(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
06 February 2020 (06.02.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/026171 A1

(51) International Patent Classification:
G16H 40/63 (2018.01) *A61G 7/05* (2006.01)
G16H 40/20 (2018.01) *A61G 7/057* (2006.01)
A61G 7/018 (2006.01) *A61B 5/00* (2006.01)

(21) International Application Number:
PCT/IB2019/056543

(22) International Filing Date:
31 July 2019 (31.07.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
18186655.9 31 July 2018 (31.07.2018) EP
18208379.0 26 November 2018 (26.11.2018) EP

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(54) Title: SENSING SYSTEM FOR PATIENT SUPPORT APPARATUS

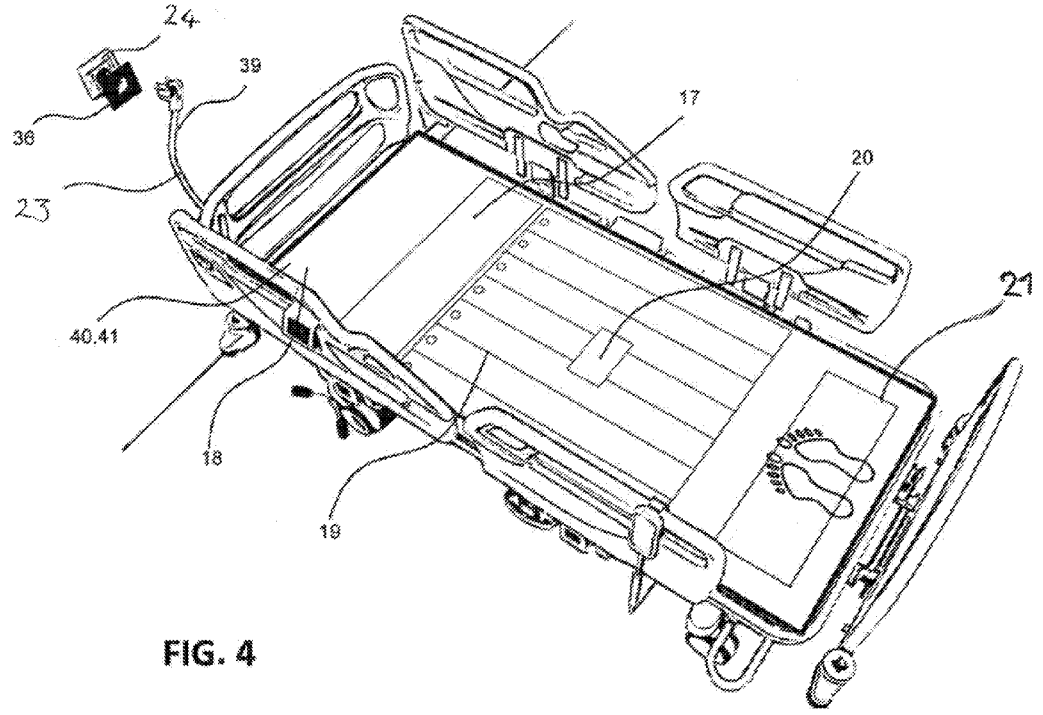

FIG. 4

(57) Abstract: A sensing system for patient support apparatus (1) including a mattress (3) supported on a patient support deck (6) mounted on a patient support apparatus frame. The sensing system comprises a flexible mat (5) for placement on the patient support deck between the mattress and the patient support deck. The flexible mat includes alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck (6) and a frame sensor or frame sensors (18) for sensing a position or orientation of the frame of the patient support apparatus, and a patient sensor or patient sensors (17, 19, 20) for sensing a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress. The flexible mat (5) also includes an electronic module (21) in communication with the sensors (17, 18, 19, 20) and a communication port coupled for transmitting data from the sensors to a location remote from the flexible mat.

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[Continued on next page]

(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, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, 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, ST, 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:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

SENSING SYSTEM FOR PATIENT SUPPORT APPARATUS

The present application claims priority, under 35 U.S.C. § 119(a), of European Application Nos. 18186655.9, filed July 31, 2018, and 18208379.0, filed November 26, 2018, each of which is hereby incorporated by reference herein.

BACKGROUND

The present disclosure relates to sensing systems for patient support apparatuses and particularly to systems that use a flexible mat or pad between a patient support deck and a mattress. Embodiments disclosed herein are suitable for use with, for example, hospital beds and/or stretchers (whether transport, trauma or procedural stretchers). More particularly, the present disclosure relates to systems that can be retrofitted to an existing patient support apparatus and allow the monitoring and/or sensing of a patient thereon and of aspects of the patient support apparatus itself and communicate sensed data to a location or data processor remote from the patient support apparatus (e.g. hospital bed, long term care bed and/or stretcher).

Good medical practice requires that patients be monitored whilst bed bound. Beds and bed systems have recently been developed and are known which allow one to separately monitor a number of patient characteristics or conditions (some of which can be used to inform treatment and/or positioning of the patient, or set off alarms warning of possible danger to the patient). These include arrangements or sensors to, for example, monitor or sense the following: patient weight, patient respiratory rate, patient heart rate, patient sleep, patient position, patient mobility and immobility, and incontinence detection.

It is also helpful to monitor the condition of the patient support apparatus, including the orientation of an articulated bed or stretcher. Patient support apparatus systems have been developed which allow one to, for example, monitor: whether or not a bed siderail is up or down; whether or not a bed is in its lowered or raised position; and/or the angle of the head section of an articulated patient support deck.

The combination of patient and patient support apparatus information allows one to control bed and care parameters which have an impact on and/or are affected by patient characteristics.

The monitoring of a patient and/or the patient support apparatus supporting that patient may be helpful for vitals tracking, falls prevention, pressure ulcer prevention, pulmonary

management, hospital and caregiver workflow solution, and earlier detection of sepsis. Detection of patient and/or patient support apparatus events or characteristics allows one to inform caregivers and/or a hospital information system (HIS) and solve or control those events which are negative.

Monitoring patient respiratory rate and heart rate allows one to detect sleep apnea and post-surgical respiratory distress. Sleep apnea and post-surgical respiratory distress can then be managed, for example, using an air mattress.

Monitoring the position of a patient in a bed or other patient support apparatus and the position of the bed siderail can be used to help prevent falls from a bed or patient support apparatus.

Sensing when a patient is immobile can help inform a caregiver or automated control system of the need to initiate a pressure ulcer prevention protocol. A sensing arrangement can be used to control an integrated air mattress or other pressure ulcer prevention apparatus or system.

Monitoring the angle of the head section of an articulated patient support apparatus (the “Head of Bed” or HOB position) helps pulmonary management by allowing control of the angle to optimize breathing.

Knowing the location of a patient support apparatus and its status (for example, whether it is available and/or clean) can inform hospital and caregiver working practices and rotas.

Monitoring respiratory rates and level of patient consciousness (by monitoring patient mobility or immobility) can help allow for earlier detection of sepsis.

Hospital beds are relatively expensive and long lasting items of equipment may be kept and used in a hospital for twenty years. This means that hospitals often have quite old beds and also have a number of different bed models and suppliers or manufacturers. In order for patient and/or bed data to be collectable from a diverse range of different beds and fed into a common hospital data processing system it is therefore desirable to have a sensing arrangement which is sufficiently flexible to be retro-fitted to a number of different bed models and be able to collect accurate bed and patient data and communicate that to a remote location for subsequent processing or monitoring.

SUMMARY

The present application discloses one or more of the features recited in the appended claims and/or the following features which, alone or in any combination, may comprise patentable subject matter:

The present disclosure in a first aspect provides a sensing system for a patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising: a flexible mat for placement on the patient support deck between the mattress and the patient support deck; a first, frame, sensor for sensing a position or orientation of the frame of the patient support apparatus, the first frame sensor being located on the flexible mat; a second, patient, sensor mounted on the flexible mat for sensing a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and a communication port coupled to the patient and frame sensors for transmitting data from the sensors to a location remote from the flexible mat.

Such a sensing system may be retrofitted to hospitals beds of varying age and manufacturer and allow a hospital to relatively inexpensively and easily upgrade aged historical beds from different manufacturers and with different built-in sensing capabilities to provide up to date sensing capability as well as communication between the sensing mat and hospital information, patient care and patient management systems.

The embodiments disclosed herein allow one to retrofit a very wide range of patient sensing capabilities.

Optionally, the sensing system may comprise alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck. The ability to align or orientate the flexible mat and any sensors fixed on it thence ensures that sensors can be accurately located at selected and pre-determined locations so as to optimize or ensure their functioning. Many patient and frame sensors should be accurately located in order to function effectively.

The flexible mat may be separate from the mattress or it may be incorporated in or attached to the bottom cover or underneath the mattress.

Optionally, a data processor is on the flexible mat and coupled to a communication port.

Also optionally, the patient sensor is selected from the group including patient position monitoring (PPM) sensor, respiratory rate sensor, heart rate sensor, piezo-electric sensor, capacitive sensor, pressure sensor, and incontinence detection. A heart rate sensor and/or a respiratory rate sensor may comprise one or more of: a piezoelectric sensor, particularly a ceramic piezoelectric sensor, vibration sensor, pressure sensor, or strain sensor, for example, a strain gauge. A heart rate sensor and/or a respiratory rate sensor may comprise a dynamic vibration sensitive electromechanical film, such as an electroactive polymer or ferroelectret, suitable for measuring the heart rate of a patient supported on a mattress above the flexible mat in the manner of a ballistocardiogram.

Further optionally, the frame sensor is selected from the group comprising head of bed angle (HOB) accelerometer or potentiometer, HiLo low frame position radar sensor, siderail up or down magnetic sensor.

A sensing arrangement may be connected to a user interface which may, for example, be mountable on the foot board of a/the hospital bed. The user interface may display status. The user interface may give an alarm when pre-defined or programmable alarm patient conditions are met or exceeded. The user interface may give an alarm when pre-defined or programmable alarm frame conditions are met or exceeded.

The present disclosure in a second aspect provides a sensing system for a patient support apparatus including a mattress supported on a patient support deck, the sensing system comprising: a flexible mat for placement on the patient support deck underneath the mattress; an incontinence event transmitter and/or receiver mounted on the flexible mat and operable to read data from an incontinence pad which, in use, is placed on an upper surface of the mattress; a further sensor mounted on the flexible mat and operable to sense a second event or parameter; and a communication bus coupled to the incontinence event transmitter and/or receiver and the further sensor for transmitting data sensed thereby to a location remote from the flexible mat.

The provision of an incontinence pad which may be located on top of the mattress but which is in communication with data processing and an antenna located on a mat placed under the mattress allows one to provide inexpensive disposable incontinence pads which can be easily replaced. An incontinence pad lying on top of a mattress rather than in a pocket or hollow provided in the mattress upper surface also means that the mattress can be easily cleaned after an incontinence event and there is no need for special mattresses.

Optionally, a data processor is on the flexible mat and the data processor receives data from the incontinence pad and from a further sensor, and is coupled to the communication port.

Also optionally, the further sensor is selected from the group comprising: a side-rail position sensor; an accelerometer for head-of-bed angle; a potentiometer of head-of-bed angle; radar sensor for bed height; a pressure sensor; a patient respiratory rate sensor; a patient heart rate sensor; a patient mobility or immobility sensor; and a load sensor.

Further optionally, the flexible mat is dimensioned such that its longitudinal dimensions correspond to the length of the patient support deck so that it is aligned or fixed on the support deck by engagement with edges of the patient support apparatus immediately surrounding an upper surface of the support deck. The flexible mat may be dimensioned such that its longitudinal dimensions correspond to a portion of the length of the patient support deck, such as a thigh section, seat section and a portion of a torso and head section of the patient support deck.

Such arrangements make use of the fact that hospital beds are designed to have standard dimensions to correspond to one or more standard sizes. Dimensioning the flexible mat so that it is held in a pre-determined position and orientation by the physical nature of the patient support deck itself means that an accurate but easy and inexpensive positioning of sensors on the mat relative to the patient support apparatus and a patient placed thereon is achieved or achievable.

If desired, the flexible mat has substantially the same length as a standard mattress and patient support deck. Additionally or alternatively, the flexible mat may have the same width as a standard mattress and patient support deck.

The flexible mat may be any suitable size. For example, the flexible mat may have a length of between about 50 millimetres and about 2500 millimetres. For example, the flexible mat may have a width of between about 50 millimetres and about 100 millimetres. Optionally, the flexible mat may be substantially 750 millimetres long and 850 millimetres wide. Optionally, the flexible mat is substantially 2 metres long and 90 centimetres wide. These are the dimensions of a standard hospital mattress in the European Union (EU). Bariatric mats of different but predetermined dimensions may be provided for mattresses for larger or obese patients or for countries having different standard mattress dimensions such as the USA. In the USA, standard mattress dimensions are 36 inches (approximately 90 cm)

wide and 80 inches (approximately 200 cm) long. A mattress wider than 36 inches (approximately 90 cm) in the USA is classified as a bariatric mattress. Although there may be a number of different possible mattress sizes, these are limited in number so a relatively small number of possible mat dimensions are necessary for any particular market or hospital.

The flexible nature of the mat means that it can be rolled up for storage and/or transport when it is not in use. They can therefore be easily stored in a hospital store room without taking up a large amount of space.

The flexible mattress may be made from a textile mesh coated with polyurethane (PU). The mat may have a thickness of about 4-5 mm (or less) other than where it supports the data processor or electronic module which may have a larger thickness of about 20 mm so as to support the data processor circuitry and components.

The data processor may be an electronic module capable of analyzing the sensor outputs. It may provide an alarm function. The data processor is optionally located on the portion of the mat which, in use, is located in the patient calf area. Alternatively the data processor may be provided remotely from the mat.

The flexible mat may comprise alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck.

The flexible mat may include straps for fixing it to the patient support deck.

The flexible mat may include a hook or loop connector arrangement for connection with a complementary hook or loop connector on the patient support deck.

The flexible mat may include a transmitter detachably connectable to a power source and configured to act as a wireless power source for the first antenna and further sensor.

The flexible mat may include an electrical lead for connection to a power source.

The sensing system may include a programmable location identifier for fixing to or adjacent a fixed power socket and connectable to the communication bus of the flexible mat, wherein the programmable location identifier is programmable with the location of the power socket to thereby identify the location of the flexible mat connected thereto.

The programmable location identifier may be wirelessly or physically connectable to the flexible mat.

The present disclosure in a third aspect provides a sensing system for a patient support apparatus including a mattress supported on a patient support deck, the sensing system comprising : a flexible mat for placement on the patient support deck underneath the mattress; a first sensor for sensing a position or orientation of the patient support apparatus, the first sensor being located on the flexible mat; a second sensor mounted on the flexible mat for sensing a condition of a patient on the mattress; a data processor mounted on the flexible mat and coupled to the first and the second sensor, wherein, in use, the data processor receives data from the first sensor and from the second sensor; and a communication port coupled to the data processor for transmitting data from the data processor to a location remote from the flexible mat.

Optionally, the sensing system may comprise alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck.

The present disclosure in a fourth aspect provides a patient support apparatus including a mattress supported on a patient support deck and a sensing system comprising: an incontinence pad on an upper surface of the mattress, the incontinence detection pad having a passive radio frequency identification (RFID) tag; a flexible mat between the mattress and patient support deck; an RFID reader mounted on the flexible mat and operable to read data from the incontinence pad RFID tag; a first antenna mounted on the flexible mat wherein, in use, the incontinence pad RFID tag is excited by energy emitted from the first antenna through the mattress and data from the RFID tag is reflected back through the mattress to an antenna on the flexible mat; a further sensor mounted on the flexible mat and operable to sense a second event or parameter; a data processor mounted on the flexible mat and coupled to the RFID reader and the further sensor, wherein, in use, the data processor receives data from the incontinence pad RFID tag and from the further sensor; and a communication port coupled to the data processor for transmitting data from the data processor to a location remote from the flexible mat.

Optionally, the sensing system may comprise alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck.

The present disclosure in a fifth aspect provides a patient support apparatus including a patient support deck supported by a frame and a mattress supported by the patient support

deck, the patient support apparatus also including a sensing system comprising : a mat on the patient support deck between the mattress and the patient support deck; a first frame sensor for sensing a position or orientation of the frame of the patient support apparatus, the first frame sensor being located on the flexible mat; a second patient sensor mounted on the flexible mat for sensing a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; a data processor mounted on the flexible mat and coupled to the first and the second sensors, wherein, in use, the data processor receives data from the first and from the second sensor; and a communication port coupled to the data processor for transmitting data from the data processor to a location remote from the flexible mat.

Optionally, the sensing system may comprise alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck.

The present disclosure in a sixth aspect provides a patient support apparatus including a patient support deck supported by a frame and a mattress supported by the patient support deck, the patient support apparatus also including a sensing system comprising: a flexible mat for placement on the patient support deck underneath the mattress; an incontinence event transmitter and/or receiver mounted on the flexible mat and operable to read data from an incontinence pad which, is use, is placed on the upper surface of the mattress; a further sensor mounted on the flexible mat and operable to sense a second event or parameter; a data processor mounted on the flexible mat and coupled to the incontinence event transmitter and/or receiver and the further sensor, whereby, in use, the data processor receives data from the incontinence pad and from the further sensor; and a communication bus coupled to the data processor for transmitting data from the data processor to a location remote from the flexible mat.

Optionally, the sensing system may comprise alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck.

The present disclosure in a seventh aspect provides a patient support apparatus including a patient support deck supported by a frame and a mattress supported by the patient support deck, the patient support apparatus also including a sensing system comprising: a flexible mat for placement on the patient support deck underneath the mattress; a first sensor for sensing a position or orientation of the patient support apparatus, the first sensor being located on the flexible mat; a second sensor mounted on the flexible mat for sensing a condition of a patient on the mattress; a data processor mounted on the flexible mat and

coupled to the first and the second sensor, wherein, in use, the data processor receives data from the first sensor and from the second sensor; and a communication port coupled to the data processor for transmitting data from the data processor to a location remote from the flexible mat.

Optionally, the sensing system may comprise alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck.

Good medical practice dictates that patients who are incontinent should be removed from the wet environment as soon as possible to avoid skin breakdown which can potentially lead to pressure ulcers. Prior art incontinent detection systems that generate an alarm when wetness is detected are known. False alarms are sometimes generated in such systems due to perspiration rather than biofluids from incontinent events. Thus, incontinence detection systems that reduce the number of false alarms would be appreciated by caregivers. Also, caregivers will appreciate incontinence detection systems that communicate with other healthcare information systems due to the enhanced alerting and data collection that such systems will permit.

The present disclosure in an eighth aspect provides a system for identifying the location of a powered care apparatus including a power lead, the system including a programmable socket device with male connectors for engaging with a wall socket or other similar power source, and a female socket portion for receiving the male connectors of the care apparatus power lead, the socket device further including a user interface for a user to program the device with the location of the power source into which it is connected.

The powered care apparatus may be a patient support apparatus.

Any embodiment of the present disclosure may, on its own or in combination with any of the features described above provide a sensing system for a patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising: a flexible mat for placement on the patient support deck between the mattress and the patient support deck; a first sensor for sensing a position or orientation of the frame of the patient support apparatus or sensing a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; the first sensor being mounted on the flexible mat; a second sensor mounted on the flexible mat for sensing a position or orientation of the frame of the patient support apparatus or sensing a

condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and a communication port coupled to the sensors for transmitting data from the sensors to a location remote from the flexible mat.

Any embodiment of the present invention may, on its own, or in combination with any of features described above provide a patient support apparatus including a mattress supported on a patient support deck and a sensing system comprising: an incontinence pad on an upper surface of the mattress, the incontinence detection pad having a passive radio frequency identification (RFID) tag; a flexible mat between the mattress and patient support deck; an RFID reader mounted on the flexible mat and operable to read data from the incontinence pad RFID tag; a first antenna mounted on the flexible mat wherein, in use, the incontinence pad RFID tag is excited by energy emitted from the first antenna through the mattress and data from the RFID tag is reflected back through the mattress to an antenna on the flexible mat; a further sensor mounted on the flexible mat and operable to sense a second event or parameter; a data processor mounted on the flexible mat and coupled to the RFID reader and the further sensor, wherein, in use, the data processor receives data from the incontinence pad RFID tag and from the further sensor; and a communication port coupled to the data processor for transmitting data from the data processor to a location remote from the flexible mat.

The present disclosure in a tenth aspect provides a sensing system for a patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising: a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and a support apparatus configured to support the plurality of sensors above a deck of a patient support apparatus, the support apparatus comprising at least one region of weakness configured to enable the flexible mat to flex at the region of weakness.

Patient support decks of patient support apparatuses, such as hospital beds, typically comprise uneven surfaces. The uneven surface of a patient support deck can affect the measurements of a sensor, particularly a pressure sensor, positioned between the patient support deck and a patient support surface, such as a mattress, that is supported on the

patient support deck. Patient support decks are also typically comprised of discrete sections that are articulable relative to each other, resulting in gaps of various sizes being formed between the deck sections. These gaps between deck sections can also have an effect on measurements of a sensor positioned between the patient support deck and a patient support surface supported on the patient support deck. Advantageously, providing a flexible mat for placement on the patient support deck with a support apparatus on which sensors of the mat are supported may reduce the effects of gaps and uneven surfaces of a patient support deck on measurements from the sensors.

The support apparatus may comprise at least one rigid element. The at least one region of weakness may comprise at least one region of reduced thickness in the at least one rigid element. The at least one region of weakness may comprise at least one cut-out region in the at least one rigid element. The at least one region of weakness may comprise at least one perforated region in the at least one rigid element. The at least one region of weakness may comprise at least one scored region in the at least one rigid element.

The at least one rigid element may be made from any suitable material. For example, the at least one rigid element may be made from a plastic material, and particularly a thermoplastic material. The at least one rigid element may be a thermoformed plastic material. For example, the at least one rigid element may be formed from a polymeric material, such as polyurethane, polyvinyl chloride (PVC) or acrylonitrile butadiene styrene (ABC). For example, the at least one rigid element may be formed from fibreglass, ceramic materials, polystyrene, or a resinous material, such as a polyphenyl ether (PPE) resin, and particularly noryl (registered trade mark).

The support apparatus may comprise a plurality of rigid elements. The at least one region of weakness may comprise a space between adjacent ones of the plurality of rigid elements.

The support apparatus may comprise at least one compressible element. The support apparatus may comprise a plurality of compressible elements. The at least one rigid element may be supported on the at least one compressible element. The at least one compressible element may be arranged in a cut-out region in a rigid element. The at least one compressible element may be arranged in a space between adjacent rigid elements.

The at least one compressible element may be formed from any suitable material. For example, the at least one compressible element may be formed from a foam material. The

foam material may be formed from any suitable materials. For example, the foam material may be formed from a polymeric material, such as: polyurethane, polyethylene or polyurethane. For example, the foam material may be formed from rubber, latex or silicone.

The flexible mat may further comprise: a thigh section for positioning on a thigh section of a patient support deck; and a torso section for positioning on a torso section of a patient support deck. In some embodiments, the flexible mat is configured to extend the length of a patient support surface, such as a mattress. However, in some embodiments, the flexible mat is configured to extend only partially along the length of a patient support surface, such as a mattress. In these embodiments, the flexible mat may be configured to extend over a thigh section of a patient support deck of a patient support apparatus, and extend at least partially over a head and torso section of a patient support apparatus. The thigh section of the flexible mat may be configured to extend over the length of a thigh section of a patient support deck, and the torso section of the flexible mat may be configured to extend at least partially over a head and torso section of a patient support deck.

The support apparatus of the flexible mat may comprises a region of weakness between the thigh section and the torso section. In use, this region of weakness may enable the flexible mat to bend or flex at the intersection between the thigh section of a patient support deck and the head and torso section of the patient support deck, when the head and torso section of the patient support deck is articulated relative to the thigh section of the patient support deck.

The present disclosure in an eleventh aspect provides a sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising: a thigh section for positioning on a thigh section of a patient support deck; a torso section for positioning on a torso section of a patient support deck; a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and an enclosure enclosing the plurality of sensors, the enclosure comprising an exterior surface at the thigh section and an exterior surface at the torso section, the exterior surface at the thigh section having a coefficient of static friction greater than the coefficient of static friction of the exterior surface of the torso section.

