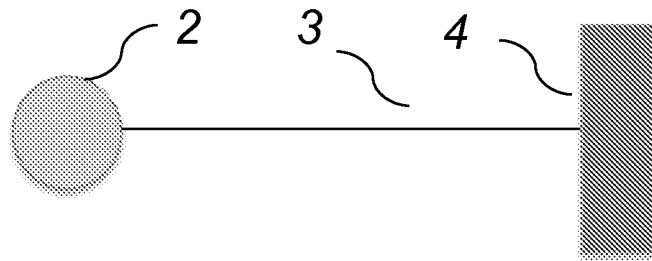


FIG. 3

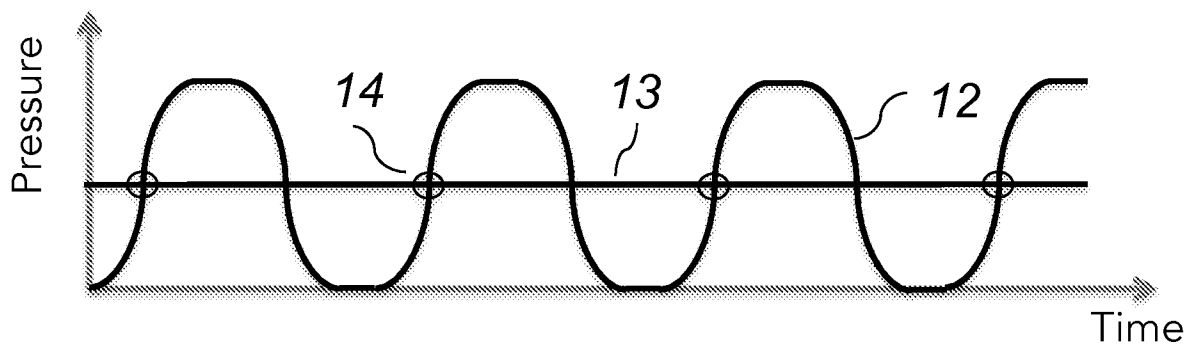


FIG. 4

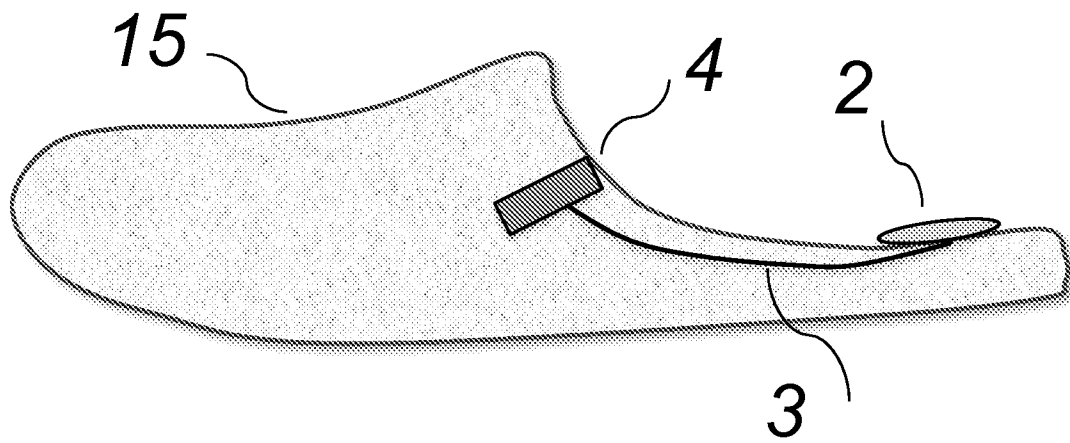


FIG. 5

