Abstract:

A body monitoring system for monitoring pressure exerted by a patient on a support surface such as the seat of a wheelchair or a bed. A pressure sensing system including an array of pressure sensors provides pressure information that is processed to determine display attributes for regions of a display. The display has reduced dimensionality so that each region of the display is a graphical display of cumulative patient risk that may be readily interpreted and utilised by a patient or caregiver.

[Continued on next page]
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))
A BODY MONITORING SYSTEM AND METHOD OF MONITORING

FIELD OF THE INVENTION

The present invention relates to a body monitoring system and method of monitoring for monitoring a patient's pressure wound risk and displaying the information in a manner that is readily usable by users and care givers.

BACKGROUND OF THE INVENTION

The management of pressure wounds, commonly known as pressure ulcers or bedsores, is an ongoing problem for patients spending significant periods of time in bed or wheelchairs. Numerous factors influence the rate and seriousness of damage due to pressure wounds. These factors relate to a patient's individual condition in combination with parameters that can be measured such as pressure distribution, temperature, humidity etc.

A wide range of systems have been developed for monitoring patient pressure applied by a patient to a support surface over time. However, these have generally been complex and expensive systems displaying detailed pressure maps designed for use by skilled staff capable of interpreting complex visual information. They have typically not taken into account a specific user's condition or provided risk information in real time in a form that is readily usable by a user or unskilled care giver.

It is an object of the present invention to provide a body monitoring system that overcomes the disadvantages of the prior art or at least provides the public with a useful choice.
SUMMARY OF THE INVENTION

According to one exemplary embodiment there is provided a body monitoring system including:

a. a pressure sensing system including a plurality of pressure sensors that provide pressure information for a plurality of areas of a body support surface;

b. a display that displays a plurality of regions corresponding to areas of a body that applies force to the support surface; and

c. a processor that determines display attributes for each region of the display, wherein each region of the display is a graphical display of cumulative patient risk having reduced dimensionality with respect to pressure information.

According to another exemplary embodiment there is provided a patient support control system including a body monitoring system and an active support surface responsive to risk information generated by the body monitoring system to control support attributes of the active support surface.

It is acknowledged that the terms "comprise", "comprises" and "comprising" may, under varying jurisdictions, be attributed with either an exclusive or an inclusive meaning. For the purpose of this specification, and unless otherwise noted, these terms are intended to have an inclusive meaning - i.e. they will be taken to mean an inclusion of the listed components which the use directly references, and possibly also of other non-specified components or elements.
Reference to any prior art in this specification does not constitute an admission that such prior art forms part of the common general knowledge.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings which are incorporated in and constitute part of the specification, illustrate embodiments of the invention and, together with the general description of the invention given above, and the detailed description of exemplary embodiments given below, serve to explain the principles of the invention.

Figure 1 shows a wheelchair having a seat incorporating pressure sensors utilizing a mobile phone as a processing, display and communications device;

Figure 2 shows a map assigning sensors to regions of a display in a first seating position;

Figure 3 shows a map assigning sensors to regions of a display in a second seating position;

Figures 4a to d show different ways of displaying risk;

Figure 5 shows a neural network for determining change in risk;

Figure 6 shows a flow diagram of processing to determine section risk and overall risk; and

Figure 7 shows a flow diagram of the life cycle of the data from collection to display.
The invention will now be described by way of example with reference to a wheelchair. Whilst this application has particular advantages the invention should not be interpreted as being limited to this application.

In the example shown in Figure 1 a wheelchair 1 has a support surface 2 in the form of a resilient squab having an array of pressure sensors embedded within. Temperature and humidity sensors may also be incorporated in the support surface. The pressure sensors supply pressure information to an interface 3. Interface 3 may perform certain processing as will be hereafter described or could potentially be omitted if the sensors within support surface 2 communicate directly with portable communications device 4.

In this embodiment interface 3 receives and processes sensed information and provides risk information to portable communications device 4. Portable communications device 4 may display risk information on its own display (and via sound) and send risk information and/or alerts to remote computers via cellular data link 5 so that caregivers may be notified of important information. A remote management system may log activity and initiate actions based on exceptions - e.g. limited movement or risk above a threshold level for a prescribed period of time may activate an alert.