Patient support decks of patient support apparatuses are typically comprised of discrete sections that are articulable relative to each other, resulting in gaps of various sizes being formed between the deck sections. Such articulation can result in the total length of a patient support deck changing depending on the positions in which the patient support deck sections are arranged. For example, a gap between a thigh section of a patient support deck and a head and torso section of a patient support deck may increase when the head and torso section of the deck is moved from a horizontal position to an inclined position, thereby increasing the total length of the patient support deck. Since the length of the flexible mat is typically fixed, it is necessary for at least a portion of the flexible mat to be slidable over the patient support deck in order to accommodate for changes in the length of the patient support deck and/or pivoting of one portion of the patient support deck relative to another portion, with or without translational movement of the pivoting portion toward or away from the non-pivoting portion. Advantageously, providing the flexible mat with an enclosure having an exterior surface with sections having different coefficients of static friction enables some portions of the flexible mat to be slidable over the patient support deck with relative ease compared to other portions of the flexible mat.

When a patient support deck is in a seated or inclined position, where the head and torso section of a patient support deck is inclined relative to the thigh section of the patient support deck, a major portion of the weight of a patient supported on the patient support deck is supported by the thigh section of the patient support deck. Accordingly, where the flexible mat comprises a patient positioning monitoring sensor, such as a pressure sensor or load sensor, it is generally desirable to maintain the position of a patient position monitoring sensor at the thigh section of the patient support deck. Advantageously, providing the enclosure at the thigh section of the flexible mat with a coefficient of static friction that is greater than the coefficient of static friction of the enclosure at the torso section may result in the thigh section of the flexible mat requiring application of a greater force to the thigh section of the flexible mat for the thigh section of the flexible mat to slide over the patient support deck than the force required to be applied to the torso section of the flexible mat for the torso section of the flexible mat to slide over the patient support deck. This may result in the torso section of the flexible mat sliding over the patient support deck more readily than the thigh section, such that the position of the thigh section of the flexible mat is maintained in position over the thigh section of a patient support deck when the head and torso section of a patient support deck is articulated relative to a thigh section of the patient support deck.

The coefficient of static friction for the exterior surface of the torso section of the flexible mat and the coefficient of static friction for the exterior surface of the thigh section of the flexible mat may be measured in accordance with ISO 8295:1995. The exterior surface at the thigh section has a coefficient of static friction greater than the coefficient of static friction of the exterior surface of the torso section when measured according to ISO 8295:1995 using felt as the test surface.

ISO 8295:1995 is entitled "Plastics – Film and sheeting – Determination of the coefficients of friction." Generally, according to this standard method, a sample of the desired surface to be tested is attached to the bottom of a sled, which is then run across a horizontal test surface for a given distance. The sled has a square-shaped contact base of about 40 square centimetres (cm^2), and an edge length of about 63 millimetres (mm). The total mass of the sled is about 200 grams (g) ± 2 grams, exerting a normal force of about 1.96 Newtons (N) ± 0.02 Newtons. The test surface is flat and smooth. For purposes of this disclosure, the test surface upon which the sled is run to measure the coefficient of static friction is felt. The sled is placed on the test surface with the sample to be tested in contact with the test surface. The sled is rested on the test surface for 15 seconds (s), before the sled is moved across the test surface for a least 6 centimetres (cm). The initial force to start the sled and the average force over the distance is measured. The force measuring device should be able to measure frictional force to at least ±5% of its value. The first peak of the force measured is caused by static friction. The measured force at the first peak is divided by the sled weight to obtain the coefficient of static friction. It should be recognized that the coefficient of static friction for each of the exterior surface of the thigh section and the exterior surface of the torso section should be measured using a film made from the same material as the exterior surfaces of the thigh section and torso section respectively. Typically, the measurements of the coefficient of static friction are carried out at an ambient temperature of about 23 degrees Celsius, but may be carried out at other ambient temperatures provided that all samples are tested at the same ambient temperature.

The enclosure of the flexible mat may be formed from any suitable material or materials. For example, the enclosure may comprise a coated textile. The coating may be any suitable coating material, such as polyvinyl chloride (PVC), polyacrylate, rubber or polyurethane. Preferably, the enclosure of the flexible mat is substantially impermeable to liquids. Advantageously, a material substantially impermeable to liquids may protect the sensors from an incontinence event or other bodily fluids from a patient.

The present disclosure in a twelfth aspect provides a sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising: a thigh section for positioning on a thigh section of a patient support deck; a torso section for positioning on a torso section of a patient support deck; a patient position monitoring sensor arranged at the thigh section of the mat; and a tilt sensor arranged at the torso section of the mat, the tilt sensor being configured to monitor the angle of the torso and head end of the patient support deck.

The sensing systems of the present disclosure may be retrofitted to existing patient support apparatuses, such as hospital beds, which do not have any "smart" features. For example, such an existing patient support apparatus may not have any means for determining the position of the patient support deck, or means for tracking how long the patient support deck has been in a particular position. Accordingly, the sensing systems of the present disclosure may require sensors for determining characteristics of the patient support apparatus, as well as sensors for determining characteristics of a patient supported on the patient support apparatus.

It is advantageous to position a tilt sensor at the torso section of a patient support deck, in order to be able to monitor the angle of the torso and head section of a patient support deck.

When a patient support deck is in a seated or inclined position, where the head and torso section of a patient support deck is inclined relative to the thigh section of the patient support deck, a major portion of the weight of a patient supported on the patient support deck is supported by the thigh section of the patient support deck. Accordingly, where the flexible mat comprises a patient positioning monitoring sensor, such as a pressure sensor or load sensor, it is advantageous to position the patient position monitoring sensor at the thigh section of the flexible mat.

In some embodiments, the plurality of sensors may comprise at least one of: a patient respiratory rate sensor, and a patient heart rate sensor, arranged at the torso section. It is generally advantageous to arrange a heart rate sensor and a respiratory rate sensor at the torso section of the flexible mat since the heart and lungs of a patient are positioned in the torso of the patient, which is supported by the head and torso section of a patient support deck.

A respiratory rate sensor and a heart rate sensor may be arranged above the patient position monitoring sensor in the flexible mat. However, preferably, a respiratory rate sensor and a heart rate sensor are arranged below the patient position monitoring sensor in the flexible mat. In embodiments in which the flexible mat comprises a support apparatus, the at least one of: a respiratory rate sensor and a heart rate sensor may be disposed between the patient position monitoring sensor and the support apparatus. Surprisingly, the inventors have found that arranging a respiratory rate sensor and a heart rate sensor below a patient position monitoring sensor provides the optimum signal to noise ratio when both sensors are comprised in the flexible mat.

The sensing system may further comprises a data processor in communication with each of the plurality of sensors. The data processor may comprise a communication interface for communication with one or more locations remote from the mat. The communication interface may comprise one or more of a communication bus and a communication port. The communication interface may be configured for wireless communication with one or more locations remote from the mat. However, the communication interface may be configured for wired communication with one or more locations remote from the mat. Wired communication between the data processor of the flexible mat and one or more locations remote from the mat is preferred, due to interference from the patient support deck and patient support surface of the patient support apparatus making reliable wireless communication difficult. Furthermore, in some regions there are restrictions on the minimum distance allowed between a wireless communications transmitter and a patient. For example, the wireless communications transmitter may need to be at least 200 millimetres away from a patient supported on the patient support apparatus. Accordingly, providing flexible mat with a communication interface configured for wired communication, rather than wireless communication, avoids the need to consider such regulations.

The data processor may be arranged at the torso section. In particular, the data processor may be arranged with the tilt sensor. Since, in certain patient support deck positions, a major portion of the weight of a patient is supported by the thigh section of a patient support deck, the likelihood of a patient supported on a patient support surface, above the patient support deck, contacting the deck (i.e. “bottoming out”) is greater at the thigh section of the patient support deck than at the head and torso section of the patient support deck. Accordingly, arranging the data processor at the torso section of the flexible mat, rather than at the thigh section, reduces the likelihood of a patient coming into contact with the data processor of the flexible mat.

The flexible mat may further comprise an incontinence detection antenna at the thigh section of the mat, the incontinence detection antenna being configured for communication with a moisture detection element placed on the upper surface of the mattress. In some embodiments, the antenna is configured to emit energy to power a passive RFID tag of an incontinence detection pad placed between a patient and the mattress. The antenna may be further configured to receive backscattered data emitted from the passive RFID tag indicating whether the incontinence detection pad is wet or dry. Multiple incontinence detection antennas are provided in the mat in some embodiments. For example, one, two, three, four, five or six antennas may be provided in the mat.

The incontinence detection antenna may be arranged above the plurality of sensors. The plurality of sensors may be disposed between the incontinence detection antenna and the support apparatus. Advantageously, arranging the incontinence detection antenna above the plurality of sensors may reduce the likelihood of interference between the moisture detection element placed on the upper surface of the mattress and the incontinence detection antenna caused by the plurality of sensors.

In embodiments in which the flexible mat comprises a data processor, the data processor may be in communication with the incontinence detection antenna.

The sensing system may further comprise an auxiliary unit in communication with the data processor of the flexible mat.

The auxiliary unit may comprise a communication interface for communication with one or more locations remote from the sensing system. In some embodiments, the auxiliary unit may comprise a wired communication interface for communication with one or more locations remote from the sensing system. In some preferred embodiments, the auxiliary unit may comprise a wireless communication interface for communication with one or more locations remote from the sensing system.

Providing the sensing system with such an auxiliary unit, remote from the flexible mat, may enable the sensing system to provide wireless communication with one or more locations remote from the sensing system. This may particularly apply when the sensing system is used with a patient support apparatus with which wireless communication directly between the flexible mat and one or more locations remote from the sensing system is not possible. Wireless communication between the flexible mat and one or more locations remote from the sensing system may be prevented by the wireless signal experiencing interference due

to features of a patient support apparatus or due to regulations preventing the use of wireless transmitters in relatively close proximity to a patient.

The auxiliary unit may be configured to supply power to the flexible mat.

The auxiliary unit may comprise a connector for connecting the auxiliary unit to an external power supply. The external power supply may be a mains power supply. In these embodiments, the auxiliary unit may comprise an AC/DC converter. the auxiliary unit may further comprise a DC/DC converter for controlling the voltage supplied to the flexible mat from the external power supply. The external power supply may be the patient support apparatus, which may itself be connected to a mains power supply.

The auxiliary unit may comprise a power supply. The power supply may be configured to supply power to the flexible mat. This may be particularly advantageous where the sensing system is used with a patient support apparatus that is regularly moved around a hospital or care facility, such as a stretcher. The power supply may be any suitable type of charge storage device. Typically, the power supply is a battery, such as a lithium ion battery or a nickel-cadmium battery. The power supply may be a rechargeable power supply.

In preferred embodiments, the auxiliary unit comprises a data processor. The data processor may be configured to receive data from the flexible mat. The data processor may be configured to communicate data received from the flexible mat to one or more locations remote from the sensing system, via the communication interface.

In some embodiments, the auxiliary unit may be configured to be attached to a patient support apparatus. This may be particularly advantageous where the sensing system is used with a patient support apparatus that is likely to be moved around a hospital or care facility on a regular basis, such as a stretcher. the auxiliary unit may be configured to be attached to a frame of a patient support apparatus. the auxiliary unit may be configured to be attached to a bed frame. the auxiliary unit may be configured to be attached to a patient support apparatus, and in particular a frame of the patient support apparatus, in any suitable manner. For example, the auxiliary unit may comprise one or more of: brackets, straps, clips, screws and adhesives for attaching the auxiliary unit to the patient support apparatus.

The present disclosure in a thirteenth aspect provides a sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient

support apparatus frame, the sensing system comprising: a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising: a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and a data processor in communication with each of the plurality of sensors and comprising a communication interface for communication with one or more locations remote from the mat; and an auxiliary unit in communication with the data processor of the flexible mat, the auxiliary unit comprising a wireless communication interface for communication with one or more locations remote from the sensing system.

The data processor of the flexible mat may be configured to store a flexible mat identifier. The flexible mat identifier may be a unique identifier, such as a unique code, assigned to the data processor of the flexible mat in order to be able to identify the flexible mat over other such flexible mats.

The data processor of the flexible mat may be further configured to communicate data from the plurality of sensors and the flexible mat identifier to one or more locations remote from the mat. This may enable a system in a remote location to identify the origin of the data from the flexible mat.

The data processor of the flexible mat may be further configured to communicate data from the plurality of sensors and the flexible mat identifier to the data processor of the auxiliary unit. The data processor of the auxiliary unit may be configured to communicate data from the plurality of sensors and the flexible mat identifier received from the data processor of the flexible mat to one or more remote locations from the sensing system via the wireless communication interface.

As used herein, the term “remote location” is intended to include systems and devices connected to a network, such as a local-area network, particularly a local-area network of a healthcare facility or the like, and systems or devices connected to a wide area network and the internet. Accordingly the communication interface of the sensing system may connect the sensing system to a network, and particularly a local-area network of a healthcare facility.

In some embodiments, the data processor of the auxiliary unit is configured to store an auxiliary unit identifier. the auxiliary unit identifier may be a unique identifier, such as a unique code, assigned to the data processor of the auxiliary unit in order to be able to identify the auxiliary unit over other such auxiliary units.

The data processor of the auxiliary unit may be further configured to communicate data from the plurality of sensors, the flexible mat identifier, and the auxiliary unit identifier to one or more remote locations from the sensing system via the wireless communication interface. This may enable a remote location to better identify the patient support apparatus, and thereby which patient, from which the data from the flexible mat originated. Such a configuration may be required in situations in which flexible mats are interchangeable with auxiliary units. Such a situation may occur where each patient support apparatus in a care facility is provided with an auxiliary unit, but flexible mats are only provided on a patient support apparatus when the patient support apparatus is supporting a patient requiring the monitoring functionality of the sensing system.

The data processor of the auxiliary unit may be configured to receive a patient support apparatus identifier from a patient support apparatus. The data processor of the auxiliary unity may be further configured to communicate data from the plurality of sensors, the flexible mat identifier, and the patient support apparatus identifier to one or more remote locations from the sensing system via the wireless communication interface. In some situations, a patient support apparatus may already have the functionality of providing a patient support apparatus identifier to a remote location. In these embodiments, the data processor of the auxiliary unit may be configured to receive the patient support apparatus identifier, and send this identifier, with the flexible mat data, such that a remote location may be able to better identify the patient from which the flexible mat data originated.

The present disclosure in a fourteenth aspect provides a patient support apparatus comprising a mattress supported on a patient support deck and a sensing system according to any one of aspects ten to thirteen described above.

The present disclosure in a fifteenth aspect provides a system comprising: a patient support apparatus comprising a mattress supported on a patient support deck mounted on a patient support apparatus frame; and a sensing system comprising: a sensing mat for placement on the patient support deck between the mattress and the patient support deck, and the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event

affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and a data processor and a communication interface, wherein: the patient support apparatus is associated with patient support apparatus identification (PSA ID) data; the sensing system is associated with sensing system identification (SS ID) data; the data processor of the sensing system is configured to store the PSA ID data and the SS ID data; the data processor of the sensing system is configured to receive sensor data from the plurality of sensors of the sensing mat; and the data processor of the sensing system is configured to communicate the sensor data, along with the PSA ID data and the SS ID data, to one or more remote locations via the communication interface.

Some healthcare facilities comprise a plurality of systems connected to a network. The systems can include: asset tracking systems, patient tracking systems, admission, discharge and transfer (ADT) systems, and nurse call systems. The inventors have realised that existing healthcare facility systems may be used to determine the location of a sensing system that is in use with a patient support apparatus, by associating an identifier of the sensing system with an identifier of the patient support apparatus or an identifier of a fixed locator module mounted to a room wall, for example.

As an example, a sensing system in use with the patient support apparatus may be configured to send sensing system data and a unique sensing system identifier (SS ID) to a patient monitoring system connected to a hospital network. An asset tracking system also connected to the hospital network may record a patient support apparatus identifier (PSA ID) and associate the PSA ID with a location in the healthcare facility. In order to identify the location of the sensing system in the healthcare facility, the sensing system may use the known location of the patient support apparatus. The sensing system may store the identifier of the patient support apparatus (PSA ID) with which it is being used, and send the patient support apparatus identifier (PSA ID) along with the sensing system identifier (SS ID) and the sensing system data to the patient monitoring system. The patient monitoring system may access the asset tracking system over the hospital network, find the matching patient support apparatus identifier (PSA ID), and determine that the location associated with the patient support apparatus in the asset tracking system is the location of the sensing system. Advantageously, such a system does not require the sensing system to be connected to the asset tracking system, and does not require the asset tracking system to store sensing system identifiers (SS ID) or sensing system locations.

The communication interface of the sensing system may be configured for wireless communication with one or more locations remote from the sensing system. The communication interface of the sensing system may be configured for wired communication with one or more locations remote from the sensing system. The communication interface of the sensing system may be configured for both wired and wireless communication with one or more locations remote from the sensing system.

In some embodiments, the sensing mat comprises the data processor and communication interface of the sensing system. In some embodiments, the data processor and communication interface of the sensing system are comprised in an auxiliary unit, remote from the flexible mat.

In some embodiments, the PSA ID data is programmable into the data processor by a user. The sensing system may comprise a user interface on which a user may enter the PSA ID data.

In some embodiments, the patient support apparatus comprises a data processor and a communication interface, and the data processor of the patient support apparatus stores the PSA ID data. The data processor of the patient support apparatus may be configured to communicate the PSA ID data to the data processor of the sensing system via the communication interface of the patient support apparatus.

Advantageously, configuring a patient support apparatus to communicate PSA ID data to the sensing system may reduce the likelihood of input errors by a user inputting the PSA ID data to the sensing system, and may also reduce the workload for a user.

The communication interface of the patient support apparatus may be connected to the communication interface of the sensing system via a wired connection. The communication interface of the patient support apparatus may be connected to the communication interface of the sensing system via a wireless connection.

The system may further comprise a locator unit. The locator unit is associated with locator unit identification (LU ID) data. The locator unit may have a data processor and a communication interface, and the data processor of the locator unit may store the LU ID data. Preferably, the locator unit is configured to be fixed in a known location of a healthcare facility. The locator unit is typically fixed in position in a room of a healthcare facility, for example, by being screwed into a wall of the healthcare facility. The LU ID data

may be stored on a system of the healthcare facility, such as an asset tracking system, and associated in the asset tracking system with the location in the healthcare facility in which the locator unit is fixed.

In some embodiments, the locator unit is configured to communicate with the patient support apparatus. In some embodiments, the locator unit is configured to communicate with the sensing system.

The data processor of the locator unit may be configured to communicate the LU ID data to the data processor of the sensing system via the communication interface of the locator unit. The communication interface of the locator unit may be connected to the communication interface of the sensing system via a wired connection. The communication interface of the locator unit may be connected to the communication interface of the sensing system via a wireless connection.

The data processor of the sensing system may be configured to store the LU ID data.

The data processor of the sensing system may be configured to communicate the sensor data, along with the PSA ID data, the SS ID data and the LU ID data, to one or more remote locations via the communication interface.

This may be particularly useful when the patient support apparatus is regularly moved around a healthcare facility, and is not associated with a particular location in the healthcare facility in an asset tracking system.

In some embodiments, the data processor of the sensing system may be configured to communicate the sensor data, along with the PSA ID data, the SS ID data and the LU ID data, via the communication interface of the sensing system, to a patient monitoring system connected to a network. The data processor of the patient support apparatus may also be configured to communicate the PSA ID data to the data processor of the locator unit via the communication interface of the patient support apparatus. The data processor of the locator unit may be configured to communicate the LU ID data along with the PSA ID data, via the communication interface of the locator unit, to an asset tracking system connected to the network.

In these embodiments, the asset location system may be configured to store LU ID data and associate the LU ID data with a location in the healthcare facility. In these embodiments, the system may further comprise a patient locating system connected to the

network, the patient locating system being configured to access the patient monitoring system and the asset tracking system and determine the location of the sensing system by matching the PSA ID data received by the patient monitoring system and the PSA ID data received by the asset tracking system.

This type of system may be advantageous in healthcare facilities in which at least some of the patient support apparatuses are not configured to send identifiers to an asset tracking system.

In some embodiments, the sensing system comprises an auxiliary unit comprising the data processor and communication interface, the auxiliary unit being arranged in a separate location from the sensing mat. Preferably, the auxiliary unit is mounted to a frame of the patient support apparatus.

In these embodiments, the sensing mat may comprise a data processor and a communication interface. The sensing mat may be associated with sensing mat identification (SM ID) data, and the data processor of the sensing mat may store the SM ID data.

The data processor of the sensing mat may be configured to communicate the sensor data along with the SM ID data to the data processor of the auxiliary unit, via the communication interface of the sensing mat.

The data processor of the sensing system, in the auxiliary unit, may be configured to communicate the SM ID data, along with the SS ID data and the other data, such as the sensor data and LU ID data, where provided, to one or more remote locations.

The auxiliary unit may be an auxiliary unit as described above in any previous aspect. the auxiliary unit may be attached to the patient support apparatus frame.

The present disclosure in a sixteenth aspect provides a system comprising: a locator unit configured to be fixed in a known location of a healthcare facility, the locator unit comprising a data processor storing location unit identification (LU ID) data and a communication interface; and a sensing system comprising: a sensing mat for placement on a patient support deck of a patient support apparatus, between a mattress and the patient support deck, and the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is

dependent on a condition of, or an event affecting, a patient on the mattress; and a data processor storing sensing system identification (SS ID) data and a communication interface, wherein: the communication interface of the sensing system is connected to the communication interface of the locator unit; the data processor of the sensing system is configured to communicate the SS ID data to the data processor of the locator unit; and wherein the data processor of the locator unit is configured to communicate the LU ID data, along with the SS ID data, to one or more remote locations, via the communication interface of the locator unit.

Advantageously, such a system provides a straightforward low complexity and relatively low cost system for identifying the location of a sensing system in a healthcare facility.

The locator unit is typically fixed in position in a room of a healthcare facility, for example, by being screwed into a wall of the healthcare facility. This may substantially prevent or inhibit movement of the locator unit in the healthcare facility. Advantageously, this may ensure that the locator unit, and the associated LU ID data, can be reliably associated with a location in the healthcare facility. The LU ID data may be stored on a system of the healthcare facility, such as an asset tracking system, and associated in the asset tracking system with the location in the healthcare facility in which the locator unit is fixed.

The connection between the locator unit and the sensing system may be a wired connection or a wireless connection. The communication between the sensing system and the one or more remote locations may be via a wired connection or a wireless connection.

The present disclosure in a seventeenth aspect provides a locator unit configured to be fixed in a known location of a healthcare facility, the locator unit comprising a data processor storing location unit identification (LU ID) data and a communication interface; and a sensing system comprising: a sensing mat for placement on a patient support deck of a patient support apparatus, between a mattress and the patient support deck, and the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and a data processor storing sensing system identification (SS ID) data and a communication interface, wherein: the communication interface of the sensing system is connected to the communication interface of the locator unit; the data processor of the locator unit is configured to communicate the LU ID data to the data processor of the sensing system; and wherein the

data processor of the sensing system is configured to communicate sensor data from the plurality of sensors, along with the SS ID data and the LU ID data, to one or more remote locations, via the communication interface of the sensing system.

As described above, the locator unit is typically fixed in position in a room of a healthcare facility, for example, by being screwed into a wall of the healthcare facility. The LU ID data may be stored on a system of the healthcare facility, such as an asset tracking system, and associated in the asset tracking system with the location in the healthcare facility in which the locator unit is fixed.

The connection between the locator unit and the sensing system may be a wired connection or a wireless connection. The communication between the sensing system and the one or more remote locations may be via a wired connection or a wireless connection.

The present disclosure in an eighteenth aspect provides a system comprising: a locator unit configured to be fixed in a known location of a healthcare facility, the locator unit comprising a data processor storing location unit identification (LU ID) data and a communication interface, the locator unit being configured to communicate with a sensing system via the communication interface.

In some embodiments, the locator unit is configured to receive identification data from a sensing system, and to communicate the LU ID data, along with the sensing system identification data, to one or more remote locations, via the communication interface.

In some embodiments, the locator unit is configured to send the LU ID data to the sensing system, via the communication interface.

The communication interface of the locator unit may comprise one or more wired connection ports, such as a USB port. The communication interface may comprise one or more wireless connectors, such as a WiFi antenna. In some preferred embodiments, the communication interface comprises a USB port for connection to a sensing system, and a WiFi antenna for connection to one or more remote locations, such as one or more systems on a healthcare facility network.