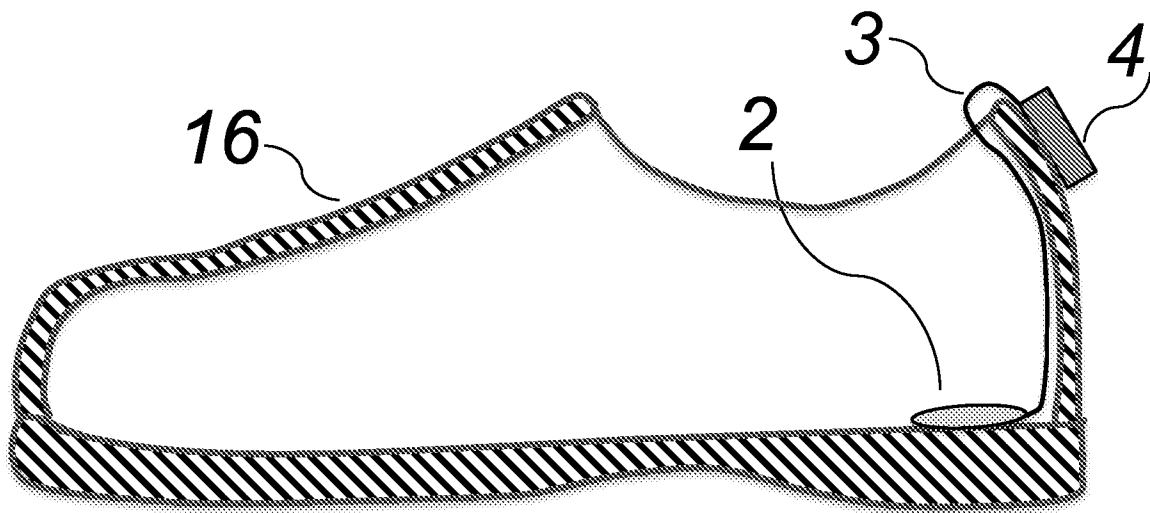


FIG. 6

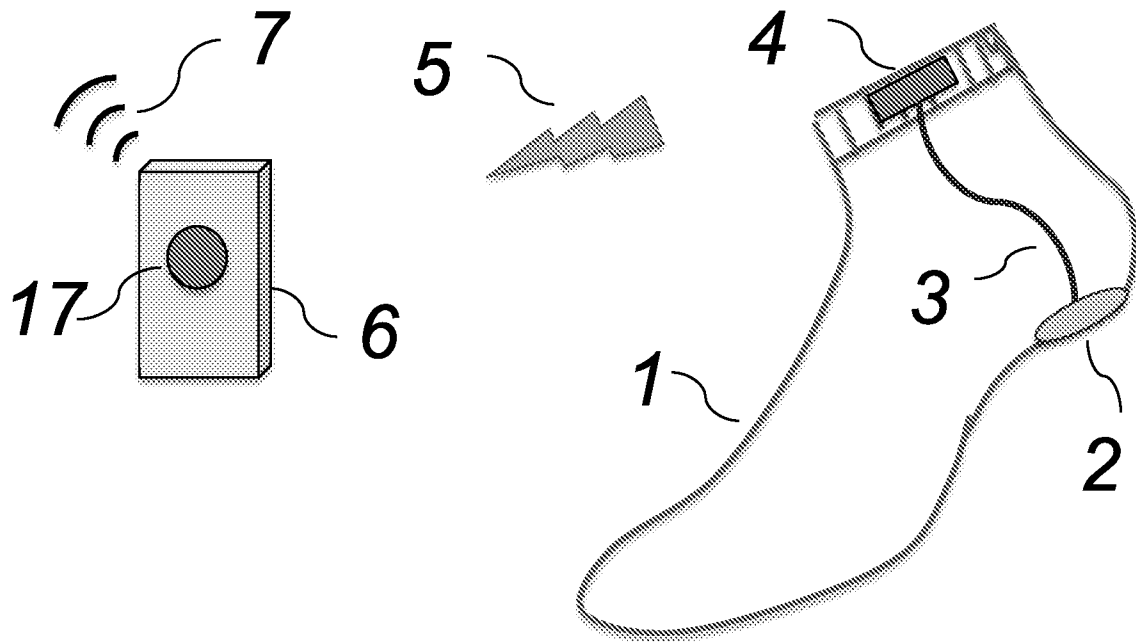


FIG. 7

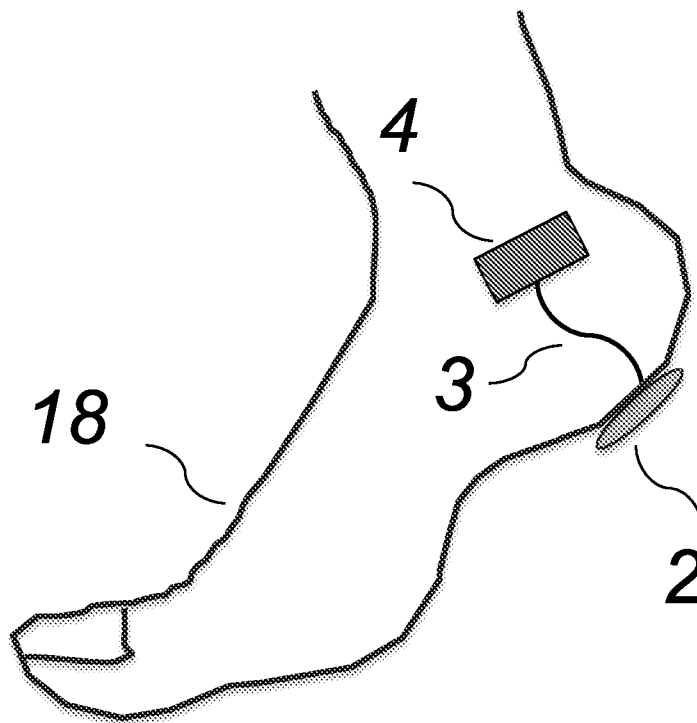


FIG. 8