Local alerts may require user action to stop continuing notifications. A local alert may be escalated to a remote supervisory system if no action is taken within a prescribed time.
Rather than simply displaying a map of sensed pressure data the present invention aims to display graphical information with reduced dimensionality that is directly usable by users and care givers in real time to manage pressure wound risk. As shown in a simplified example in figure 2 an array of sensors S1 to S16 is provided in support surface 2. Outlines 6 and 7 represent the pressure distribution applied to support surface 2 by the posterior of a subject. In this case it may be seen that the right rear posterior maps to sensor S11, the right front to sensor S7, the left rear to sensor S9 and the left front to sensor S5. In this example these sensors would be mapped to regions 11, 9, 10 and 8 of display 1. Based on pressure information and other data such as user profile, temperature, humidity etc. a risk factor is calculated for each display region 8 to 11 and displayed.

By providing a simplified display of four quadrants a user or care giver can easily interpret a risk level for a major body region and determine an appropriate relief strategy. The risk may be communicated by the colour (see figures 4b and 4c) displayed in each display region 8 to 11 and/or a symbol, such as a numerical value. A global risk value may also be displayed in a separate display region which in the examples shown in Figures 4a to 4d is a central region 13 which can display colour (see Figures 4b and 4c) and/or a symbol, such as a numerical value (see Figures 4a to 4c). Other information such as a graph of historical global risk 14 may also be displayed.

The example of Figure 2 is a simplified example for illustrative purposes and a more detailed explanation is provided below. Normally a plurality of sensors map to each display region to provide reduced dimensionality of the displayed information. Thus for the case shown in Figure 3 the right rear posterior display region 11 maps to sensors S11 and S12; the right front display region 9 maps to sensors S3, S4, S7 and S8; the left rear
display region 10 maps to sensors S9 and S10; and the left front display region 8 maps to sensors S1, S2, S5 and S6. Based on pressure information from pressure sensors mapped to a given region (and other data such as user profile, temperature, humidity etc.) a risk factor is calculated for each display region 8 to 11 and displayed.

Since risk is analysed and displayed in quadrants, patients are given the information on how they may shift pressure to reduce risk. The system then displays how effective these measures have been. The patient can decide if and when further actions are required. The risk information is held locally and is available for transmission to a remote location via the cell phone.

As well as monitoring pressure wound risk other monitoring may be effected as follows:

1. Presence - pressure above a threshold level in a pattern corresponding to a human may be utilized to monitor presence on a support surface;

2. Well being - presence combined with temperature may be used to monitor wellbeing - ie if a patient is present and the temperature is too high or too low this may indicate a problem.

A support surface may include active controls to modify the support surface in response to risk information. In one aspect the support surface may have cells that may be differentially inflated or deflated to adjust pressure distribution across the support surface. Alternatively surfaces below the support surface may be differentially raised or lowered. Where possible the wheelchair etc. may be reconfigured (e.g. reclined) to change pressure distribution. The support surface may also include channels for heating or cooling fluid to be circulated to effect heating or cooling.
Determining Risk From Pressure

Preparing Data for Determining Risk

An NxM matrix of pressure sensors gives an array of pressure values. Quasi peak averaging may be employed for more stable pressure readings. The array is then split into P sections of interest (corresponding to the number of risk display regions). By using different sections of interest the problem areas can be identified, and feedback can be provided on where to focus attention. Each of the sections of interest is processed to calculate a number of output parameters such as peak and average pressures, movement within the section etc. Once each section has a calculated set of parameters, the parameters are passed on to the Neural Network. Data from moisture, temperature and other relevant sensors can be added to this set also.

The sections of interest may or may not have a static boundary. For example a patient lying on a bed will not necessarily be in the same position at all times, yet it may be desired to monitor the risk for a part of the body and not the part of the bed, so the regions of interest may use different sensing cells based on the location of the patient on the bed. A similar example is that a wheelchair user may slide forward in his/her chair, and one may wish to monitor the part of the body - not part of the chair.

Determining Risk

A Neural Network is used to determine the instantaneous change in risk before being accumulated so that risk can be monitored over time.
Determine Instantaneous Change in Risk
A Neural Network combines independent inputs to produce a number of desired outputs. Instead of manually trying to create links between likely related parameters, it assumes links between all parameters, and adds hidden nodes to allow more complex relationships.

Neural Network Method for Risk Assessment
An instantaneous change in risk is determined for each section of interest. To determine the instantaneous change in risk, the parameters from each section are passed through a Neural Network of which the output is a standardised change in risk that goes positive and negative for risk increasing and pressure relieving respectively. The higher the standardised change in risk the faster the risk increases, and the more negative the standardised change in risk, the faster the risk decreases (more efficient pressure relief).