The locator unit may also be configured to supply power to a sensing system. In some embodiments, the locator unit comprises a power connector, separate from the communication interface, for supplying power to a sensing system. In some embodiments, the locator unit comprises a port configured for the transfer of data and power between the

locator unit and the sensing system. For example, the locator unit may comprise a USB port. The locator unit may be configured to be connected to an AC power supply, and may comprise an AC/DC converter, such that the locator unit is configured to supply DC power to the sensing system.

The present disclosure in a nineteenth aspect provides a system comprising: a sensing system comprising: a sensing mat for placement on a patient support deck of a patient support apparatus, between a mattress and the patient support deck, the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and an auxiliary unit comprising an RFID tag storing sensing system identification (SS ID) data; and a locator unit configured to be fixed to a location of a healthcare facility, the locator unit comprising: a data processor storing locator unit identification (LU ID) data; an RFID reader; and a communication interface configured to communicate with one or more remote locations. The RFID reader of the locator unit is configured to interrogate the RFID tag of the sensing system and receive the SS ID data from the RFID tag. The data processor of locator unit is configured to communicate the LU ID data, along with the SS ID data, to one or more remote locations via the communication interface.

Advantageously, such a system may provide an inexpensive and reliable way to identify the location of a sensing system in a healthcare facility.

The sensing system may further comprise a power connector for receiving power from an external power supply, and wherein the RFID tag is located on or around the power connector.

The locator unit may comprise a power connector for connection with the power connector of the sensing system, and wherein the RFID reader of the locator unit is arranged to interrogate the RFID tag of the sensing system when the power connector of the sensing system is connected to the power connector of the locator unit.

The locator unit may be connectable to an AC power supply, and wherein the locator unit comprises an AC/DC converter for supplying DC power to the sensing system via the power connector.

An asset tracking system connected to a network may store the LU ID data and associates the LU ID data with a location in a healthcare facility.

The data processor of the sensing system may be configured to communicate the LU ID data, along with the SS ID data, to the asset tracking system, over the network, via the communication interface of the locator unit.

The asset tracking system may determine the location of the sensing system in the healthcare facility based on the LU ID data.

The communication interface of the locator unit may be a wireless communication interface.

The present disclosure in a twentieth aspect provides a locator unit for locating a sensing system in a healthcare facility, the locator unit comprising: a data processor storing locator unit identification (LU ID) data; an RFID reader for reading an RFID tag of a sensing system; and a communication interface configured to communicate with one or more remote locations.

The locator unit may comprise a power connector for connection to a power connector of a sensing system, and wherein the RFID reader of the locator unit is located on or around the power connector.

The locator unit may be connectable to an AC power supply, and wherein the locator unit comprises an AC/DC converter for supplying DC power to a sensing system via the power connector.

The communication interface may be a wireless communication interface.

It will be understood that features mentioned with reference to one aspect may also be applicable to other aspects. Additional features alone or in combination with any other feature(s), including those listed above and those listed in the claims and those described in detail below, may comprise patentable subject matter. Others will become apparent to those skilled in the art upon consideration of the following detailed description of illustrative embodiments exemplifying the best mode of carrying out the embodiments as presently perceived.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention in its various aspects will now be further described by way of example only and with reference to the accompanying Figs. in which:

Fig. 1 is a prospective view of a hospital bed suitable for use with embodiments of the disclosure;

Fig. 2 is a top plan view of the patient support deck of the hospital bed of Fig. 1;

Fig. 3 is a top plan schematic view of an embodiment of the disclosure;

Fig. 4 is a top plan view of the flexible mat of Fig. 3 in situ on the patient support deck of Fig. 3;

Fig. 5 is a schematic view of a moisture detection and alert system showing an incontinence detection pad (in phantom) beneath a patient, a receiving antenna pad (in phantom) beneath the incontinence detection pad, and a controller (in phantom) coupled to the receiving antenna pad configured to communicate one or more signals regarding incontinence detection to at least one of a hallway call light alert, a remote computer for display on a computer monitor, status board and a mobile;

Fig. 6 is a side elevation view of a patient hospital bed with an articulated deck including deck sections, showing the decks supported in an upper position and the deck sections in a linear configuration;

Fig. 7 is a front perspective view of a user interface for the health care bed of Fig. 1;

Fig. 8 is a simplified schematic view of the side elevational view of the bed of Fig. 1 showing an angled sensor mounting arrangement;

Fig. 9 is a plan schematic view of a sensing pad of an embodiment of the disclosure;

Fig. 10 is a side schematic view of the sensing pad of Fig. 9 positioned on a deck of a patient support apparatus in a flat position;

Fig. 11 is a side schematic view of the sensing pad of Fig. 9 positioned on a deck of a patient support apparatus with the patient support apparatus in a cardiac position, for raising the head and knees of a patient;

Fig. 12 is an exploded view of the sensing pad of Fig. 9;

Fig. 13 is an exploded view of a capacitive patient position monitoring sensor of the sensing pad of Fig. 9;

Fig. 14 is a lateral cross-section schematic view of the sensing pad of Fig. 9; positioned on a deck of a patient support apparatus;

Fig. 15 is a side schematic view of the sensing pad of Fig. 9 in use with a patient support apparatus;

Fig. 16 is a plan schematic view of the sensors and circuitry of the sensing pad of Fig. 9 forming part of a sensing system of an embodiment of the disclosure;

Fig. 17 is a schematic view of the circuitry of the sensing pad of Fig. 9;

Fig. 18 is a schematic view of an auxiliary unit of the sensing system of Fig. 15;

Fig. 19 is a lateral cross-section schematic view of a sensing pad of an embodiment of the disclosure;

Fig. 20 is a schematic view of an auxiliary unit of a sensing system of an embodiment of the present invention;

Fig. 21a is a schematic view of an auxiliary unit of a sensing system of an embodiment of the present invention;

Fig. 21b is a schematic view of an auxiliary unit of a sensing system of another embodiment of the present invention;

Fig. 22 is a process flow diagram illustrating a process for communicating data between a sensing pad and a hospital network;

Fig. 23 is a process flow diagram illustrating a process for communicating data between a patient support apparatus, a sensing pad and a hospital network;

Fig. 24 is a process flow diagram illustrating a process for communicating data between a locator unit, a sensing pad and a hospital network;

Fig. 25 is a process flow diagram illustrating a process for communicating data between a locator unit, a patient support apparatus, a sensing pad and a hospital network;

Fig. 26 is a process flow diagram illustrating a process for communicating data between a locator unit, a patient support apparatus, a sensing pad and a hospital network;

Fig. 27 is a process flow diagram illustrating a process for communicating data between a sensing pad of a sensing system, an auxiliary unit of the sensing system and a hospital network;

Fig. 28 is a process flow diagram illustrating a process for communicating data between a patient support apparatus, a sensing pad of a sensing system, an auxiliary unit of the sensing system and a hospital network;

Fig. 29 is a process flow diagram illustrating a process for communicating data between a locator unit, a patient support apparatus, a sensing pad of a sensing system, an auxiliary unit of the sensing system and a hospital network; and

Fig. 30 is a process flow diagram illustrating a process for communicating data between a locator unit, a patient support apparatus, a sensing pad of a sensing system, an auxiliary unit of the sensing system and a hospital network.

DETAILED DESCRIPTION

As used herein the term “width” is used to describe the dimension in the transverse direction of the support device and the term “length” is used to mean the dimension in the longitudinal direction of the support device. Similarly, the term “in a direction along the width of the support device” is used to mean in a direction along the transverse axis of the support device, and the term “in a direction along the length of the support device” is used to mean in a direction along the longitudinal axis of the support device. For example, where the support device comprises a mattress, the length of the mattress extends between the head end and the foot end of the mattress and the width of the mattress is the dimension perpendicular to the length, and extends between the sides of the mattress.

References to a bed are intended to encompass patient support apparatuses including beds, stretchers and other apparatuses including a surface for supporting a patient.

General

Fig. 1 shows a patient support system 1 (e.g., hospital bed or stretcher) including a base frame 2 and a patient support surface such as a mattress 3. A sensing mat 5 (see Fig. 3) is located between the mattress 3 and a support surface or support deck 6 of the patient support apparatus. The base frame 2 comprises a lower frame, supports or lift mechanisms coupled to the lower frame, and an upper frame movably supported above the lower frame by the supports. The lift mechanisms may be configured to raise and lower the upper frame with respect to the lower frame and move the upper frame between various orientations, such as, Trendelenburg and reverse Trendelenburg.

The upper frame includes a support deck 6 and a plurality of siderails 11. The deck may include a leg section 12, a thigh section 13, a seat section 14, and a head and torso section 15 as shown in Fig. 2. The leg section 12 and the thigh section 13 define a lower limb support section. The head and torso section 15 define an upper body support section. The leg section 12, the thigh section 13, and the seat section 14 define a lower body support section.

The siderails 11 are configured to move between a deployed position and a storage position, and are used to locate the perimeter of the upper frame and assist with ingress to the patient support apparatus and egress from the patient support apparatus.

The patient support surface 3 (e.g. mattress) is preferably configured to support a person thereon and move with the deck 6 between the various configurations. The patient support surface preferably includes a leg portion, a thigh portion, a seat portion, and a head and torso portion, which are each supported on corresponding sections 12, 13, 14, 15 of the deck.

Referring to Figs. 3 and 4, a plurality of patient sensors 17, 19, 20 arranged on the sensing mat 5 may be configured to monitor physical and physiological characteristics of a patient. At least one bed or frame sensor 18 for monitoring one or more characteristics of the bed's configuration is also provided on the sensing mat 5. The patient sensors may monitor at least one of: patient movement; patient breathing rate; patient heart rate; patient temperature. The data processor or mat control unit 21 has a WiFi module for communication with, for example, a hospital data network. A wired communication is also

a possible alternative solution. In some embodiments, a wired communication may be provided in addition to a WiFi module as a back-up solution if communication over WiFi is not possible. The bed or frame sensor may, for example, be an accelerometer for monitoring head of bed angle. The outputs of the sensors are transmitted to a controller or data processor 21.

A caregiver bed or patient support apparatus control graphical user interface (GUI) module 22 may be located on an outboard side of a siderail 11, although this need not be the case. The caregiver control module 22 includes bed position adjustment controls, such as head up and down controls, leg up and down controls, chair positioning controls, Trendelenburg and reverse Trendelenburg controls, and bed up and down controls.

Referring to Fig. 3, the flexible mat 5 is made from a textile or nylon mesh coated with polyurethane on which various sensors and associated circuitry are mounted. The mat is relatively thin (about 4 to 5 mm) over most of its area with a thicker section (about 20 mm) being provided to support the data processor 21 mounted thereon. The mat is thin and flexible so that it can be rolled up for transport and/or storage when it is not in use on a patient support deck.

The mat 5 is sized so as to snugly align with a standard patient support deck and be held in place by the upstanding edges of the patient support deck. In the European Union standard (non-bariatric) hospital mattresses are 200 cm long and 90 cm wide. The patient support deck is very slightly larger so as to accommodate that mattress size. The mats may in addition or alternatively to the alignment provided by the snug fit, include fasteners to fix and/or align the mat on the deck. These may include at least one of hook and loop fasteners (e.g. Velcro – registered trade mark) and straps to fix the mat to the frame or deck 6. It is desirable that the mat take up a pre-determined orientation on the deck so that the location of at least its frame characteristic sensors are in a pre-determined location relative to the frame and support deck. As will be described in more detail below, at least some of the sensors should be at selected positions for efficient working. These positions are typically relative to the longitudinal axis (i.e. length) of the bed so the key alignment is in the longitudinal direction. The mat may therefore be dimensioned so that it is held in place along that longitudinal axis by virtue of being adjacent to the footboard and headboard at the respective foot and head ends of the bed.

The sensing mat includes a plurality of sensors. These include at least one patient sensor 17, 19, 20 for sensing a condition or characteristic of a patient; and at least one bed or

frame sensor 18 for sensing a condition or characteristic of the frame or bed. In the example embodiment shown in Fig. 3, the mat includes:

a capacitive or piezo-electric pressure sensing sensor array 17 at the head end of the mat for monitoring respiratory rate, heart rate and the sleep condition of a patient on the mattress above the mat;

a patient position monitoring sensor 19 at the thigh section of the mat;

an incontinence detection antenna 20 for communication with a moisture detection element placed on the upper surface of the mattress;

an accelerometer 18 for monitoring the head of bed ("HOB") angle of the head end of the bed frame; and

a data processor or controller 21 in communication with each of the sensors on the mat and with one or more locations remote from the mat and the bed on which it is placed. The data processor 21 is provided with wireless and/or wired communication with that location remote from the bed. In some embodiments, the data processor is provided with wired communication with that location remote from the bed. The remote location may include at least one of: a hospital information network, nurse station computer monitor, ward status board, a hallway alarm or call light and a mobile device.

A graphical user interface of the caregiver module 22 is provided either as a separate standalone graphical interface unit which may be attached to the bed (e.g. the footboard) or be at a remote caregiver location such as a nurse station.

In the embodiment shown in Figs. 3 and 4 the mat and its associated sensors and electronics may be powered by a power line 23 for wired connection to a power socket 24 in, for example, the wall of the hospital ward or room in which the bed is located. The sensors may be in a wired communication with the power source accessed via the power cable. Alternatively or additionally the mat may include a transmitter which is detectably connected to the bed power and communication by which to provide a wireless power source for the sensor. A battery may also be provided on the mat as a primary or back-up power source. That battery may be charged by the transmitter or some other wireless charging system.

Sensing pressure distribution (e.g. capacitive sensor) and monitoring patient vital signs

Examples of sensors suitable for monitoring the respiratory rate, and heart rate sensor are described in EP3231356 and/or EP3231407. Below we describe an illustrative example of a capacitive sensor system 17 used to detect the essential characteristics of the patient's morphology and position on an articulated or non-articulated supporting structure of a bed or other patient support apparatus. The sensor construction is described in more detail in, for example, US2017/0290548 to which reference is now made and whose contents are hereby incorporated herein by way of reference. Such a sensor may also be used, for example, to adjust the fluid pressure within the air compartment(s) of an air mattress.

Further examples and details of possible sensors with which embodiments of the invention may be used are provided below.

The capacitive sensor 17 can be used to detect incremental body displacements allowing the detection and monitoring of vital signs. The ability of the sensing system to detect vital signs depends on its operating frequency when the capacitive sensor is connected to the oscillating circuit. Respiration causes potentially detectable movements.

The normal respiration frequency of a patient spans from around 0.1 Hz – 0.4 Hz, which corresponds to around 6 to 24 breaths/min and can be correctly detected by the sampling rate of the sensing system of the applicant's ClinActiv+ (a registered trade mark of the applicant) support system.

Controlling Air Mattress (not shown in Figs.)

Further capacitive pressure sensors (or the same pressure sensors used for monitoring vital signs such as respirator rate and heart rate) pressure sensors may be located on the mat 5 under the mattress 3 in an air support system and used to determine whether the air support system should be inflated or deflated. Whether the air support system should be inflated or deflated may be determined by comparison with the signal from one or more pressure transducers, which are used to measure the air pressure within the air compartment(s). The capacitive mat pressure sensor cooperates with one or more pressure sensors that measure the fluid pressures in the air mattress and the system computes the appropriate pressures to immerse and envelop the patient. Both types of sensor may be used because information from either the capacitive sensor or the pressure

sensors alone may not be enough for a closed loop sensing system to operate automatically. The pressure sensor output signals may also be combined with the signal from an accelerometer that is used as a tilt sensor to determine bed back rest angle, since back rest angle also impacts the pressure required to support a patient. This is only an example of the possible ways to determine whether inflation or deflation are required.

The overall capacitive sensor system may be described as the capacitive sensor and the relevant control environment including the electronic circuitry, the pressure transducer(s) and their respective interconnections.

According to one embodiment, the capacitive sensor may be the same type of sensor used within a "ClinActiv +" air mattress replacement system, which herein is used as an example of an air support system. An exemplary support device suitable for the present invention is provided in a mattress system available commercially and is marketed as the ClinActiv™ Therapy Mattress System from Hill-Rom Company, Inc. A schematic illustration of such an exemplary mattress is shown in U.S. Patent No. 7,849,545, the content of which is hereby incorporated herein by reference in its entirety. The mattress system comprises a mattress and a control unit. The control unit is spaced-apart from the mattress and is coupled pneumatically and electrically with the mattress by a connector assembly. The control unit includes a plurality of user interface modules which may be selectively coupled to the control unit to configure the mattress system with various functionalities. For example, one module may enable the mattress to be operated in a continuous low pressure mode and another module may enable the mattress to be operated in an alternating pressure therapy mode.

As described in U.S. Patent No. 7,849,545, an exemplary mattress includes an upper inflatable bladder layer having a plurality of laterally-extending inflatable cells or bladders. The plurality of laterally-extending cells or bladders cooperate to define various zones of the layer.

The mattress may also include a cardiopulmonary resuscitation (CPR) assembly.

Patient immobility and patient position monitoring using pressure

The flexible mat 5 may include thereon, at its thigh section, a patient mobility sensor 19 including a set of four pressure sensors or sensing elements of the type described in, for example, U.S. Patent No. 5,276,432 or EP 2,995,242.

The output from each sensing element is connected via wires to a patient mobility data processor which may be part of the mat controller and data processor 21 or may be incorporated in the patient mobility or immobility sensor 19. The patient mobility data processing hardware and software processes the forces sensed by each of the sensing elements to determine the location of the center of gravity of the combined mattress and patient which weigh down on the flexible sensing mat 5. As the position of the center of gravity of the mattress on its own is known, the center of gravity of a patient on the mattress can then be determined and used as part of a patient position monitoring system or apparatus in the manner described in U.S. Patent Application Publication No. 2012/0259245, U.S. Patent No. 5,276,432 or EP2995242.

The system includes or is connected to a buzzer or alarm for warning a caregiver if the patient position indicates a dangerous or potentially dangerous position, or bed exit is imminent or has happened. Bed exit is imminent when the center of gravity moves towards the edge of the bed. A center of gravity moving or moved towards the edge of the bed also indicates a potentially dangerous position with a possible fall from the bed being imminent or more likely.

The four pressure sensors may in an alternative embodiment be capacitive, piezo-electric or dielectric sensors.

The system functions by monitoring variables determined based upon output from the sensors. Preferably these variables may include a patient gravity center position and patient weight. One or more detection modes can be defined and implemented using the system based upon user selection, each detection mode having different predetermined parameters. These detection modes may include: a high sensitivity mode to monitor and alert for relatively small movements of a patient, applicable to patients who have tubes in their mouths or throats for example; a medium sensitivity mode used to monitor mobile patients and alert a caregiver if the patient attempts to sit up, or roll towards a side of the bed; and a low sensitivity bed exit mode used to monitor mobile patients to ensure they remain “in bed” as indicated by the user interface of Fig. 7.

Optionally the values of one or more of the center of gravity, Gc, and the global weight, Gw, may be subject to corrections to account for one or more of the angle of a back rest and the type of patient support element used.

For embodiments in which the patient support apparatus includes an adjustable back rest, the back rest can move from between a first angle and a second angle, such as from a substantially flat position to an angle that supports a patient in a sitting position. The angle of the back rest can affect the distribution of the patient's weight on each of the sensor boards.

When the back rest is raised or lowered, the gravity center Gc is modified by the mattress mass supported by the backrest frame. To correct for this error a rule is applied to modify the center of gravity as a function of the angle of the backrest. The modified center of gravity may be calculated based on the backrest angle (BA) and the mattress weight (Mw), taking into account the detected weight of the patient. In particular, the backrest angle compensation to Gc may be calculated as: $Gc\_c = Gc * Gw / (Gw - Mw*\sin^2(BA))$.

A correction to the value of the weight Gw can also be made, factoring in the back rest angle. In particular, a corrected value Gw_ref may be determined as a function of Gw_init and the change in backrest angle. To correct the load applied on the sensors when the backrest moves the corrected weight Gw_ref may be calculated as: Gw_ref = Gw_init * law(BA) / law(BA_init). Gw_init is the initial weight detected using the sensors when the system is activated, BA is the measured backrest angle, and BA_init is the initial backrest angle. The function "law(X)" is a predetermined function determined by experiment, with one example being: law(X) = (a*x^3+b*x^2+C*x+d)/d. The coefficients a, b, c and d are determined by experiment and may vary depending upon the type of mattress used.

The angle of the back rest may be determined continuously or at regular intervals using an accelerometer as described in more detail below. It is possible to use a different type of device to detect the backrest position provided the device signal can be translated into an angle to allow the correction law to be applied. Other embodiments may allow the user to input a value indicative of the angle of the back rest, if this value is fixed whilst the patient is in the bed.

It has been appreciated that the type of patient support element may affect the distribution of weight of the patient and therefore may affect the calculated center of gravity. Therefore, the calculation of Gc, or alternatively the rule threshold values for Gc, may be

corrected to account for the type of mattress. For example, the value of Gc may have a correction factor applied depending upon the type of mattress. In particular, the correction factor may differ depending upon whether the mattress is a foam or air variety.

The systems and arrangements described above and in more detail in, for example, U.S. Patent Application Publication No. 2012/0259245, U.S. Patent No. 5,276,432 or EP 2,995,242 can be used to detect movement by noting changes in the location of the center of gravity. They can therefore also be used to detect inactivity. In such a capacity, they could form part of a system or care protocol to, for example, reduce the risk of pressure ulcers, bed sores and other ailments which are or can be associated with prolonged periods of inactivity or bed rest.

Hospitals have specific procedures to reduce the risk of pressure ulcers and other ailments which are associated with prolonged periods of inactivity. These include at least one of repositioning of the patient at defined intervals and the use of inflatable air mattresses such as those described in, for example, EP 2,198,822. However, it is not always easily and/or immediately recognized when a particular patient is at risk of developing bed sores, pressure ulcers and/or similar, and should therefore be placed on a bed with an air mattress of the type developed and available for reducing the risk of such ailments. Patients are often placed on simple non-inflatable foam or similar mattresses at the start of their hospital stay. The systems described above are particularly suitable for use with such a foam or standard mattress to detect prolonged inactivity and hence a risk of pressure ulcers, bed sores and/or the like. A system could be provided in which the arrangements for detecting the center of gravity and hence the movement of the center of gravity associated with movement of the patient above and as set out in the following numbered paragraphs could be used to detect inactivity on a standard or foam mattress. When a defined prolonged period of inactivity is sensed or determined, at least one of an alarm could be activated and a message displayed on a caregiver screen prompting the caregiver to alter the change to the standard mattress for an air mattress (or similar) designed to reduce the risk of bed sores etc., or reposition the patient.

Head of bed angle

In some embodiments, the healthcare bed or other patient support apparatus has an on-board head of bed angle monitoring system. In some embodiments, an angle sensor is

mounted to the healthcare bed to detect changes in the head of bed angle. Programming logic embodied in computer circuitry installed on the bed calibrates the angle sensor and operates the head of bed angle monitoring system.

A suitable angle sensor arrangement is described in U.S. Patent No. 7,487,562 whose contents are hereby incorporated herein by reference.

Referring to Fig. 8, an accelerometer of the type described in U.S. Patent No. 7,487,562 is fixed to the sensing mat 5 rather than on the bed frame itself as shown in U.S. Patent No. 7,487,562. The healthcare bed 1 includes an upper frame 7 coupled to a base 2. The base 2 is movably supported by wheels 25.

As described above, the bed 1 includes longitudinally spaced head, seat, and leg sections 15, 14, 12, respectively. Each of the head, seat and leg sections of the bed has corresponding deck and mattress portions as will be readily understood by those skilled in the art. At least the head and leg sections 15, 12 are pivotable relative to the frame 7. In some embodiments, the seat section 14 may be pivotable relative to the frame 7, as well.

The head of bed angle monitoring system 18 of the bed 1 measures the angle of the head section 15 relative to gravity as described in U.S. Patent No. 7,487,562. The head of bed angle monitoring system accounts for changes in the angular position of the head section 15 relative to the frame, as well as changes in the angular position of the frame relative to the horizontal.

A number of mechanisms may be used to accomplish pivoting of the head section relative to the frame. For example, U.S. Patent No. 5,682,631 illustrates one example in which a healthcare bed has a head section mounted to a bed frame to pivot using a reduced-shear pivoting technique.

Incontinence detection

In some embodiments, the sensing mat 5 may include an RFID reader to communicate with an incontinence pad 28 located on the top of the mattress 3 (see Fig. 5). The RFID reader and incontinence pad provide an incontinence detection system of the type described in WO 2017/087452 whose contents are hereby incorporated by reference herein in their entirety. The sensor system or incontinence pad 28 and sensing pad 5 with

RFID antenna 20 in communication therewith may be implemented as part of a remote alert system 29 as shown in Fig. 5.

The construction of incontinence pad 28 may be as described in WO 2017/087452. An incontinence pad 28 is placed between a patient and an underlying mattress 3 of a patient bed 1 beneath the patient's pelvic area. In some embodiments, pad 28 is integrated into mattress 3 to form a part thereof, but is removable for replacement with a clean pad after an incontinence event occurs. A communication system or incontinence sensor 20 antenna is included in a substrate mounted on the flexible mat 5. The sensing mat 5 has on its surface an RFID reader and controller.

Upon detection of a moisture event the mat data processor or controller 21 communicates with remote circuitry to activate one or more in-room alerts such as indicators or illuminating devices that may located on or near bed 1 and that are easily viewed by a caregiver. Additionally or alternatively, the controller or data processor 21 communicates the event to devices for remote alerting such as a status board 30 or other visual display of a hospital information system, a hallway call light 31 such as a light in a dome light or alert light assembly, a computer monitor 32 of a nurse call system and/or an electronic medical records (EMR) system, or even a caregiver's mobile device 33.

The controller 21 may communicate the moisture event via Wi-Fi antenna or other known wireless communication equipment and protocols in some embodiments. Alternatively or additionally, controller 21 communicates the moisture event via a wired connection, such as a 37-pin nurse call cable. It will be appreciated that a healthcare facilities' network infrastructure, represented diagrammatically by arrow 34 in Fig. 5, serves as an intermediary between the incontinence sensor 20 and the one or more remote alerting devices 30, 31, 32, 33 with which the mat controller or data processor 21 communicates. Thus, wireless access points, gateways, routers, cabling, connection ports, jacks, and the like are the type of equipment represented by arrow 34 in Fig. 5. The communication described above in connection with detection of a moisture or incontinence event may also be used to communicate any event or activity sensed by the other sensors on the sensing mat 5. Consequently any discussion herein of communication involving the incontinence sensor 20 or antenna is equally applicable to the other sensors located on the sensing mat 5.

In some embodiments, information indicating that the incontinence pad 28 is dry or that no moisture event (or any other event sensing by one or more of the mat sensors) has

occurred is communicated by controller 21 to one or more remote computer devices, such as an EMR (electronic medical records) or HIS (hospital information systems) computer, for storage in a patient's EMR. Such information is communicated at pre-set intervals, such as every hour or every half hour or more or less frequently, for example. The interval for communicating such information is programmable by caregivers in some embodiments. Further alternatively or additionally, a caregiver selects a user input such as an icon on a graphical display of a patient bed or at remote computer to command the reader to poll the incontinence pad to obtain information regarding the wet/dry status of the pad. By permitting the caregiver to determine when the incontinence pad status information is received, alert fatigue is avoided because the caregiver receives the information when the caregiver is able to act on it.

An "on demand" system for requesting of moisture status from an incontinence detection apparatus such as those discussed above is described in WO 2017/087452 whose contents are already incorporated herein by way of reference.

Siderail

Some embodiments contemplated herein may include a siderail position sensor (not shown in Figs.). A proximity sensor capable of sensing when a complementary element on a siderail is nearby may be provided at a pre-determined location on the sensing mat so that it is actuated to produce a signal when the complementary element of the side rail is in a selected position.

The proximity sensor may be a Hall effect sensor of the type described in U.S. Patent Application Publication No. 2004/ 0177443 which combines with a magnet placed on a corresponding location on one or both of the siderails 11.

Referring to Fig. 6, a magnet 35 may be placed on a siderail 11 such that when the siderail is in its fully down position it is alongside a Hall effect sensor located on the flexible mat 5 such that a "siderail down" signal is produced in the manner described in U.S. Patent Application Publication No. 2004/ 0177443.

Patient support apparatus (e.g. bed) height

Embodiments within the scope of the present disclosure may also include a bed height sensor (not shown) on the sensing mat 5 for determining the height of the bed. The bed height sensor might include a radar for sensing when the moveable frame is in its raised (or lowered) position.

Patient support apparatus (e.g. bed) location

Embodiments contemplated herein include a mechanism or mechanisms for identifying the location of the bed. The location identification system may be an RFID on the sensing mat 5 which interacts with a hospital network to identity the bed location.

Referring to Figs. 3 and 4, an alternative bed location system includes a programmable socket location unit 36 which may be attached to a power socket 24. The socket unit 36 is programmed with the room location when it is connected to the power socket 24. The sensing mat power cable 23 has running alongside it a location cable 39 which is coupled to the socket location unit 36 when the bed 1 is in situ and the sensing mat 5 is connected to the power socket 24. The programmed location is then fed into the sensing mat data processor and thence to the subsequent data processing and information gathering and processing network(s) and system(s).

Referring to Fig. 4, the flexible mat 5 may have integrated WiFi capability 40 and a battery 41.

Preferred embodiments

Figs 9 to 17 show a preferred embodiment of a sensing system according to this disclosure.

The sensing system of the preferred embodiment includes a flexible mat 105 comprising a plurality of sensors. The flexible mat 105 is similar in many respects to the flexible mat 5 described above with reference to Fig. 3.

The flexible mat 105 is generally rectangular, having a length of about 750 millimetres and a width of about 850 millimetres. As such, the flexible mat 105 is not sized to extend over

the entire support deck of a patient support apparatus, but rather is sized to extend over a thigh and seat section, and at least partially over a head and torso section of a support deck of a patient support apparatus. The flexible mat 105 is relatively thin, having a thickness of between about 4 millimetres and about 5 millimetres.

The flexible mat 105 is divided into two sections, a thigh section 108 and a torso section 109. The thigh section 108 is sized to extend over a thigh section of a patient support deck. The torso section 109 is sized to extend over at least a portion of a head and torso section of a patient support deck. In this embodiment, the lengths of the thigh section 108 and the torso section 109 are substantially equal. On the outer surface of the flexible mat 105, an indicator line 110 is provided across the width of the mat, between the thigh section 108 and the torso section 109, to indicate the division between the sections. The indicator line 110 may be used by a caregiver when positioning the flexible mat 105 on a patient support deck, and may indicate the position at which the hips of a patient should be located, when a patient is supported on a patient support apparatus above the flexible mat 105.

Figs 10 and 11 show the flexible mat 105 in position on a support deck 6 of a patient support apparatus. As shown in Figs 10 and 11, the flexible mat 105 is positioned with the thigh section 108 extending over the thigh section 13 of the support deck 6, and extending partially over the seat section 14 of the support deck 6. The thigh section 108 of the flexible mat 105 does not extend over the leg section 12 of the support deck 6. Also as shown in Figs 10 and 11, the torso section 109 of the flexible mat 105 is positioned to extend over the remaining portion of the seat section 14 of the support deck 6 and partially over the head and torso section 15 of the support deck 6.

In some embodiments, the thigh section 108 of the flexible mat 105 may be held in position on the thigh section 13 of the support deck 6 by one or more of: straps, hook and loop fasteners or any other such attachment means. However, in this embodiment, the weight of a mattress supported on the support deck 6, above the flexible mat 105, is sufficient to maintain the flexible mat 105 in position on the support deck 6.

The flexible mat 105 comprises a plurality of sensors that are surrounded by an enclosure 160. The enclosure 160 typically comprises a textile or nylon coated with a plastic material, such as polyurethane. In this embodiment, the outer surface of the enclosure 160 at the thigh section 108 is different to the outer surface of the enclosure 160 at the torso section 109. The outer surface of the enclosure 160 at the thigh section 108 has a greater

coefficient of static friction than the outer surface of the enclosure 160 at the torso section 109. As a result, the torso section 109 of the flexible mat slides over the support deck 6 more easily than the thigh section 108. Enabling the torso section 109 of the flexible mat 105 to slide more easily over the support deck 6 than the thigh section 108 ensures that the thigh section 108 of the flexible mat 105 remains in position on the thigh section 13 of the support deck 6 when the head and torso section 15 of the support deck is articulated relative to the thigh section 13.

As the head and torso section 15 of the support deck 6 is articulated relative to the thigh section 13 of the support deck 6, a gap 16 between the head and torso section 15 of the support deck 6 and the seat section 14 of the support deck 6 widens or narrows, depending on the direction of articulation. For example, when the head and torso section 15 of the support deck 6 is raised from a lie flat position (Fig. 10) to an inclined cardiac position (Fig. 11), the gap 16 widens. As the gap 16 widens, the overall length of the support deck 6 effectively increases. To compensate for the changes in overall length of the support deck 6 due to articulation of the head and torso section 15 of the support deck 6, the outer surface of the enclosure 160 at the torso section 109 of the flexible mat 105 is configured with a lower coefficient of static friction than the outer surface of the enclosure 160 at the thigh section 108 of the flexible mat 105, such that the torso section 109 of the flexible mat 105 slides over the head and torso section 15 of the support deck 6, while the thigh section 108 of the flexible mat 105 remains in position on the thigh section 13 of the support deck 6.

The coefficient of static friction of the outer surface of the enclosure 160 is dependent on the material of the enclosure and the preparation of the outer surface of the enclosure. In some embodiments, the outer surface of the enclosure 160 at the thigh section 108 is formed of a different material to the outer surface of the enclosure 160 at the torso section 109. However, in this embodiment, the outer surface of the enclosure 160 is formed from the same material at both the thigh section 108 and the torso section 109, and the outer surface of the enclosure 160 at the thigh section 108 is treated to increase the ruggedness of the outer surface, thereby increasing the coefficient of static friction at the thigh section 108 relative to the torso section 109. An outer surface of the enclosure 160 may be treated in any suitable way to increase or decrease the coefficient of static friction of the outer surface. For example, an outer surface of the enclosure 160 may be polished to reduce the coefficient of static friction, or an outer surface of the enclosure 160 may be scored, notched or roughened in any suitable manner to increase the coefficient of static friction. In

some embodiments, friction increasing or reducing elements may be attached to the outer surface of the enclosure.

As mentioned above, the flexible mat 105 comprises a plurality of sensors. The plurality of sensors are shown in more detail in the exploded view of Fig. 12. As shown in Fig. 12, the flexible mat 105 generally comprises: a heart rate and respiratory rate sensor 117; a tilt sensor 118; and a patient position monitoring sensor 119. The flexible mat 105 also comprises incontinence detection antennas 120 for communication with a moisture detection element placed on the upper surface of the mattress of the patient support apparatus.

In this embodiment, the heart rate and respiratory rate sensor 117 comprises dynamic vibration sensitive electromechanical film, such as an electroactive polymer or ferroelectret, suitable for measuring the heart rate of a patient supported on a mattress above the flexible mat 105 in the manner of a ballistocardiogram. It will be appreciated that the heart rate and respiratory rate sensor 117 may be any suitable capacitive or piezoelectric pressure sensor or sensor array. The heart rate and respiratory rate sensor 117 extends over substantially the entire torso section 108 of the flexible mat 105, but does not extend beyond the torso section 108 to the thigh section 109.

The tilt sensor 118 is comprised in a controller module 121 arranged at the head end of the torso section 109 of the flexible mat 105. The tilt sensor 118 comprises an accelerometer that is suitable for monitoring the angle of inclination of the torso section 108 of the flexible mat 105.

The patient position monitoring sensor 119 comprises a flexible capacitive pressure sensing array, which is shown in more detail in Fig. 13. The patient position monitoring sensor 119 extends over substantially the entire thigh section 108 and torso section 109 of the flexible mat 105.

As shown in Fig. 13, the patient position monitoring sensor 119 comprises an array of capacitive pressure sensing elements. In this embodiment, the patient position monitoring sensor 119 comprises eight pressure sensing elements, each pressure sensing element extending substantially the length of the flexible mat 105. Accordingly, each pressure sensing element is arranged to extend longitudinally along a support deck 6 of a patient support apparatus. The capacitive sensing elements are arranged in a row extending substantially the width of the flexible mat 105.

In more detail, the patient position monitoring sensor 119 comprises an array of eight upper capacitive plates 163 formed from an electrically conductive fabric, such as a nickel/copper (NiCu) coated nylon. Each plate 163 has a width of about 85 millimetres, a length of about 710 millimetres and a thickness of about 0.13 millimetres. Adjacent plates 163 are spaced apart with a gap of about 15 millimetres being provided between adjacent plates. The sensor 119 also comprises eight lower capacitive plates 164, identical to the eight upper capacitive plates 163, with each lower capacitive plate 164 being aligned below one of the upper capacitive plates 163. A thin polyurethane (PU) dielectric sheet 165 is disposed between the upper capacitive plates 163 and lower capacitive plates 164, such that each pair of upper and lower capacitive plates 163, 164 forms a capacitor. Accordingly, the sensor comprises eight elongate capacitors. The dielectric sheet 165 has a thickness of about 320 micrometres, and extends substantially across the length and width of the patient position monitoring sensor 119. Pairs of wires 166 are connected to each capacitor, a first wire being connected to the upper capacitive plate 163 and the second wire being connected to the lower capacitive plate 164. The capacitive plates 163, 164 and dielectric sheet 165 are enclosed between a polyurethane top cover 167 and an identical a bottom cover 168, the top and bottom covers 167, 168 being welded together at the edges.

Referring back to Fig. 12, the incontinence detection antennas 120 comprise RFID reader antennas arranged at the thigh section 108 of the flexible mat 105. The RFID reader antennas are operable to read data from an RFID tag (not shown) of a moisture detection element or incontinence pad (not shown) placed on the upper surface of the mattress of the patient support. In use, the incontinence pad RFID tag is excited by energy emitted from the RFID reader antennas through the mattress and data from the RFID tag is reflected back through the mattress to the RFID reader antennas 120 on the flexible mat 105.

In this embodiment, the incontinence detection antennas 120 are offset from centre on the flexible mat 105, at one side of the thigh section 108 of the flexible mat 105. This arrangement of the incontinence detection antennas 120 is complementary to the arrangement of an RFID tag (not shown) of a moisture detection element or incontinence pad (not shown) placed on the upper surface of the mattress of the patient support. Accordingly, the arrangement of the incontinence detection antennas 120 is such as to minimise the distance between the incontinence detection antennas 120 and the RFID tag of the moisture detection element.

The heart rate and respiration rate sensor 117, the patient position monitoring sensor 119 and the incontinence detection antennas 120 are supported on a support apparatus 150.

The support apparatus 150 is configured to mask or hide uneven surfaces or gaps in the support deck 6 of the patient support apparatus from the sensors, and particularly from the patient position monitoring sensor 119.

In this embodiment, the support apparatus 150 comprises a rigid layer 151 including a plurality of rigid elements 152, 154. Each rigid element comprises a substantially flat, rigid plastic plate. Adjacent rigid elements 152, 154 are spaced apart to provide a gap 153 between the adjacent rigid elements that enable the flexible mat 105 to flex at that position. In more detail, the rigid layer 151 comprises four laterally extending rigid elements 152, and four longitudinally extending rigid elements 153. The four laterally extending rigid elements 152 are arranged in a row along the length of the flexible mat 105, with each laterally extending rigid element 152 extending substantially the width of the flexible mat 105. The four longitudinally extending rigid elements 153 extend either side of the laterally extending rigid elements 152, with two of the longitudinally extending rigid elements 153 extending on one side of the laterally extending rigid elements 152, and two of the longitudinally extending rigid elements 153 extending on the other side of the laterally extending rigid elements 152.

In this embodiment, the support apparatus 150 also comprises a compressible layer 155 including a plurality of compressible elements 156. Each compressible element 156 comprises a generally rectangular, substantially flat, compressible foam element. The plurality of compressible elements are spaced over the flexible mat, leaving longitudinal channels 157 free of compressible elements 156.

The compressible layer 155 forms the base of the flexible mat 105, with each compressible element 156 being attached to the underside of one of the rigid elements 152, 153 of the rigid layer 151. The heart rate and respiration rate sensor 117 is arranged directly on top of the rigid layer 151 of the support apparatus 150, at the torso section of the flexible mat 105. The patient position monitoring sensor 119 is arranged directly above the heart rate and respiration rate sensor 117. Surprisingly, the inventors have found that arranging the patient position monitoring sensor 119 above the heart rate and respiration rate sensor 117 provides an optimal signal compared to arranging the heart rate and respiration rate sensor above the patient position monitoring sensor.

An upper compressible layer 158 is provided directly above the patient position monitoring sensor 119 to help to distribute forces applied to the upper surface of the flexible mat 105 across the patient position monitoring sensor 119. The upper compressible layer 158 is

formed from a single flat foam element that extends substantially across the upper surface of the patient position monitoring sensor 119. The incontinence detection antennas 120 are arranged directly on top of the upper compressible layer 158, at one side of the thigh section 109 of the flexible mat 105. The incontinence detection antennas are arranged above the other sensors in order to avoid interference between the sensors, the incontinence detection antennas 120 and the RFID tag of the moisture detection element.

The support apparatus 150, heart rate and respiration rate sensor 117, patient position monitoring sensor 119, upper compressible layer 158 and incontinence detection antennas 120 are enclosed within the enclosure 160, as shown in Fig. 14.

The controller module 121 is provided at the head end of the torso section 108 of the flexible mat 105. Each of the heart rate and respiration rate sensor 117, patient position monitoring sensor 119 and incontinence detection antennas 120 are connected to the controller module 121 by a wired connection. The controller module 121 comprises circuitry housed in a substantially rigid plastic box, having a thickness or height of about 20 millimetres.

In Figs 14 and 15, the flexible mat 105 is shown supported on a support deck 6 of a patient support apparatus. As shown in Fig. 14, the support deck 6 generally comprises a central portion extending the length of each deck section, the central portions having longitudinal ridges 61, resulting in an uneven surface. The longitudinal channels 157 between the compressible elements 156 of the compressible layer 155 are arranged to accommodate the ridges 61 of the central sections of the support deck 6, such that the ridges 61 of the central sections of the support deck 6 are supported on the ridged elements 152 of the rigid layer 151.

Also as shown in Fig. 14, the support deck 6 generally comprises inclined end sections 62 at either side of the central portions. The compressible elements 156 at the sides of the compressible layer 155, and the longitudinally extending rigid elements 153 at the sides of the rigid layer 151 are arranged to enable the sides of the flexible mat 105 to flex to accommodate the inclined end sections 62 of the support deck 6. In particular, a gap is provided between the longitudinally extending rigid elements 153 and the laterally extending rigid elements 152 to enable the rigid layer 151 to flex at both sides. It has been found that providing a region of weakness between the longitudinally extending rigid elements 153 and the laterally extending rigid elements 152, such as the gap, reduces the

effect of the inclined end sections 62 on the end ones of the capacitive sensors at each side of the patient position monitoring sensor 119.

In Fig. 15, the flexible mat 105 is shown in use on a patient support apparatus, supported on a support deck 6, beneath a mattress 3. The flexible mat 105 is arranged with the controller module 121 towards the head end of the head and torso section 15 of the patient support deck 6.

In Figs 15 and 16, the controller module 121 of the flexible mat 105 is shown connected to an auxiliary unit 127, and the auxiliary unit 127 is connected to a mains power socket 24 via a power line 123. the auxiliary unit 127 is securely attached to the base frame 2 of the patient support apparatus. However, it is envisaged that in some embodiments the auxiliary unit 127 may be removably attached to the bed frame.

The controller module 121 is shown in more detail in Fig. 17. The controller module 121 comprises the tilt sensor 118, as mentioned above, and also comprises a data processor, in the form of a microcontroller 170, and a communication interface. The communication interface comprises a plurality of communication ports for connection to the sensors of the flexible mat 105, including: a port 171 for connection to the heart rate and respiration rate sensor 117, a port 172 for connection to the patient position monitoring sensor 119, and a port 173 for connection to the incontinence detection antennas 120. The communication interface also comprises a port 174 for connecting the controller module 121 to the auxiliary unit 127. In this embodiment the port 174 for connection to the auxiliary unit 127 is a USB port, configured for the transfer of power and data between the controller module 121 and the auxiliary unit 127. The controller module 121 may be configured to supply power to each of the sensors and antennas connected to the controller module 121. It is envisaged that the communication interface may comprise any suitable communication buses and ports for either wired or wireless connection to each of the sensors, antennas and the auxiliary unit 127. In particular, it is envisaged that the communication interface may comprise separate power and data ports. The communication interface may comprise a data port for communication of data between the controller module and the auxiliary unit. In some embodiments, the controller module may be configured to receive power directly from a mains power source.

The auxiliary unit 127 is shown in more detail in Fig. 18. the auxiliary unit 127 comprises a data processor, in the form of a microcontroller 180, and a communication interface. The communication interface comprises: a port 181 for connection to the controller module 121;

and a wireless connector 182 for establishing a wireless connection with one or more remote locations. The wireless connector 182 may be configured to communicate with one or more remote locations using at least one wireless protocol selected from Near Field Communication, Bluetooth, ZigBee, Wi-Fi, and Ultra-wideband.

The auxiliary unit 127 further comprises a power supply 183, in the form of a rechargeable nickel-cadmium battery, and a port 184 for connection to a mains power supply. In this embodiment, the ports 181, 184 are USB ports. However, it is envisaged that the port 181 for connection to the controller module 121 may be any suitable port for the transfer of data and power between the auxiliary unit 127 and the controller module 121. In embodiments in which the auxiliary unit 127 does not supply power to the controller module 121, the port 181 may be any suitable port for the communication of data between the auxiliary unit 127 and the controller module 121. In these embodiments, the port 181 may be a wireless connector, for wirelessly communicating data between the auxiliary unit 127 and the controller module 121. It is also envisaged that the port 184 for connection to a mains power supply may be any suitable port for the transfer of power from a mains power supply to the auxiliary unit 127. Since the port 184 in this embodiment is a USB port, DC power is supplied to the auxiliary unit 127. However, in some embodiments, AC power may be supplied to the auxiliary unit 127 via the port 184, and in these embodiments, it will be necessary to include an AC/DC converter in the auxiliary unit 127 to convert the AC power to DC power for powering the microcontroller 180 and recharging the battery 183.

It is generally advantageous to provide the sensing system with an auxiliary unit, separate from the flexible mat, in order to reduce the size of the electrical components comprised on and around the flexible mat. Furthermore, it may be advantageous to provide the wireless connector remote from the flexible mat, in order to obtain a better wireless connection to the one or more remote locations, and to ensure that the wireless connector is positioned sufficiently far away from a patient supported on the mattress above the flexible mat.

An alternative embodiment of the flexible mat 105 is shown in Fig. 19. The alternative embodiment of the flexible mat 105 shown in Fig. 19 is substantially similar to the flexible mat 105 shown in Figs 12 and 14, having the same heart rate and respiration rate sensor 117, patient position monitoring sensor 119, upper compressible layer 158 and enclosure 160. However, the flexible mat 105 shown in Fig. 19 does not comprise incontinence detection antennas, and includes an alternative support apparatus 150. The alternative support apparatus 150 comprises a single rigid element 152 extending substantially the length and width of the flexible mat 105. Where gaps 154 were provided between adjacent

rigid elements 152, 153 of the support arrangement of Figs 12 and 14, the rigid element 152 shown in Fig. 19 comprises regions of weakness 159 to enable the rigid element 152, and the flexible mat 105, to flex at these locations. The regions of weakness 159 comprise thinner regions of the rigid element 152, which are more easily bent and flexed than the other regions of the rigid element 152. The support arrangement of the flexible mat 105 of Fig. 19 also does not comprise a compressible layer, and so the rigid element 152 is only supported on the ridges 61 and inclined edges 62 of the support deck sections.

An alternative embodiment of the auxiliary unit 127 is shown in Fig. 20. The alternative embodiment of the auxiliary unit 127 shown in Fig. 20 is substantially similar to the auxiliary unit 127 shown in Fig. 18, having the same data processor, in the form of microcontroller 180, and communication interface, comprising USB port 181 for connection to the controller module and wireless connector 182 for wireless communication with one or more remote locations. the auxiliary unit 127 shown in Fig. 20 differs from the auxiliary unit 127 shown in Fig. 18 in that the auxiliary unit 1278 shown in Fig. 20 does not comprise a power supply, but rather comprises a plug 185 for direct connection to a mains power supply, an AC/DC converter 186 for converting the AC power supply from the mains connection to DC power, and a DC/DC converter 187 for controlling the DC power from the AC/DC converter 186. the auxiliary unit 127 is configured to supply power to the controller module, and to receive sensor data from the controller module.

In some embodiments, the auxiliary unit 127 may be configured to be secured or fixed in a particular location in a healthcare facility. For example, the auxiliary unit 127 may be configured to be secured by screws to a wall of a patient room of a healthcare facility. In these embodiments, the auxiliary unit 127 may be associated with identifying data, such as an auxiliary unit identifying code. In turn, the auxiliary unit identifying code may be associated with the location in the healthcare facility on an asset tracking system of the healthcare facility. The data processor of the auxiliary unit may store the auxiliary unit identifying code, and may be configured to transmit the auxiliary unit identifying code, along with sensor data received from the controller module, to one or more remote locations. In these embodiments, the asset tracking system is able to determine the originating location of the sensor data received from the sensing system based on the auxiliary unit identifying code communicated with the sensor data. These embodiments may be particularly useful in healthcare facilities in which patient support apparatuses, and flexible mats, are moved between different positions in a healthcare facility.

Locator units

Locator units are shown in Figs 21a and 21b. The locator units may be provided in addition to an auxiliary unit, such as the auxiliary unit 127 shown Figs 18, or may be provided instead of the auxiliary unit 127.

As shown in Fig 21a, a locator unit according to an embodiment of this disclosure includes a locator unit 190. Preferably, the locator unit 190 is fixed to a known location in a healthcare facility, such as by being screwed to a wall at the known location. The locator unit 190 comprises a port 190 for the transfer of data and power to an auxiliary unit or directly to a flexible mat, via line 123. In this embodiment, the port 190 is a USB port. The locator unit 190 a plug 195 for connection to a mains power supply, an AC/DC converter and DC/DC converter 196 for converting the AC power supply from the mains connection to DC power and controlling the DC power from the AC/DC converter. The locator unit 190 further comprises a data processor, in the form of a microcontroller 198, and a wireless connector 199 configured to wirelessly transmit data to one or more remote locations.

The microcontroller 198 of the second unit 193 stores location identifying data (LU ID). The location identifying (LU ID) data is data that is associated with the known location of the locator unit in the healthcare facility. The LU ID data is stored on an asset tracking system of the facility, and is associated with the known location of the locator unit 190. The asset tracking system is connected to a network of the healthcare facility, and the wireless connector 199 is configured to communicate wirelessly with the asset tracking system over the network.

A sensing system configured for use with such a locator unit may comprise sensing system identification (SS ID) data stored on a memory of the sensing system. The SS ID data may be stored in the memory of a data processor of a flexible mat or an auxiliary unit.

The data processor storing the SS ID data may be configured to communicate the SS ID data to the locator unit when the sensing system is connected to the port 191 of the locator unit 190. When the locator unit 190 receives the SS ID data from the sensing system, the microcontroller 198 and wireless connector 199 of the locator unit 190 are configured to wirelessly communicate the SS ID data, along with the LU ID data, to the asset tracking system, via the healthcare facility network. Since the LU ID data is associated with the known location of the locator unit 190 in the healthcare facility on the asset tracking

system, the asset tracking system is able to locate the sensing system at that known location in the healthcare facility.

It will be appreciated that in some embodiments, the wireless connector 199 of the locator unit 190 may be a wired connector configured for communication with one or more remote locations, such as the asset tracking system on the healthcare facility network. Similarly, the connection between the sensing system and the locator unit 190 may be a wireless connection. Furthermore, it will be appreciated that in some embodiments, the locator unit may not be configured to communicate the LU ID data with one or more remote locations. Alternatively, in these embodiments, the locator unit may not comprise the wireless connector 199. In these alternative embodiments, the microprocessor 198 of the locator unit 190 may be configured to communicate the LU ID data to the sensing system, and the sensing system may be configured to communicate the LU ID data, along with the SS ID data to one or more remote locations, such as the asset tracking system. Furthermore, it will be appreciated that, in some embodiments, the locator unit 190 may be configured for the communication of data with the sensing system. In these embodiments, the locator unit 190 may not be configured to supply power to the sensing system.

As shown in Fig. 21b, a locator system according to another embodiment of this disclosure includes a first unit 190, comprising a port 191 for the transfer of power to an auxiliary unit or directly to a flexible mat, and an RFID tag 192. The RFID tag 192 may be programmed to store and transmit identification data for the sensing system (SS ID) data. The SS ID data is unique to each sensing system, such that SS ID data from one sensing system would identify the sensing system over another sensing system. The SS ID data may be associated with an entire sensing system, such as a flexible mat and auxiliary unit, or may be associated with a flexible mat only, or an auxiliary unit only.

The programmable location identifying system also includes a second unit 193. The second unit 193 comprises: a port 194 for connection to the port 191 of the first unit 190, a plug 195 for connection to a mains power supply, an AC/DC converter and DC/DC converter 196 for converting the AC power supply from the mains connection to DC power and controlling the DC power from the AC/DC converter. The second unit 193 also comprises an RFID reader 197 arranged to communicate with the RFID tag 192 of the first unit 190, when the port 191 of the first unit 193 is connected to the port 194 of the second unit 193. The second unit 193 further comprises a data processor, in the form of a microcontroller 198, and a wireless connector 199 configured to wirelessly transmit data to one or more remote locations.

The microcontroller 198 of the second unit 193 stores location identifying data. The location identifying data is data that is associated with a particular location in a healthcare facility on an asset tracking system of the facility. The asset tracking system is connected to a network of the healthcare facility, and the wireless connector 199 is configured to communicate wirelessly with the asset tracking system over the network.

When the first unit 190 is engaged with the second unit 193, the RFID reader 198 is configured to read the RFID tag 192 of the first unit 190, and receive the SS ID data from the RFID tag. The microcontroller 198 and wireless connector 199 of the second unit 193 are configured to wirelessly communicate the SS ID data, along with the location identifying data, to the asset tracking system, via the healthcare facility network. Since the location identifying data stored in the microcontroller of the second unit 193 is associated with a location in the healthcare facility on the asset tracking, the asset tracking system is able to locate the sensing system at that location in the healthcare facility.

These types of systems may be useful when sensing systems are used with patient support apparatuses that do not have their own location identifying systems.

Location identifying systems

Figs 22 to 30 show process flow diagrams for a plurality of embodiments of location identifying systems, which may be used to determine the location of the sensing system in a healthcare facility. The location identifying systems are described with reference to a "sensing mat". The sensing mat may be a "flexible mat" as previously described. However, it will be appreciated that the location identifying system may be used with other sensing systems and apparatus, particularly sensing systems and apparatus used with patient support apparatuses in healthcare facilities.

Fig. 22 shows a first embodiment of a location identifying system for a sensing system according to this disclosure. The sensing system comprises a sensing mat 200 comprising a plurality of sensors, as previously described. In this embodiment, the sensing mat 200 comprises a data processor and a communication interface, and the sensing mat 200 is connected to a network 202 of the healthcare facility via the communication interface. The connection between the sensing system and the network may be a wired connection or a wireless connection.

The data processor of the sensing mat 200 stores sensing system identification (SS ID) data. The SS ID data is unique to each sensing mat 200, such that SS ID data from one flexible mat would identify the flexible mat over another flexible mat. The data processor of the sensing mat 200 is also programmable to store personal support apparatus identification (PSA ID) data. The PSA ID data is unique to each personal support apparatus, such that PSA ID data from one patient support apparatus would identify the flexible mat over another flexible mat. A user interface (not shown) is connected to the data processor of the sensing mat 200, and enables a user to input PSA ID data associated with a patient support apparatus with which the sensing system is being used.

The sensing mat 200 is configured to communicate sensor data from the plurality of sensors, along with the SS ID data and the PSA ID data, to one or more remote locations on a network 202, via the communication interface.

In some healthcare facilities, an asset tracking system, or other such system, may be used to keep track of the location of patient support apparatuses by varies means. In this embodiment, an asset tracking system is connected to the network 202 and stores PSA ID data in association with known locations of patient support apparatuses. The asset tracking system receives the SS ID data, the PSA ID data, and the sensor data from the sensing mat 200. The asset tracking system recognises the PSA ID data, and may associate the location of the patient support apparatus with the sensing mat 200. Accordingly, by sending the PSA ID data with the sensor data, the location of the sensing system may be determined by the asset tracking system. This type of system may be particularly useful in healthcare facilities in which patient support apparatuses are generally fixed in a known location in a healthcare facility.

Fig. 23 shows a second embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 23 is substantially similar to the location identifying system shown in Fig. 22. However, instead of the data processor of the sensing mat 200 being programmable for a user to enter the PSA ID data, the patient support apparatus 204 with which the sensor is being used is configured to send the PSA ID data to the data processor of the sensing mat 200. In more detail, the patient support apparatus 204 comprises a data processor storing the PSA ID data, and a communication interface connected to the communication interface of the sensing mat 200. The connection between the patient support apparatus 204 and the sensing mat 200 may be a wired or a wireless connection. The patient support apparatus

204 is configured to communicate the PSA ID data to the sensing mat 200 over the connection.

In the embodiments of Figs 22 and 23, there may be provided a locator unit fixed at a known location of a healthcare facility. The locator unit is a unit that is separate from the sensing system and the patient support apparatus, and is fixed in a location of a healthcare facility. The locator unit is associated with locator unit identification (LU ID) data, which is stored on the asset tracking system and associated with the location of the locator unit in the healthcare facility. The locator unit comprises a data processor storing the locator unit identification data, and a communication interface. The communication interface of the locator unit may be connected to a communication interface of the patient support apparatus. The connection may be a wired connection or a wireless connection.

In some embodiments, the data processor of the locator unit is configured to communicate the LU ID data to the patient support apparatus, and the patient support apparatus is configured to send the LU ID data along with the PSA ID data to one or more remote locations on a network, such as an asset tracking system.

In some embodiments, the patient support apparatus is configured to communicate the PSA ID data to the locator unit, and the locator unit is configured to send the LU ID data along with the PSA ID data to one or more remote locations on a network, such as an asset tracking system.

In these embodiments, the location of the sensing system may be determined by matching the PSA ID data sent with the sensor data and SS ID data to the PSA ID data sent with the LU ID data, and determining that the sensing system is at the known location of the locator unit associated with the LU ID data on the asset tracking system.

Fig. 24 shows a third embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 24 is substantially similar to the location identifying system shown in Fig. 23, but instead of a patient support apparatus 204 communicating the PSA ID data to the sensing mat 200, a locator unit 206 communicates identification data to the sensing mat 200. The locator unit 206 is a unit that is separate from the sensing system and the patient support apparatus, and is fixed in a location of a healthcare facility. The locator unit 206 is associated with locator unit identification data, which is stored on the asset tracking system and associated with the location of the locator unit in the healthcare facility. The locator unit comprises a

data processor storing the locator unit identification data, and a communication interface configured to communicate the locator unit data to the sensing mat 200. The connection between the locator unit 206 and the sensing mat 200 may be a wired or a wireless connection.

In some embodiments, the locator unit data may be used by an asset tracking system instead of PSA ID data to track the location of patient support apparatuses. It may be preferable to use locator units, rather than patient support apparatuses, to identify the location of patient support apparatuses and sensing systems in situations in which patient support apparatuses and sensing systems are moved between different locations in a healthcare facility on a regular basis.

The communication interface of the locator unit may be further configured to communicate with one or more remote locations on the healthcare facility network. The locator unit may also communicate the LU ID data to one or more remote locations, such as to an asset tracking system. The LU ID data may be associated with a particular location in a healthcare facility on the asset tracking system, and may be used to determine the location of the sensing system 200, as described previously with reference to the PSA ID data.

In some embodiments, the communication interface of the locator unit 206 is also configured to communicate the LU ID data to the patient support apparatus 204. In these embodiments, a communication interface of the patient support apparatus may be configured to communicate the PSA ID data, along with the LU ID data, to one or more remote locations. The connection between the locator unit and the patient support apparatus may be a wired connection or a wireless connection. In these embodiments, the communication interface of the patient support apparatus may be configured to communicate the LU ID data and PSA ID data to an asset tracking system on a network of the healthcare facility. The asset tracking system may be configured to locate the patient support apparatus in the healthcare facility using the LU ID data. Furthermore, the asset tracking system may be configured to determine that the sensing system 200 is being used with the patient support apparatus using the matching LU ID data.

In some embodiments, the sensing system may be configured to communicate the SS ID data to the locator unit. In these systems, the locator unit may communicate the LU ID data, along with the SS ID data to an asset tracking system on the network 202. The connection between the locator unit and the one or more remote locations may be a wired connection or a wireless connection. For example, the communication interface of the

locator unit may comprise a wireless connector. For example, the communication interface of the locator unit may comprise a communication port, such as a USB or Ethernet port, configured for wired connection with a network.

In these embodiments, where the locator unit is configured to communicate the LU ID data along with the SS ID data to an asset tracking system on the network 202, the LU ID data need not be sent to the sensing system 200. Accordingly, the data processor of the locator unit may not be configured to send the LU ID data to the data processor of the sensing system. In these embodiments, an asset tracking system receiving the LU ID data and SS ID data from the locator unit is able to identify the location of the sensing system based on the known locator unit location.

As mentioned above, the locator unit may also be configured to supply power to the sensing system. Preferably, the locator unit is configured to be connected to a mains power supply. In these preferred embodiments, the locator unit comprises an AC/DC converter, and is configured to supply DC power to the sensing system. In some preferred embodiments, the locator unit comprises a communication port configured to communicate data and supply power to the sensing system. For example, the locator unit may comprise a USB port.

Fig. 25 shows a fourth embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 25 is substantially similar to the location identifying system shown in Fig. 24, but rather than the locator unit 206 sending the locator unit identification data directly to the sensing mat 200, the locator unit is configured to send the locator unit identification data to the patient support apparatus 204. The patient support apparatus 204 is configured to send the locator unit identification data, along with the PSA ID data, to the sensing mat 200. The sensing mat 200 is configured to communicate the sensor data from the plurality of sensors, along with the locator unit identification data, PSA ID data, and SS ID data to one or more remote locations, via the communication interface. In this embodiment, the PSA ID data, or the locator unit identification data, may be used to determine the location of the flexible mat by identifying the location of the locator unit on an asset tracking system.

Fig. 26 shows a fifth embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 26 is substantially similar to the location identifying system shown in Fig. 25, but rather than the locator unit 206 being connected to the patient support apparatus 204, the locator unit 206

is connected directly to the sensing mat 200. Accordingly, the locator unit 206 directly communicates the locator unit identification data to the sensing mat 200.

Fig. 27 shows a sixth embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 27 is substantially similar to the location identifying system shown in Fig. 22. However, in this embodiment, the sensing system comprises a sensing mat 210, comprising a plurality of sensors, and an auxiliary unit 212.

The sensing mat 210 comprises a data processor storing sensing mat identification (SM ID) data, and a communication interface. The communication interface of the sensing mat 210 is not connected to the network 202 of the healthcare facility, but rather the communication interface of the sensing mat 210 is connected to the auxiliary unit 212. The sensing mat 210 is configured to communicate sensor data from the plurality of sensors, along with the SM ID data, to the auxiliary unit 212.

The auxiliary unit 212 comprises a data processor storing auxiliary identification (SS ID) data, and a communication interface. The data processor of the auxiliary unit 212 is configured to communicate sensor SS ID data, along with sensor data and SM ID data received from the flexible mat 20, to one or more remote locations, via the communication interface.

Such systems, including both identification data for the sensing mat 210 and the auxiliary unit 212 of the sensing system may be useful in healthcare facilities in which flexible mats 210 are interchangeable with auxiliary units 212, such that different flexible mats 210 may be paired with different auxiliary units 212 depending on the current needs of patients in the healthcare facility.

In these embodiments, an auxiliary unit 212 of a sensing system may be fixed to a patient support apparatus, and the SS ID data of the auxiliary unit 212 may replace the PSA ID data of the system shown in Fig. 22. Similarly to the system described above with reference to Fig. 22, the location of the patient support apparatus, and therefore the auxiliary unit 212 fixed to the patient support apparatus, may be known to an asset tracking system. As a result, the SS ID data from the auxiliary unit 212 may be used to identify the location of the person support apparatus.

Alternatively, as in the system shown in Fig. 22, the patient support apparatus may be associated with PSA ID data, and the PSA ID data may be stored by the data processor of the auxiliary unit 212. Where PSA ID data is stored by the data processor of the auxiliary unit 212, the data processor of the auxiliary unit 212 may be configured to communicate the PSA ID data, along with the SS ID data, sensor data and SM ID data to one or more remote locations, via the communication interface.

It is envisaged that in some embodiments, the sensing mat 210 may not store SM ID data, or any other data identifying the sensing mat 210. In these embodiments, the sensing mat 210 communicates only sensor data to the auxiliary unit 12, and the auxiliary unit communicates only sensor data along with SS ID data, and optionally PSA ID data, to one or more remote locations. Such embodiments are preferably used where flexible mats are not interchangeable with auxiliary units.

Fig. 28 shows a seventh embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 28 is substantially similar to the location identifying system shown in Fig. 27. However, in this embodiment the patient support apparatus 204 with which the sensor is being used is configured to send PSA ID data to the data processor of the sensing mat 200. The patient support apparatus 204 comprises a data processor storing the PSA ID data, and a communication interface connected to the communication interface of the auxiliary unit 212. The connection between the patient support apparatus 204 and the auxiliary unit 212 may be a wired or a wireless connection. The patient support apparatus 204 is configured to communicate the PSA ID data to the auxiliary unit 212 over the connection.

Fig. 29 shows an eighth embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 29 is substantially similar to the location identifying system shown in Fig. 28. However, in this embodiment, a locator unit 206 is connected to the auxiliary unit 212 and is configured to communicate locator unit identifying data to the auxiliary unit 212. The connection between the locator unit 206 and the auxiliary unit 212 may be a wired or a wireless connection. The data processor of the auxiliary unit 212 is configured to communicate the locator unit identifying data, the PSA ID data, the SS ID data, and optionally the SM ID data, to one or more remote locations on the network 202.

Fig. 30 shows a ninth embodiment of a location identifying system for a sensing system according to this disclosure. The location identifying system shown in Fig. 30 is

substantially similar to the location identifying system shown in Fig. 29. However, in this embodiment, the locator unit 206 is connected to the patient support apparatus 204 and is configured to communicate the locator unit identifying data to the patient support apparatus 204. The data processor of the patient support apparatus is configured to communicate the locator unit identifying data, along with the PSA ID data, to the auxiliary unit 212.

A number of different possible sensor arrangements have been described. Embodiments of the disclosure may include any combination of the individual sensing arrangements described or other patient and/or bed/frame sensing arrangements which have not been described but which may be placed on or near a patient support deck. The alignment of the sensing mat 5 in a predetermined location allows it to incorporate sensors whose effectiveness requires them to have a predetermined location relative to a patient or frame/bed as well as those which do not require a particular location.

Although certain illustrative embodiments have been described in detail above, variations and modifications exist within the scope and spirit of this disclosure as described and as defined in the following claims.

CLAUSES

The present disclosure also provides for the following list of numbered clauses:

1. A sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising:

a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress.

2. A sensing system according to clause 1, wherein the flexible mat further comprises a support apparatus configured to support the plurality of sensors above a deck of a patient support apparatus, the support apparatus comprising at least one region of weakness configured to enable the flexible mat to flex at the region of weakness.

3. A sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising:

a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and

a support apparatus configured to support the plurality of sensors above a deck of a patient support apparatus, the support apparatus comprising at least one region of weakness configured to enable the flexible mat to flex at the region of weakness.

4. A sensing system according to clauses 2 or 3, wherein the support region comprises at least one rigid element.

5. A sensing system according to clause 4, wherein the at least one region of weakness comprises at least one region of reduced thickness in the at least one rigid element.

6. A sensing system according to clause 4, wherein the at least one region of weakness comprises at least one cut-out region in the at least one rigid element.

7. A sensing system according to clauses 2 or 3, wherein the support apparatus comprises a plurality of rigid elements.

8. A sensing system according to clause 7, wherein the at least one region of weakness comprises a space between adjacent ones of the plurality of rigid elements.

9. A sensing system according to any one of clauses 4 to 8, wherein the support apparatus comprises at least one compressible element.

10. A sensing system according to clause 9, wherein the at least one rigid element is supported on the at least one compressible element.

11. A sensing system according to clauses 9 or 10, wherein the support apparatus comprises a plurality of compressible elements.

12. A sensing system according to any one of clauses 1 to 11, wherein the flexible mat further comprises:

a thigh section for positioning on a thigh section of a patient support deck; and

a torso section for positioning on a torso section of a patient support deck;

13. A sensing system according to any one of clauses 2 to 11, wherein:

the flexible mat further comprises: a thigh section for positioning on a thigh section of a patient support deck; and a torso section for positioning on a torso section of a patient support deck, and

the support apparatus comprises a region of weakness between the thigh section and the torso section.

14. A sensing system according to clauses 12 or 13, wherein the flexible mat further comprises an enclosure enclosing the plurality of sensors, the enclosure comprising an exterior surface at the thigh section and an exterior surface at the torso section, the exterior surface at the thigh section having a coefficient of static friction greater than the coefficient of static friction of the exterior surface of the torso section.

15. A sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising:

a thigh section for positioning on a thigh section of a patient support deck;

a torso section for positioning on a torso section of a patient support deck;

a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and

an enclosure enclosing the plurality of sensors, the enclosure comprising an exterior surface at the thigh section and an exterior surface at the torso section, the exterior surface at the thigh section having a coefficient of static friction greater than the coefficient of static friction of the exterior surface of the torso section.

16. A sensing system according to any one of clauses 12 to 15, wherein the plurality of sensors comprise:

a patient position monitoring sensor arranged at the thigh section of the mat; and

a tilt sensor arranged at the torso section of the mat, the tilt sensor being configured to monitor the angle of the torso and head end of the bed frame.

17. A sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising:

a thigh section for positioning on a thigh section of a patient support deck;

a torso section for positioning on a torso section of a patient support deck;

a patient position monitoring sensor arranged at the thigh section of the mat; and

a tilt sensor arranged at the torso section of the mat, the tilt sensor being configured to monitor the angle of the head and torso section of the patient support deck.

18. A sensing system according to any one of clauses 12 to 17, wherein the plurality of sensors comprise at least one of: a patient respiratory rate sensor, and a patient heart rate sensor, arranged at the torso section.

19. A sensing system according to any one of clauses 12 to 15, wherein the plurality of sensors comprise:

a patient position monitoring sensor arranged at the thigh section of the mat; and

a tilt sensor arranged at the torso section of the mat, the tilt sensor being configured to monitor the angle of the torso and head end of the bed frame,

and wherein the plurality of sensors further comprise at least one of: a patient respiratory rate sensor, and a patient heart rate sensor, arranged at the torso section, and disposed between the patient position monitoring sensor and the support apparatus.

20. A sensing system according to any one of clauses 1 to 19, wherein the sensing system further comprises a data processor in communication with each of the plurality of sensors and comprising a communication interface for communication with one or more locations remote from the mat.

21. A sensing system according to clause 20, wherein the data processor is arranged at the torso section.

22. A sensing system according to any one of clauses 12 to 19, wherein the flexible mat further comprises an incontinence detection antenna at the thigh section of the mat, the incontinence detection antenna being configured for communication with a moisture detection element placed on the upper surface of the mattress.

23. A sensing system according to clause 22, wherein the plurality of sensors are disposed between the incontinence detection antenna and the support apparatus.

24. A sensing system according to clauses 22 or 23, wherein the sensing system further comprises a data processor in communication with each of the plurality of sensors and the incontinence detection antenna, and comprising a communication interface for communication with one or more locations remote from the mat.

25. A sensing system according to clause 24, wherein the data processor is arranged at the torso section.

26. A sensing system according to any one of clauses 20, 21, 24 or 25, wherein the sensing system further comprises an auxiliary unit in communication with the data processor of the flexible mat, the auxiliary unit comprising a wireless communication interface for communication with one or more locations remote from the sensing system.

27. A sensing system according to clause 26, wherein the auxiliary unit is configured to supply power to the flexible mat.

28. A sensing system according to clause 27, wherein the auxiliary unit comprises a connector for connecting the auxiliary unit to an external power supply.

29. A sensing system according to clause 28, wherein the auxiliary unit comprises an AC/DC converter.

30. A sensing system according to any one of clauses 26 to 29, wherein the auxiliary unit comprises a power supply configured to supply power to the flexible mat.

31. A sensing system according to any one of clauses 26 to 30, wherein the auxiliary unit comprises a data processor, and wherein the data processor is configured to receive

data from the flexible mat and communicate the data to one or more locations remote from the sensing system.

32. A sensing system according to any one of clauses 26 to 31, wherein the auxiliary unit is configured to be attached to a bed frame.

33. A sensing system according to clause 1, wherein the flexible mat further comprises a data processor in communication with each of the plurality of sensors and comprising a communication interface for communication with one or more locations remote from the mat, and wherein the sensing system further comprises an auxiliary unit in communication with the data processor of the flexible mat, the auxiliary unit comprising a wireless communication interface for communication with one or more locations remote from the sensing system.

34. A sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising:

a flexible mat for placement on the patient support deck between the mattress and the patient support deck, the flexible mat comprising:

a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and

a data processor in communication with each of the plurality of sensors and comprising a communication interface for communication with one or more locations remote from the mat; and

an auxiliary unit in communication with the data processor of the flexible mat, the auxiliary unit comprising a wireless communication interface for communication with one or more locations remote from the sensing system.

35. A sensing system according to clauses 33 or 34, wherein the data processor of the flexible mat is configured to store a flexible mat identifier, and the data processor of the flexible mat is further configured to communicate data from the plurality of sensors and the flexible mat identifier to the data processor of the auxiliary unit.

36. A sensing system according to clause 35, wherein the data processor of the auxiliary unit is configured to communicate data from the plurality of sensors and the flexible mat identifier received from the data processor of the flexible mat to one or more remote locations from the sensing system via the wireless communication interface.

37. A sensing system according to clause 36, wherein the data processor of the auxiliary unit is further configured to store an auxiliary unit identifier and to communicate data from the plurality of sensors, the flexible mat identifier, and the auxiliary unit identifier to one or more remote locations from the sensing system via the wireless communication interface.

38. A sensing system according to clauses 36 or 37, wherein the data processor of the auxiliary unit is configured to receive a patient support apparatus identifier from a patient support apparatus, and is further configured to communicate data from the plurality of sensors, the flexible mat identifier, and the patient support apparatus identifier to one or more remote locations from the sensing system via the wireless communication interface.

39. A patient support apparatus comprising a mattress supported on a patient support deck and a sensing system according to any one of clauses 1 to 38.

40. A system comprising:

a patient support apparatus comprising a mattress supported on a patient support deck mounted on a patient support apparatus frame,

a sensing system comprising:

a sensing mat for placement on the patient support deck between the mattress and the patient support deck, and the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and

a data processor and a communication interface,

wherein:

the patient support apparatus is associated with patient support apparatus identification (PSA ID) data;

the sensing system is associated with sensing system identification (SS ID) data;

the data processor of the sensing system is configured to store the PSA ID data and the SS ID data;

the data processor of the sensing system is configured to receive sensor data from the plurality of sensors of the sensing mat; and

the data processor of the sensing system is configured to communicate the sensor data, along with the PSA ID data and the SS ID data, to one or more remote locations via the communication interface.

41. A system according to clause 40, wherein the sensing mat comprises the data processor and communication interface of the sensing system.

42. A system according to any one of clauses 40 to 41, wherein the PSA ID data is programmable into the data processor by a user.

43. A system according to any one of clauses 40 to 41, wherein the sensing system comprises a user interface on which a user may enter the PSA ID data.

44. A system according to any one of clauses 40 to 41, wherein the patient support apparatus comprises a data processor and a communication interface, the data processor of the patient support apparatus storing the PSA ID data, and wherein the data processor of the patient support apparatus is configured to communicate the PSA ID data to the data processor of the sensing system via the communication interface of the patient support apparatus.

45. A system according to clause 45, wherein the communication interface of the patient support apparatus is connected to the communication interface of the sensing system via a wired connection.

46. A system according to clause 45, wherein the communication interface of the patient support apparatus is connected to the communication interface of the sensing system via a wireless connection.

47. A system according to any one of clauses 40 to 46, the system further comprising:

a locator unit coupled to the patient support apparatus, the locator unit being associated with locator unit identification (LU ID) data, the locator unit having a data

processor and a communication interface, and wherein the data processor of the locator unit stores the LU ID data.

48. A system according to clause 47, wherein:

the data processor of the locator unit is configured to communicate the LU ID data to the data processor of the sensing system via the communication interface of the locator unit; and

the data processor of the sensing system is configured to store the LU ID data; and

the data processor of the sensing system is configured to communicate the sensor data, along with the PSA ID data, the SS ID data and the LU ID data, to one or more remote locations via the communication interface.

49. A system according to clause 47, wherein:

an asset tracking system connected to a network stores the LU ID data and associates the LU ID data with a location in a healthcare facility;

the data processor of the sensing system is configured to communicate the LU ID data, along with the sensor data, the PSA ID data, and the SS ID data, to the asset tracking system, over the network, via the communication interface of the sensing system; and

the asset tracking system determines the location of the patient support apparatus and the sensing system in the healthcare facility based on the LU ID data.

50. A system according to any one of clauses 40 to 50, wherein the sensing system comprises an auxiliary unit comprising the data processor and communication interface, the auxiliary unit being arranged remotely from the sensing mat.

51. A system according to clause 50, wherein:

the sensing mat comprises a data processor and a communication interface, the sensing mat being associated with sensing mat identification (SM ID) data, and the data processor of the sensing mat storing the SM ID data;

the data processor of the sensing mat is configured to communicate the sensor data along with the SM ID data to the data processor of the auxiliary unit, via the communication interface of the sensing mat; and

the data processor of the sensing system, in the auxiliary unit, is configured to communicate the SM ID data, along with the SS ID data and other data to one or more remote locations.

52. A system according to clauses 50 or 51, wherein the auxiliary unit is attached to the patient support apparatus frame.

53. A system comprising:

a locator unit configured to be fixed in a known location of a healthcare facility, the locator unit comprising a data processor storing location unit identification (LU ID) data and a communication interface; and

a sensing system comprising:

a sensing mat for placement on a patient support deck of a patient support apparatus, between a mattress and the patient support deck, and the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and

a data processor storing sensing system identification (SS ID) data and a communication interface,

wherein:

the communication interface of the sensing system is connected to the communication interface of the locator unit;

the data processor of the sensing system is configured to communicate the SS ID data to the data processor of the locator unit; and

the data processor of the locator unit is configured to communicate the LU ID data, along with the SS ID data, to one or more remote locations, via the communication interface of the locator unit.

54. A system comprising:

a locator unit configured to be fixed in a known location of a healthcare facility, the locator unit comprising a data processor storing location unit identification (LU ID) data and a communication interface; and

a sensing system comprising:

a sensing mat for placement on a patient support deck of a patient support apparatus, between a mattress and the patient support deck, and the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress

condition is dependent on a condition of, or an event affecting, a patient on the mattress; and

a data processor storing sensing system identification (SS ID) data and a communication interface,

wherein:

the communication interface of the sensing system is connected to the communication interface of the locator unit;

the data processor of the locator unit is configured to communicate the LU ID data to the data processor of the sensing system; and

the data processor of the sensing system is configured to communicate sensor data from the plurality of sensors, along with the SS ID data and the LU ID data, to one or more remote locations, via the communication interface of the sensing system.

55. A locator unit configured to be fixed in a known location of a healthcare facility, the locator unit comprising a data processor storing location unit identification (LU ID) data and a communication interface, the locator unit being configured to communicate with a sensing system via the communication interface.

56. A locator unit according to clause 55, wherein the locator unit is configured to receive identification data from a sensing system, and to communicate the LU ID data, along with the sensing system identification data, to one or more remote locations, via the communication interface.

57. A locator unit according to clause 55, wherein the locator unit is configured to send the LU ID data to the sensing system, via the communication interface.

58. A locator unit according to clause 55 to 57, wherein the locator unit comprises a power connector for connection with a power connector of the sensing system

59. A locator unit according to clause 58, wherein the locator unit is configured to be connected to an AC power supply, and wherein the locator unit comprises an AC/DC converter between the AC power supply connection and the power connector, such that the locator unit is configured to supply DC power to the sensing system.

60. A system comprising:

a sensing system comprising:

a sensing mat for placement on a patient support deck of a patient support apparatus, between a mattress and the patient support deck, the sensing mat comprising a plurality of sensors for sensing at least one of: a position or orientation of the frame of the patient support apparatus; and a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and

an auxiliary unit comprising an RFID tag storing sensing system identification (SS ID) data; and

a locator unit configured to be fixed to a location of a healthcare facility, the locator unit comprising:

a data processor storing locator unit identification (LU ID) data;

an RFID reader; and

a communication interface configured to communicate with one or more remote locations,

wherein:

the RFID reader of the locator unit is configured to interrogate the RFID tag of the sensing system and receive the SS ID data from the RFID tag; and

the data processor of locator unit is configured to communicate the LU ID data, along with the SS ID data, to one or more remote locations via the communication interface.

61. A system according to clause 60, wherein the sensing system further comprises a power connector for receiving power from an external power supply, and wherein the RFID tag is located on or around the power connector.

62. A system according to clause 61, wherein the locator unit comprises a power connector for connection with the power connector of the sensing system, and wherein the RFID reader of the locator unit is arranged to interrogate the RFID tag of the sensing system when the power connector of the sensing system is connected to the power connector of the locator unit.

63. A system according to clause 62, wherein the locator unit is connectable to an AC power supply, and wherein the locator unit comprises an AC/DC converter for supplying DC power to the sensing system via the power connector.

64. A system according to any one of clauses 60 to 63, wherein:

an asset tracking system connected to a network stores the LU ID data and associates the LU ID data with a location in a healthcare facility;

the data processor of the sensing system is configured to communicate the LU ID data, along with the SS ID data, to the asset tracking system, over the network, via the communication interface of the locator unit; and

the asset tracking system determines the location of the sensing system in the healthcare facility based on the LU ID data.

65. A system according to any one of clauses 60 to 64, wherein the communication interface of the locator unit is a wireless communication interface.

66. A locator unit for locating a sensing system in a healthcare facility, the locator unit comprising:

a data processor storing locator unit identification (LU ID) data;

an RFID reader for reading an RFID tag of a sensing system; and

a communication interface configured to communicate with one or more remote locations.

67. A locator unit according to clause 66, further comprising a power connector for connection to a power connector of a sensing system, and wherein the RFID reader of the locator unit is located on or around the power connector.

68. A locator unit according to clause 67, wherein the locator unit is connectable to an AC power supply, and wherein the locator unit comprises an AC/DC converter for supplying DC power to a sensing system via the power connector.

69. A locator unit according to any one of clauses 66 to 68, wherein the communication interface is a wireless communication interface.

Claims

1. A sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising:
   a) a flexible mat for placement on the patient support deck between the mattress and the patient support deck;
   b) a first sensor for sensing a position or orientation of the frame of the patient support apparatus, the first sensor being mounted on the flexible mat;
   c) a second sensor mounted on the flexible mat for sensing a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and
   d) a communication port coupled to the sensors for transmitting data from the sensors to a location remote from the flexible mat.

2. A sensing system according to claim 1 further comprising a data processor mounted on the flexible mat and coupled to the first and the second sensors, wherein, in use, the data processor receives data from the first sensor and from the second sensor; and wherein the communication port is coupled to the data processor.

3. A sensing system according to any preceding claim wherein the first sensor is selected from the group of sensors including a side-rail position sensor; a head-of-bed angle sensor; and a radar sensor for bed height.

4. A sensing system according to any preceding claim wherein the second sensor is selected from the group of sensors including: a pressure sensor; a patient respiratory rate sensor; a patient heart rate sensor, a patient mobility or immobility sensor and a load sensor.

5. A sensing system for patient support apparatus including a mattress supported on a patient support deck, the sensing system comprising:
   a. a flexible mat for placement on the patient support deck underneath the mattress;
   b. an incontinence event transmitter and/or receiver mounted on the flexible mat and operable to read data from an incontinence pad which, in use, is placed on the upper surface of the mattress;

c. a further sensor mounted on the flexible mat and operable to sense a second event or parameter; and

d. a communication bus coupled to the incontinence event transmitter and/or receiver and the further sensor for transmitting data from the data processor to a location remote from the flexible mat.

6. A sensing system according to claim 5 further comprising a data processor mounted on the flexible mat and coupled to the first and the second sensors, wherein, in use, the data processor receives data from the first and from the second sensor; and wherein the communication port is coupled to the data processor.

7. A sensing system according to claim 5 or claim 6 wherein the further sensor is selected from the group comprising: a side-rail position sensor; a head-of-bed angle sensor; a radar sensor for bed height; a pressure sensor; a patient respiratory rate sensor; a patient heart rate sensor, a patient mobility or immobility sensor and a load sensor.

8. A sensing system according to any preceding claim wherein the flexible mat is dimensioned such that its longitudinal dimensions correspond to the length of the patient support deck so that it is aligned or fixed on the support deck by engagement with edges of the patient support apparatus immediately surrounding the upper surface of the support deck.

9. A sensing system according to claim 8 wherein the flexible mat is substantially 2 metres long and 90 centimetres wide.

10. A sensing system according to any preceding claim wherein the flexible mat includes straps for fixing it to the patient support deck.

11. A sensing system according to any preceding claim wherein the flexible mat includes a hook or loop connector arrangement for connection with a complementary hook or loop connector on the patient support deck.

12. A sensing system according to any preceding claim wherein the flexible mat includes a transmitter detachably connectable to a power source and configured to

act as a wireless power source for the first antenna and further sensor, or the first and second sensors

13. A sensing system according to any preceding claim wherein the flexible mat includes an electrical lead for connection to a power source.

14. A sensing system according to any preceding claim including a programmable location identifier for fixing to or adjacent a fixed power socket connectable to the communication bus of the flexible mat, wherein the programmable location identifier is programmable with the location of the power socket to thereby identify the location of the flexible mat connected thereto.

15. A sensing system for patient support apparatus including a mattress supported on a patient support deck, the sensing system comprising:

a. a flexible mat for placement on the patient support deck underneath the mattress, and including alignment or fixing means to fix the mat in a selected location and orientation on the patient support deck;
b. a first sensor for sensing a position or orientation of the patient support apparatus, the first sensor being located on the flexible mat;
c. a second sensor mounted on the flexible mat for sensing a condition of a patient on the mattress;
d. a data processor mounted on the flexible mat and coupled to the first and the second sensor, wherein, in use, the data processor receives data from the first sensor and from the second sensor; and
e. a communication port coupled to the data processor for transmitting data from the data processor to a location remote from the flexible mat.

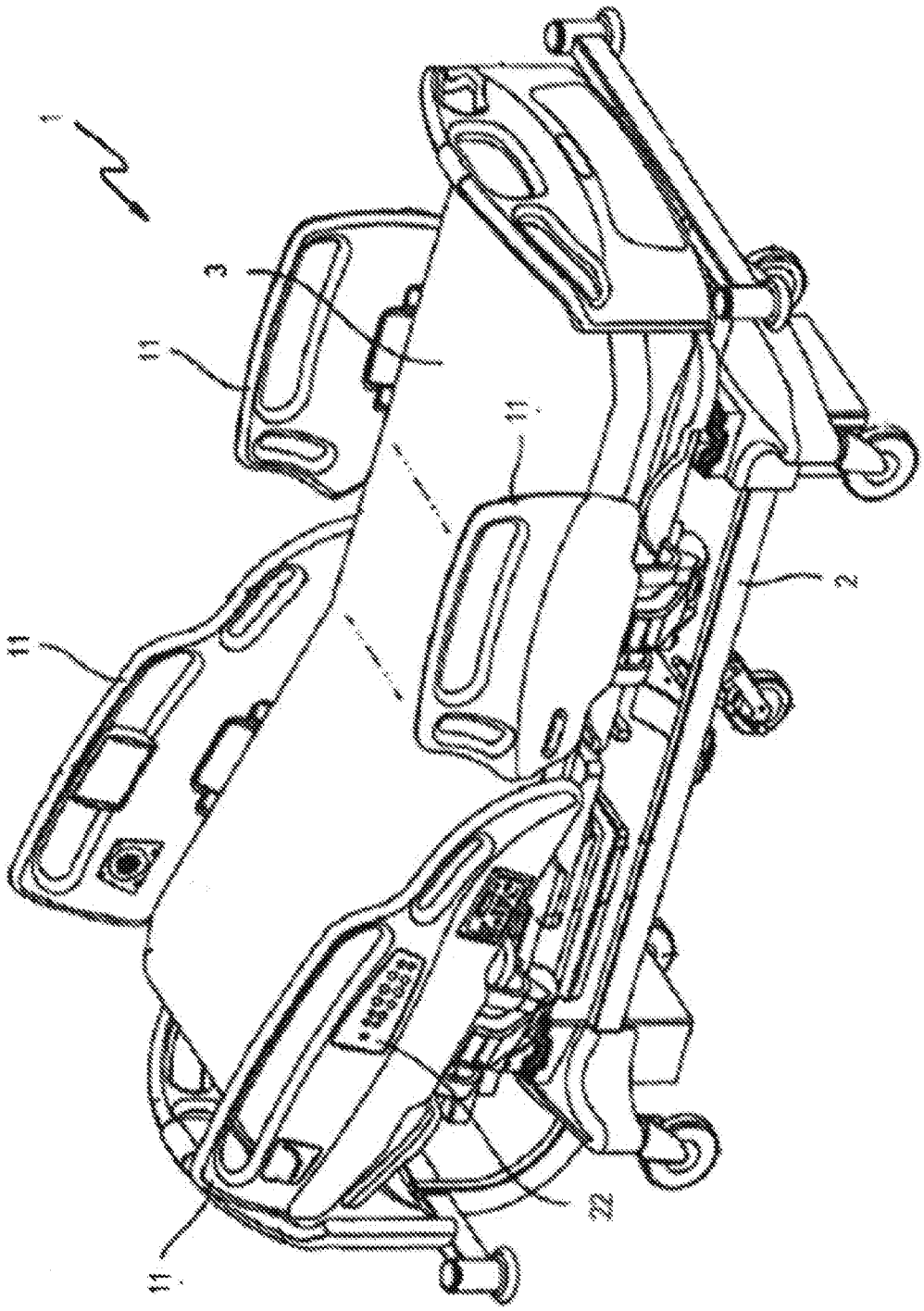

FIG. 1

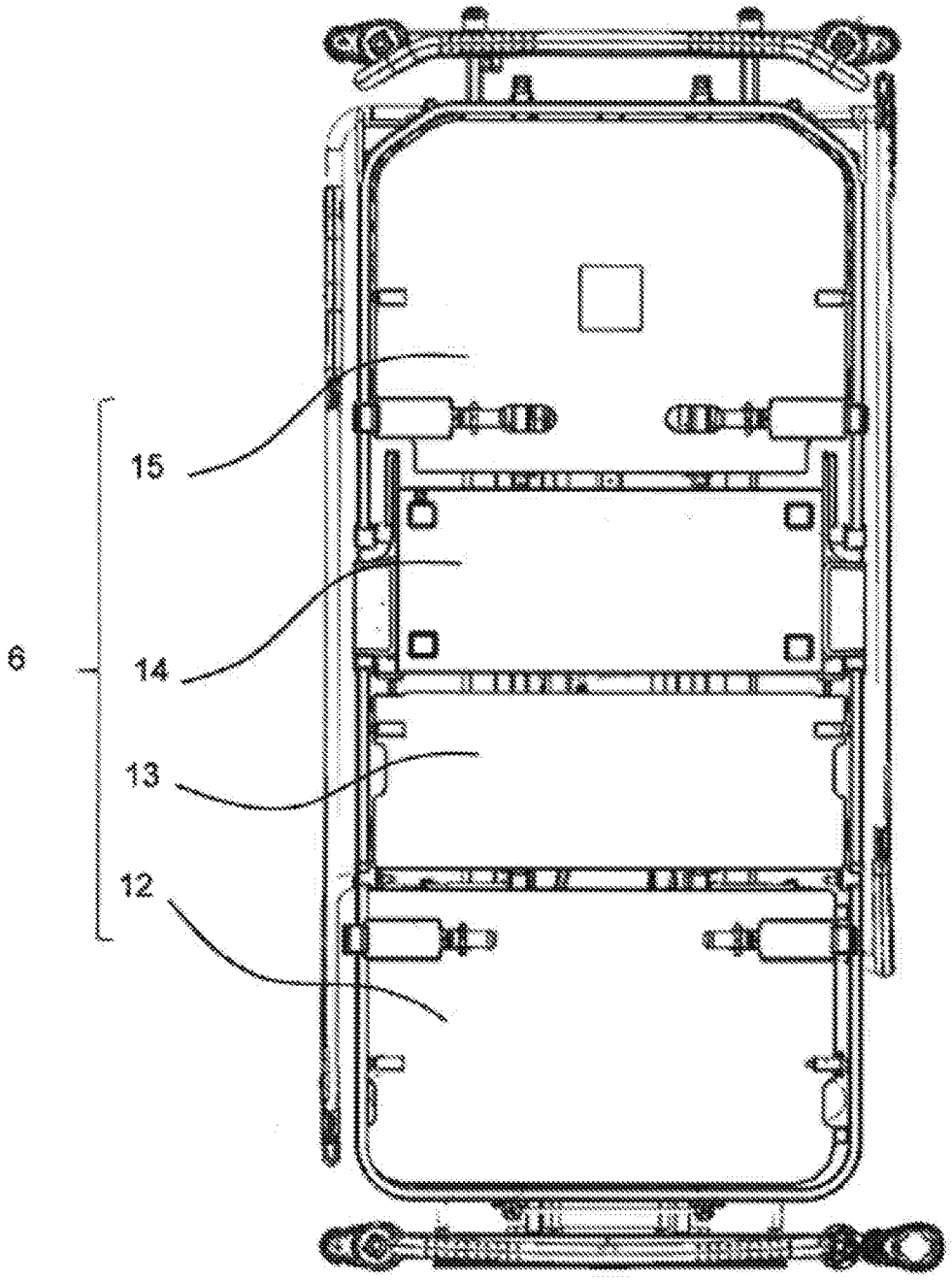

FIG. 2

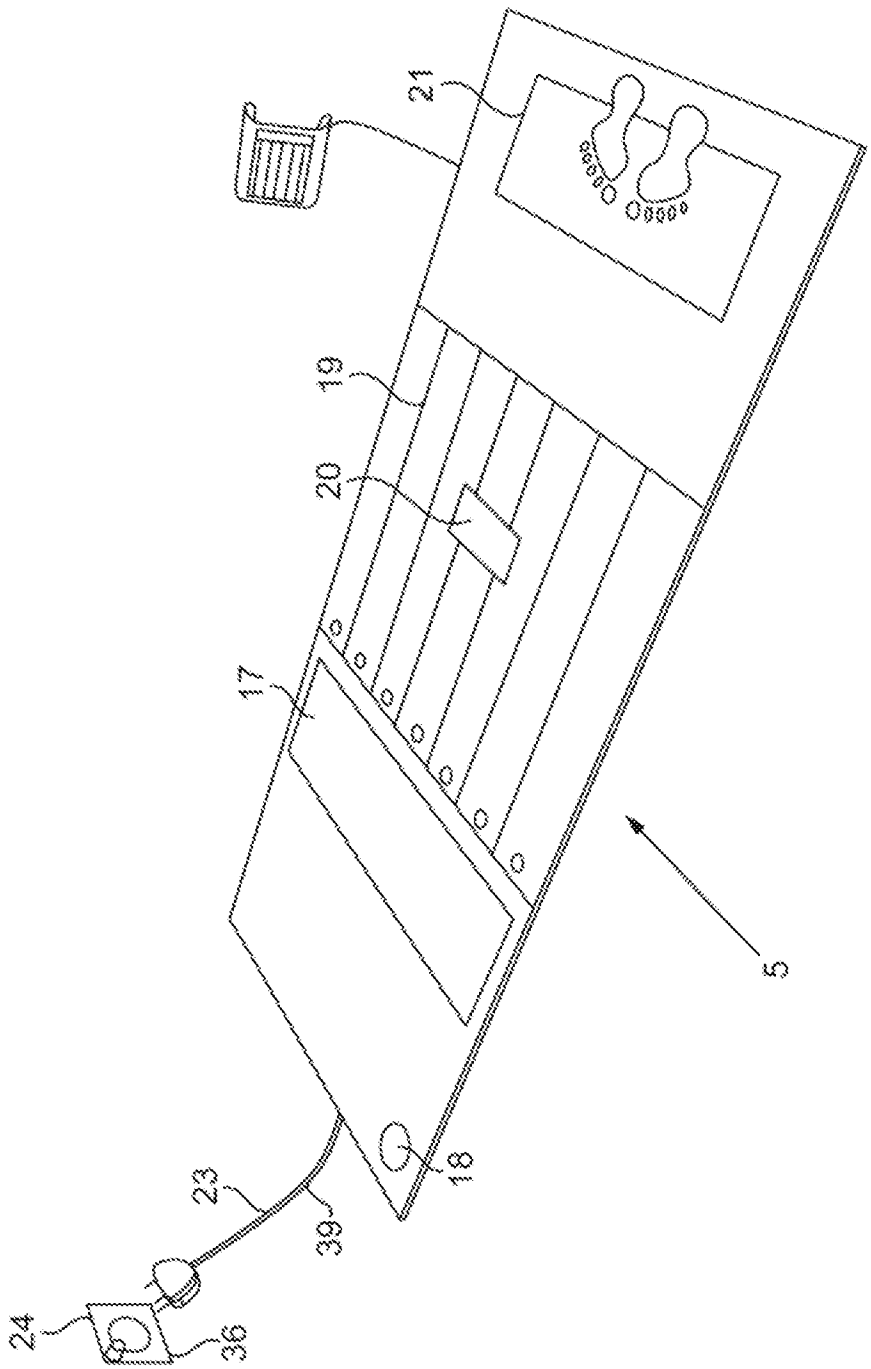

FIG. 3

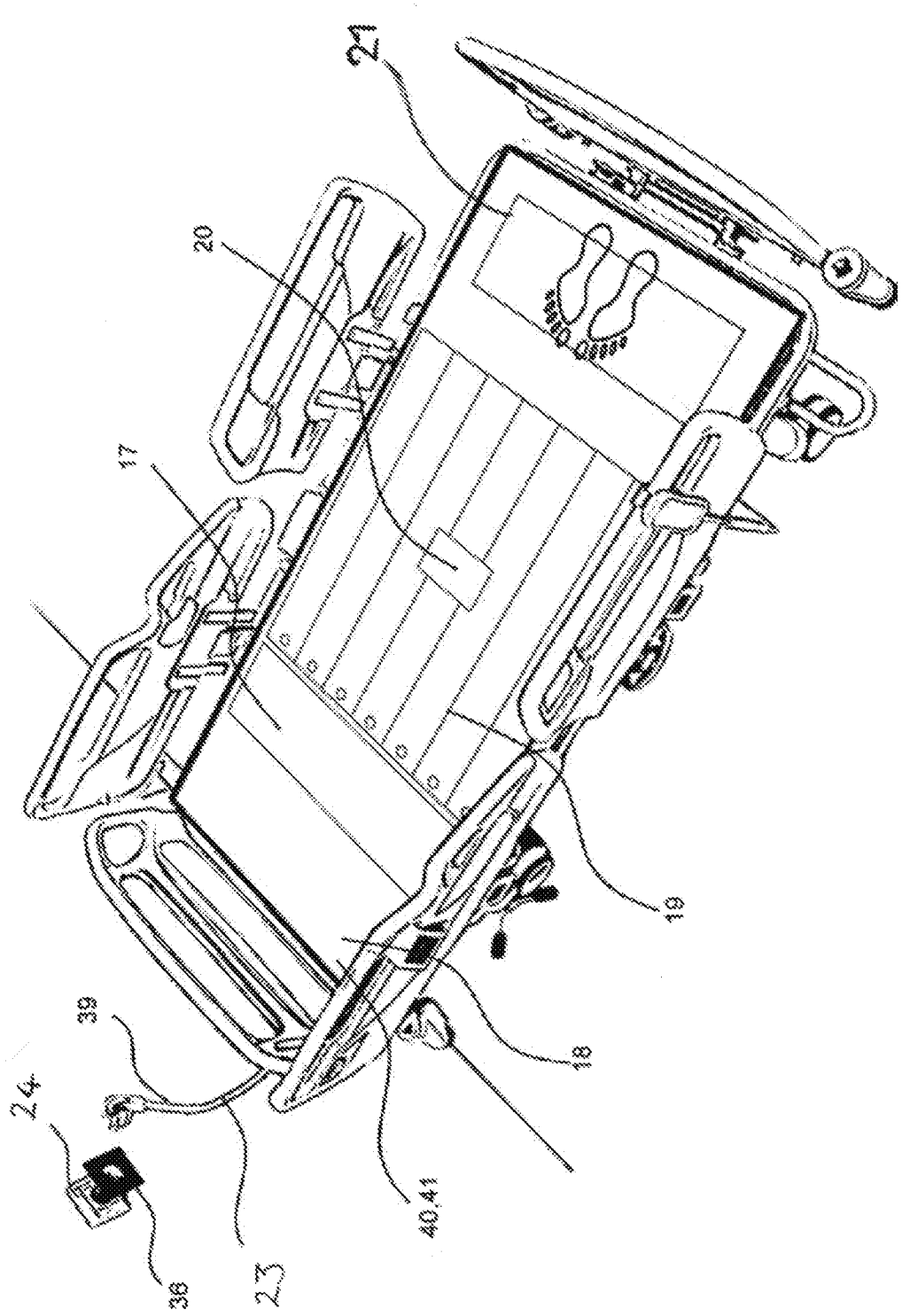

FIG. 4

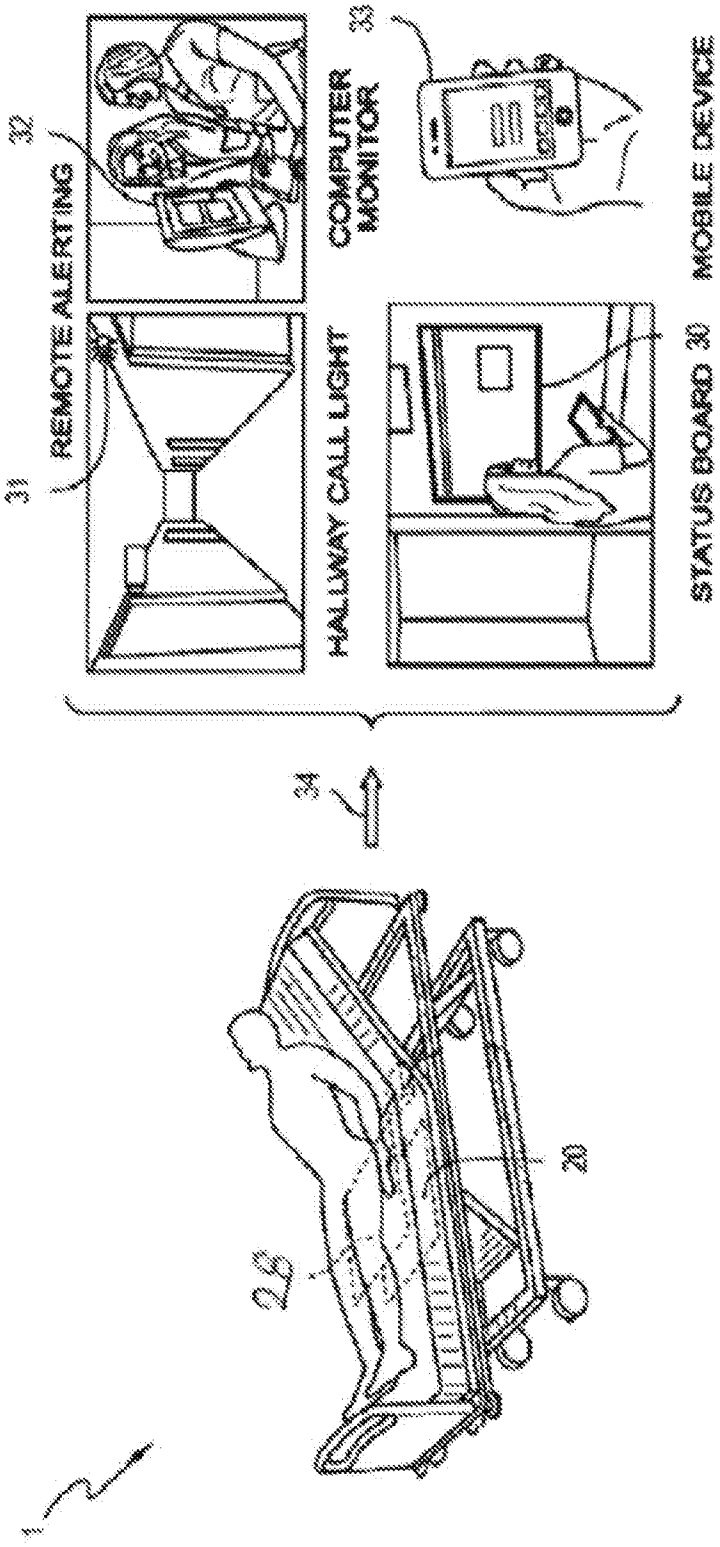
REMOTE ALERTING
32
COMPUTER MONITOR
33
MOBILE DEVICE
31
HALLWAY CALL LIGHT
STATUS BOARD 30
34
20
29

FIG. 5

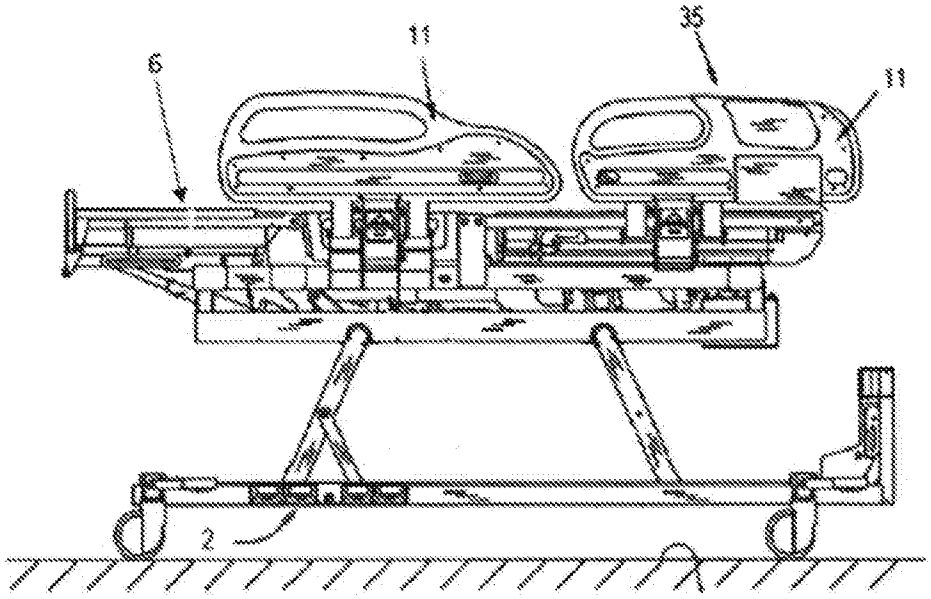

FIG. 6

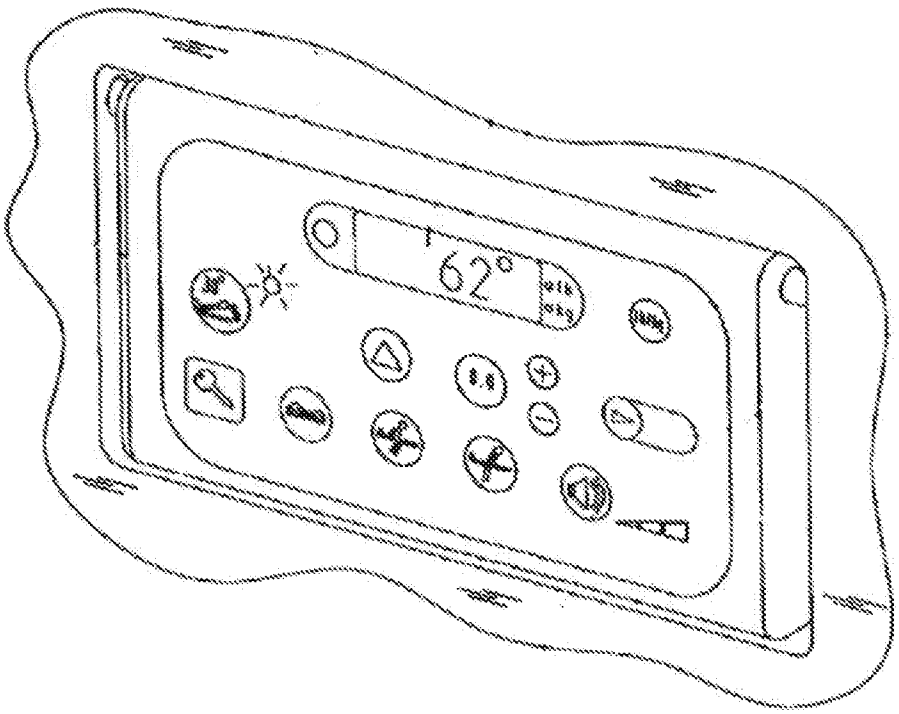

FIG. 7

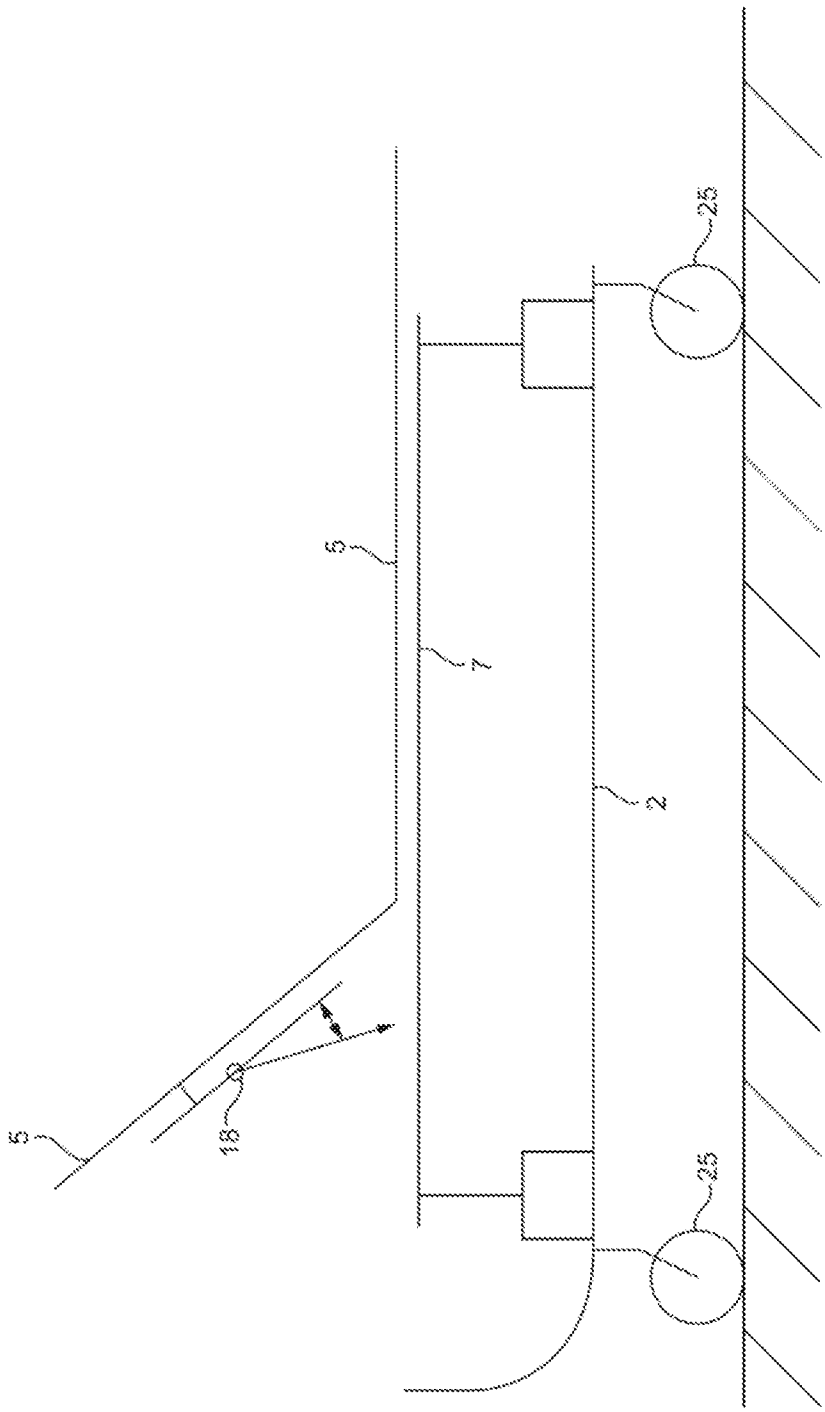

FIG. 8

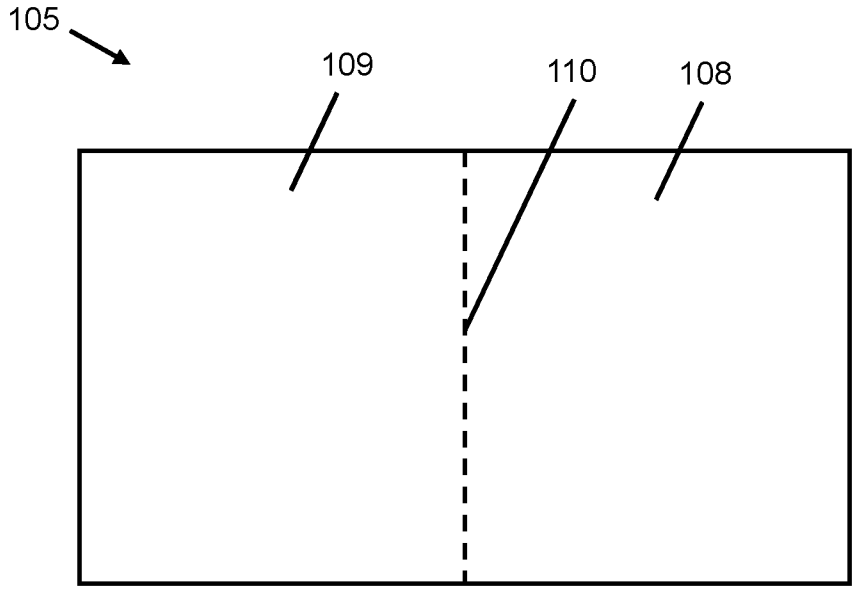

FIG. 9

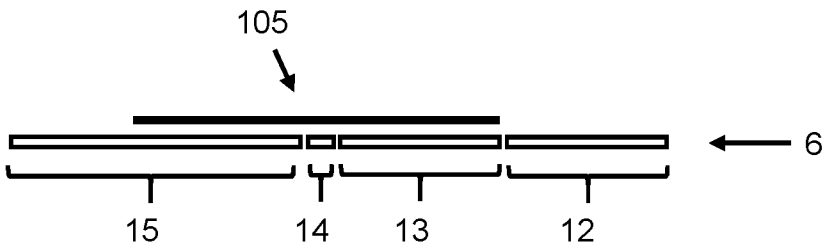

FIG. 10

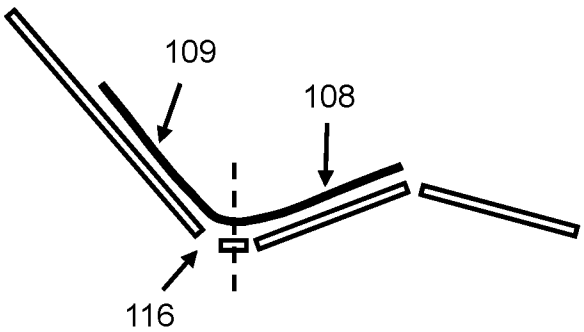

FIG. 11

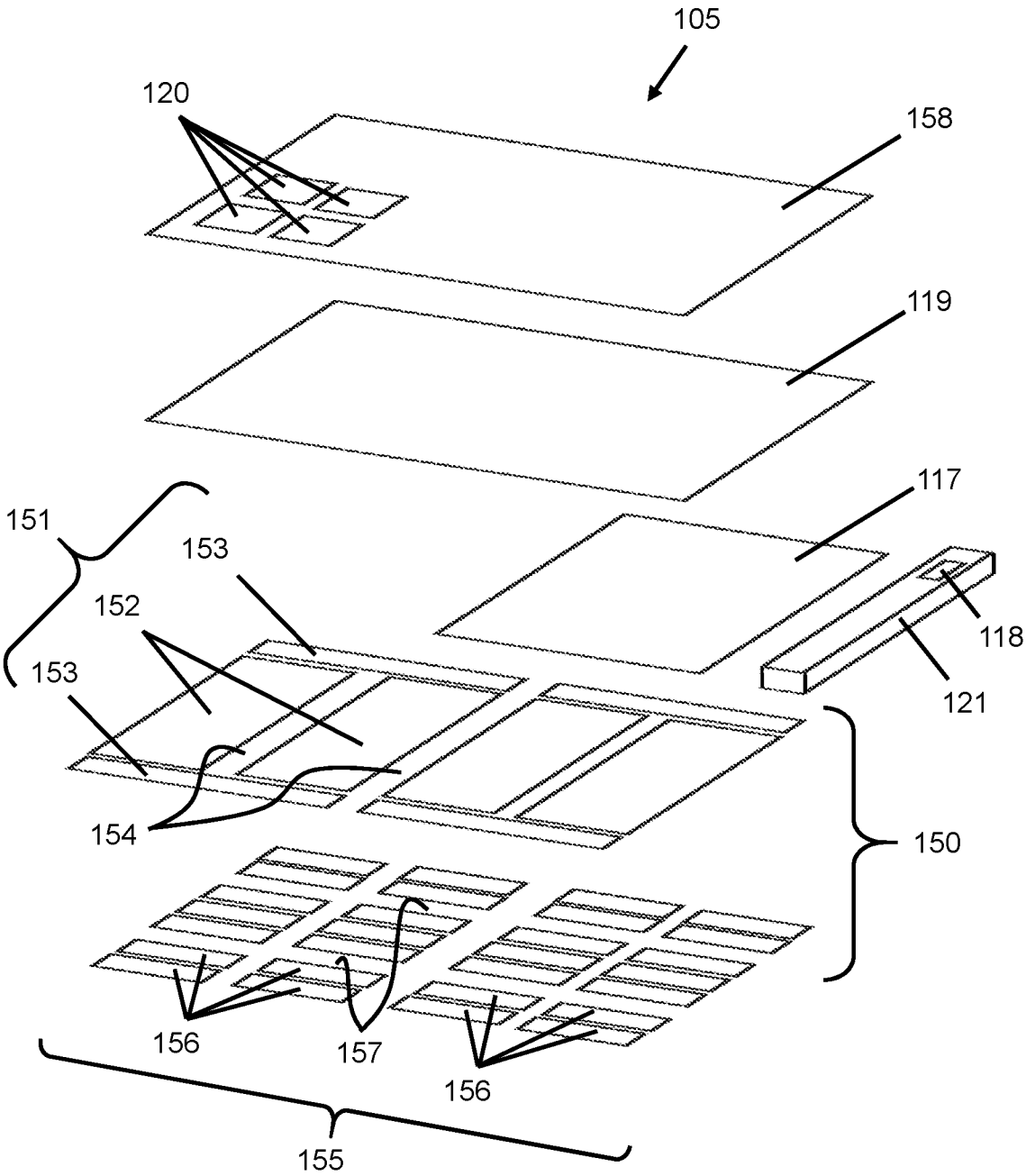
105
120
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FIG. 12

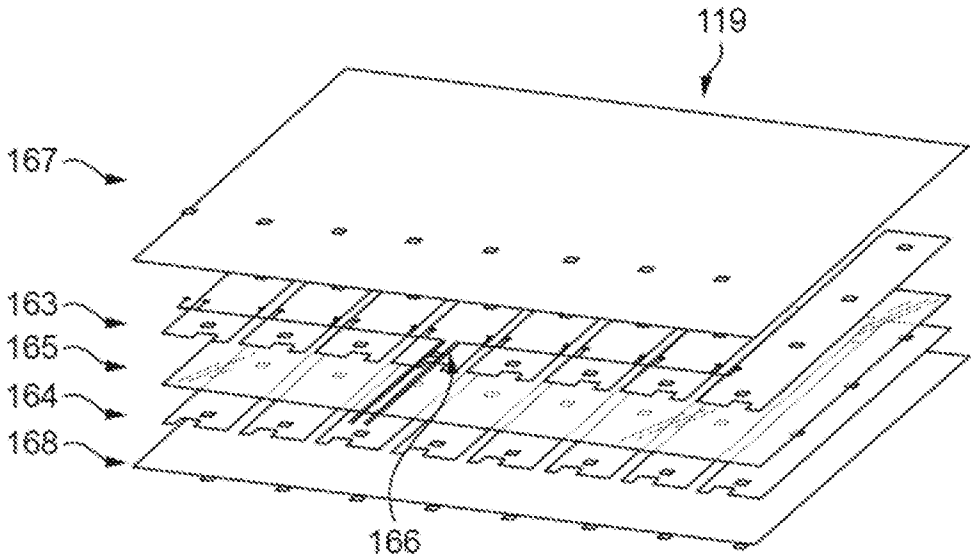
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FIG. 13

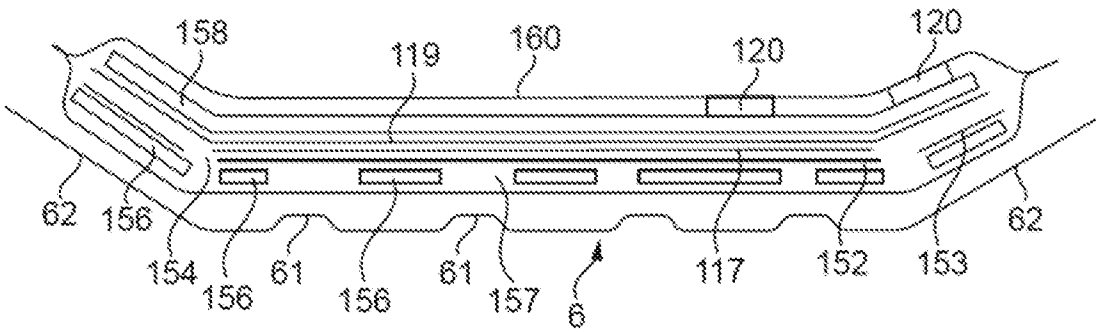
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FIG. 14

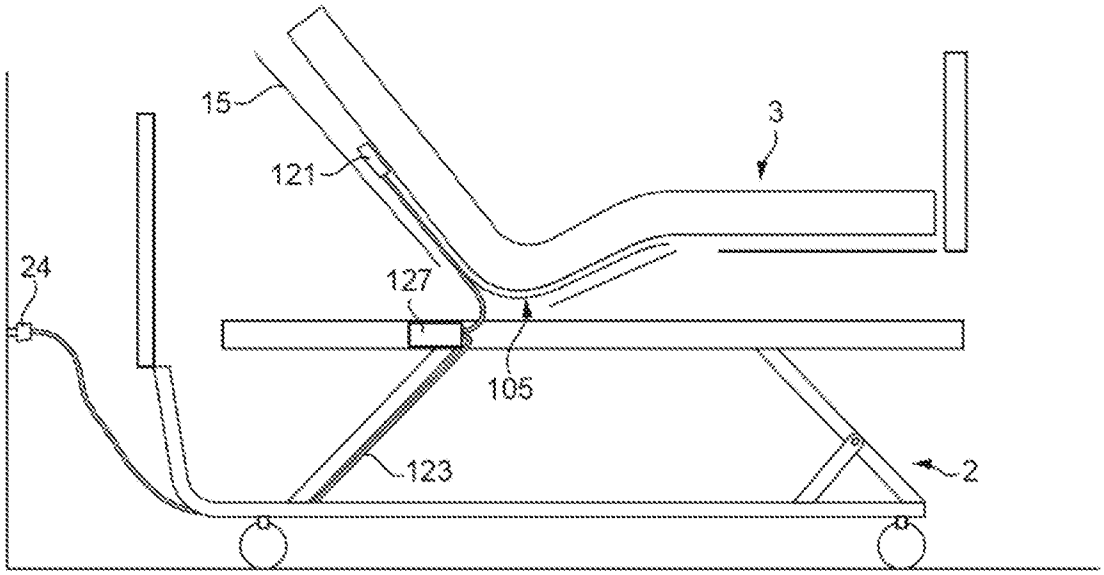

FIG. 15

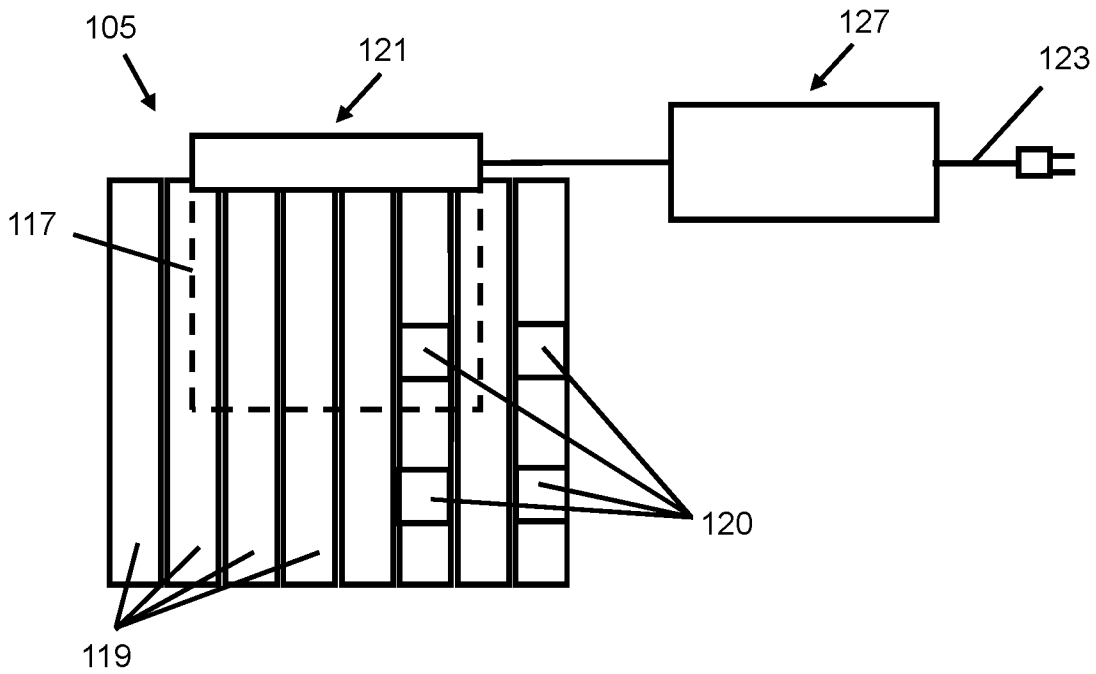

FIG. 16

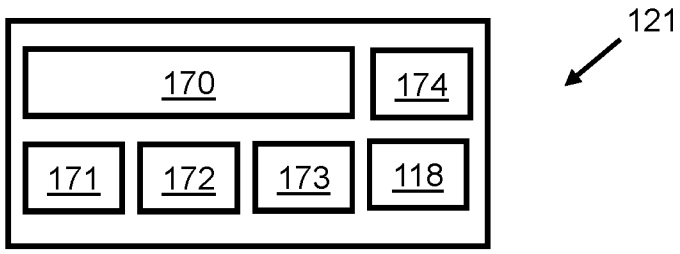

FIG. 17

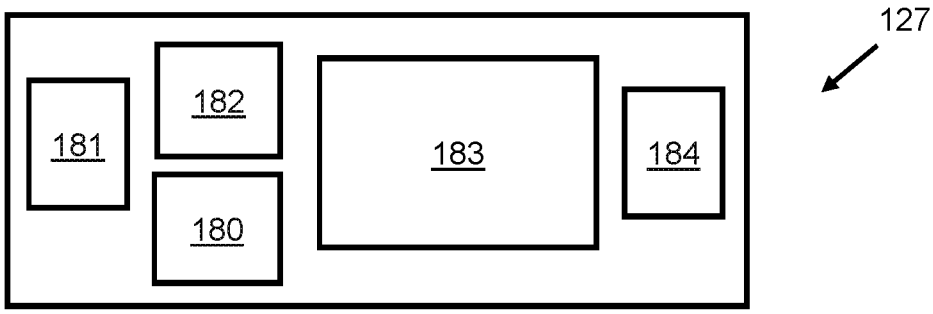

FIG. 18

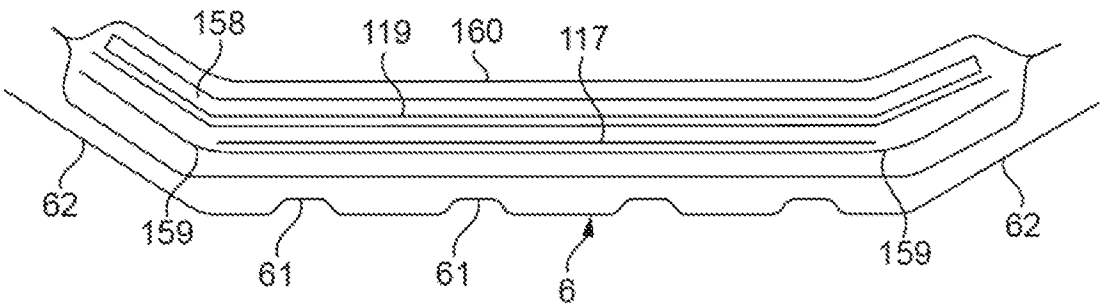

FIG. 19

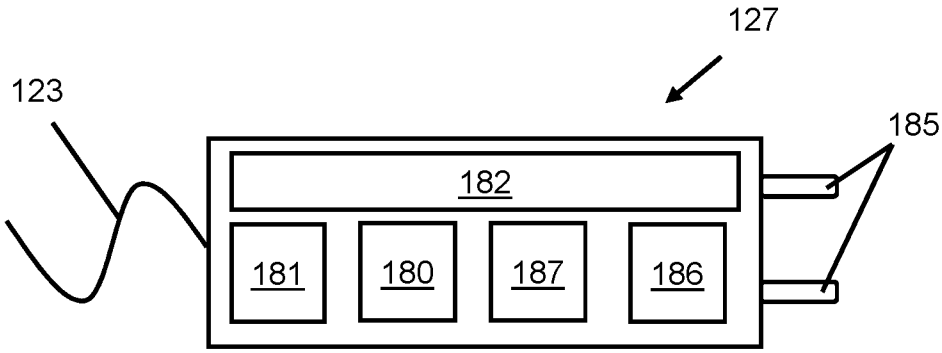

FIG. 20

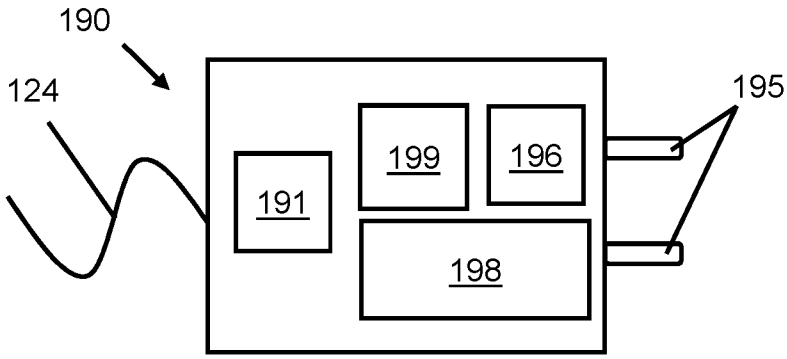

FIG. 21a

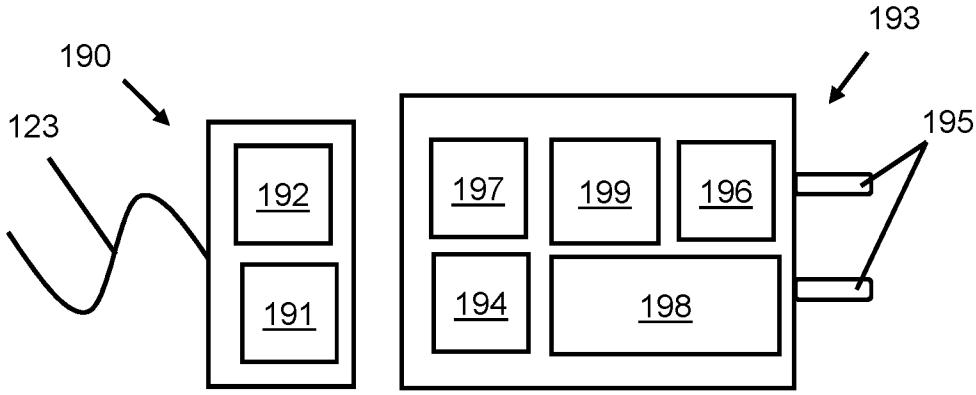

FIG. 21b

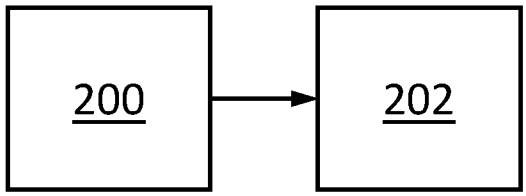

FIG. 22

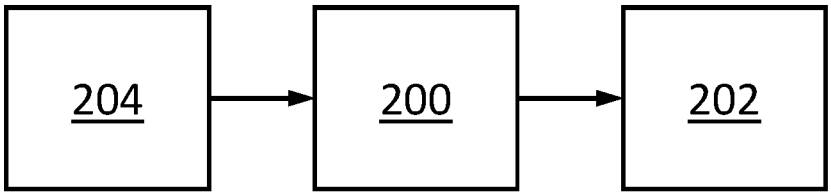

FIG. 23

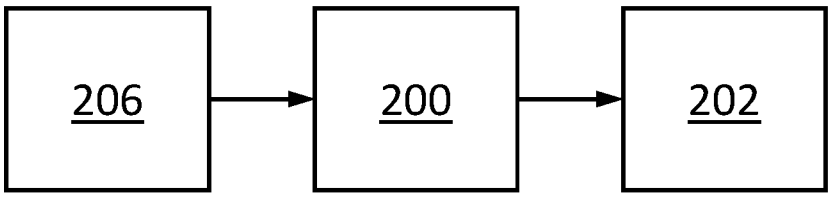

FIG. 24

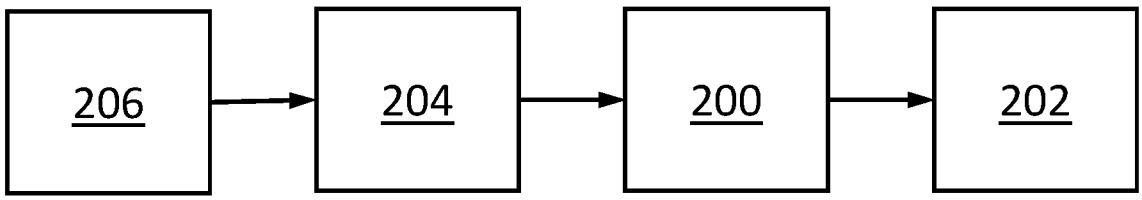

FIG. 25

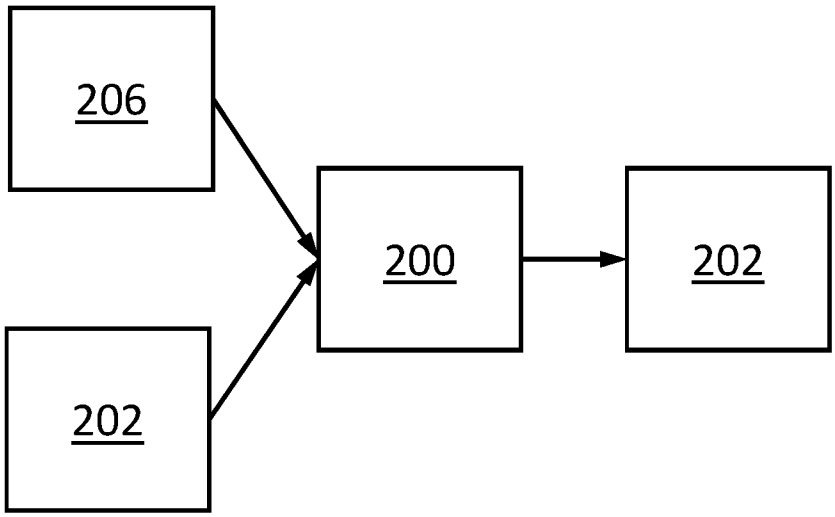

FIG. 26

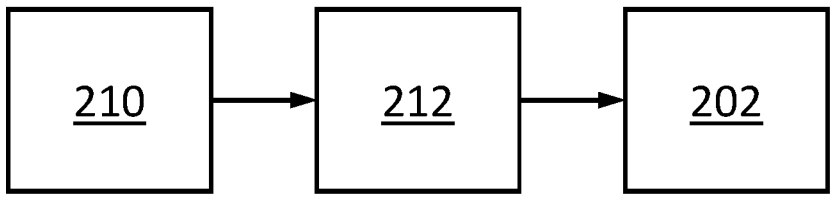

FIG. 27

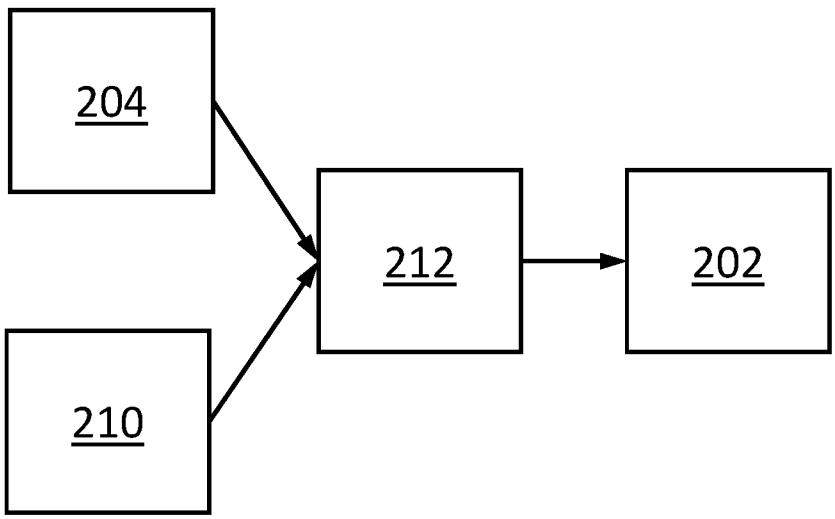

FIG. 28

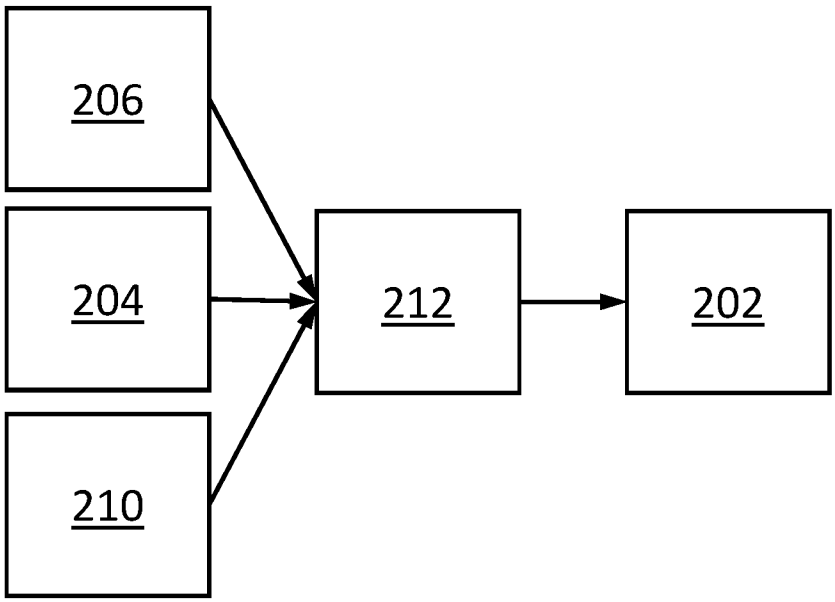

FIG. 29

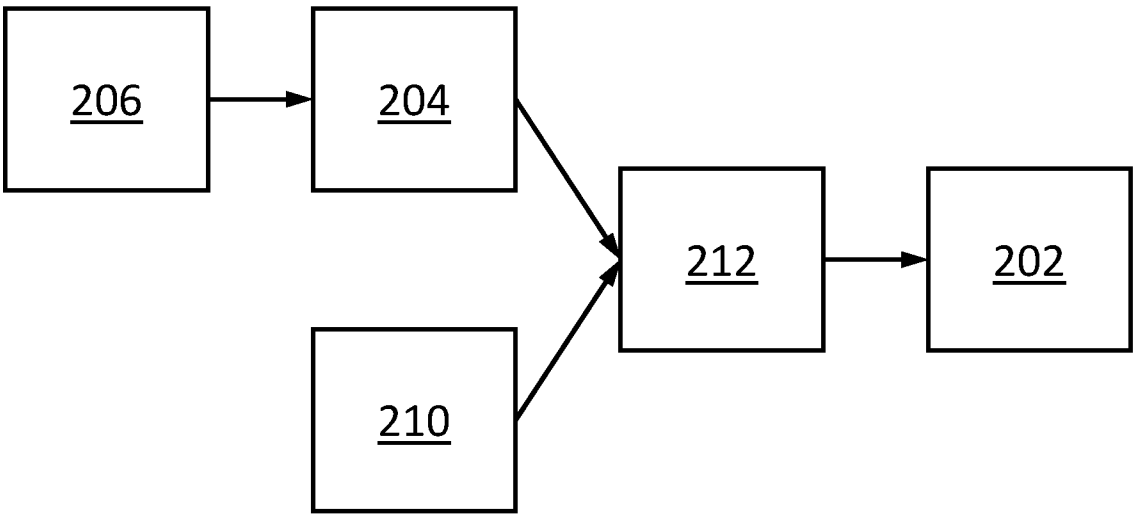

FIG. 30

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/056543

A. CLASSIFICATION OF SUBJECT MATTER
INV. G16H40/63 G16H40/20 A61G7/018 A61G7/05 A61G7/057 A61B5/00
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G16H A61G A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/122002 A1 (STRYKER CORP [US]; BALAKRISHNAN SANTOSHKUMAR [US] ET AL.) 13 September 2012 (2012-09-13) figures paragraph [0003] paragraph [00107] - paragraph [00114] paragraph [00157] paragraph [00172] paragraph [00213] paragraph [00228] paragraph [0019] -----	1-4,8-15
X	US 2015/371522 A1 (MRAVYAN DAVID [CA] ET AL) 24 December 2015 (2015-12-24) figure 2 paragraph [0026] paragraph [0030] - paragraph [0031] paragraph [0033] -----	5-14
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 November 2019	27/11/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Edlauer, Martin

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/056543

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/276504 A1 (HEIL THOMAS F [US] ET AL) 18 September 2014 (2014-09-18) figures paragraph [0121] paragraph [0050] - paragraph [0051] -----	5-14
A	EP 2 995 242 A1 (HILL ROM SAS [FR]) 16 March 2016 (2016-03-16) cited in the application the whole document -----	1-4,8-15
A	US 2016/314672 A1 (WIGGERMANN NEAL [US] ET AL) 27 October 2016 (2016-10-27) the whole document -----	1-4,8-15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2019/056543

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

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

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

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

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

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

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

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-4, 15(completely); 8-14(partially)

A sensing system for patient support apparatus including a mattress supported on a patient support deck mounted on a patient support apparatus frame, the sensing system comprising: a) a flexible mat for placement on the patient support deck between the mattress and the patient support deck;b) a first sensor for sensing a position or orientation of (the frame of) the patient support apparatus, the first sensor being mounted on the flexible mat;c) a second sensor mounted on the flexible mat for sensing a condition of, or event affecting, the mattress, wherein the sensed mattress condition is dependent on a condition of, or an event affecting, a patient on the mattress; and d) a communication port coupled to the sensors for transmitting data from the sensors to a location remote from the flexible mat.
(Problem: Managing patient parameters influenced by bed positioning).

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2. claims: 5-7(completely); 8-14(partially)

A sensing system for patient support apparatus including a mattress supported on a patient support deck, the sensing system comprising:a. a flexible mat for placement on the patient support deck underneath the mattress;b. an incontinence event transmitter and/or receiver mounted on the flexible mat and operable to read data from an incontinence pad which, in use, is placed on the upper surface of the mattress;c. a further sensor mounted on the flexible mat and operable to sense a second event or parameter; and d. a communication bus coupled to the incontinence event transmitter and/or receiver and the further sensor for transmitting data from the data processor to a location remote from the flexible mat.
(Problem: Managing incontinent patients)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2019/056543

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012122002 A1	13-09-2012	AU 2012225814 A1	19-09-2013
		EP 2680744 A1	08-01-2014
		JP 2014515628 A	03-07-2014
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		US 2018089979 A1	29-03-2018