Referring now to Figure 5 a neural network for determining a change in risk will be described. A neural network may be provided for each display region 8 to 11 shown in Figure 4a. The pressure sensors mapped to the display region may be supplied as inputs to the neural network. Temperature and humidity information may also be provided as inputs. A user profile may also be provided as an input. All these inputs are identified as Parameters 1 to Q in Figure 5.

To get the Neural Network to output the correct information for the particular occupant and situation is programmed. The risk of pressure sores is intimately connected to numerous health factors ranging from diet, to sensory perception. The traditional tool for recoding this assessment is a questionnaire called the Braden scale. This outputs a risk factor score which can be inputted to the risk assessing process. It sets the interval time (time between pressure reliefs) and the duration of each relief.
The clinician is able to set how long the nominal interval between pressure reliefs should be, and how long to pressure relieve for. The accumulation phase takes this into account by scaling the K constant which changes the effect of each update to speed up or slow down increase of risk, or effect of pressure relief.

A user profile may be obtained by taking a user through a series of scenarios, such as sitting normally, and different pressure relieving techniques, and recording the parameters calculated for the given situation. The clinician gives feedback on the type of action being performed (good or bad pressure relief, high risk area) by the occupant, and the feedback is recorded. The recorded parameters and feedback are then taken and a configuration is learnt giving a unique configuration for the user.

Accumulate Over Time
Referring now to Figure 6 a flow diagram illustrates how the change in risk outputs from the neural network may be utilized to adjust an overall risk value for a display sector. To determine the risk at a point in time, the changes in risk are accumulated. A different model is used for increasing risk and decreasing risk as risk increases far slower than it decreases during a pressure relief. To fit the standardised change in risk to different models, the gradient of the appropriate model (linear or non-linear) at the current risk is multiplied by a scaled change in risk. The scale factor K determines relatively how responsive the model is compared to its norm. This scaled change in risk can then be added onto the current risk.

Aggregating Output
As well as providing a risk for each section of interest an overall risk is provided to give a general unified trend over time, and trigger alerts. If any
one section of interest is displaying a high risk, the risk to the occupant is high. To make this visible a majority portion of the maximum risk is taken, with a minority portion of each of the other sections of interest. The total possible overall risk is higher than the maximum risk, but if it is exceeded, it is then truncated. The advantage is that if two areas of interest are at high risk it can reach maximum or nearly maximum risk, even if the other areas are at zero risk, or if all are at high risk, risk accelerates faster.

Data Life Cycle

Figure 7 shows the life cycle of data from collection to display. The data array (snapshot) is collected and processed to clean up the signal. The data array is then processed in an instantaneous spatial domain to determine a set of parameters. Parameters can then have a time domain element of processing, comparing to the previous data collected. Once the parameters have been determined the parameters are passed onto the Aggregator for processing to give a simplified output (achieved using the Neural Network in figure 5). The Up/Down counter and Scaling blocks take the output of the aggregator and adjust it to the appropriate data/time model (achieved according to the Accumulate Over Time section and Figure 6).

There is thus provided a body monitoring system having the following advantages:

- Simplified display of information that a user/care giver can interpret.
- Enables a user to see how a change in their position can change their risk.
- Uses low cost sensors - as monitoring change and not absolute pressure.
- Patient or care giver can readily interact with the display to make their own final assessment of risk or change of risk.
- Reduced cost as less caregiver time is required.
• More timely intervention.
• More appropriate intervention - based on empirical data.
• Discrete pad may be retrofitted to wheelchairs.
• Enhanced functionality.
  • It teaches the user good habits.
• The caregiver assesses the patient's pressure relief process and trains them regarding best practice then inputs an effectiveness quotient.
• The caregiver can complete a physiological assessment of the patient and enter a risk factor score using an assessment tool such as the Braden Scale.
• Calculate and display cumulative patient risk based on regional risk, patient physiological data and assessed pressure relief effectiveness.
  • Display historical data as well as real time data so users can get a good feel of trends and the effectiveness of pressure relief.
• A cell phone can the primary means of display.
• Change of pressure utilised instead of absolute pressure to avoid calibration issues. Thus change of risk is the dominant measure.

While the present invention has been illustrated by the description of the embodiments thereof, and while the embodiments have been described in detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications will readily appear to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative apparatus and method, and illustrative examples shown and described. Accordingly, departures may be made from such details without departure from the spirit or scope of the applicant's general inventive concept.
CLAIMS

1. A body monitoring system including:
   a. a pressure sensing system including a plurality of pressure sensors that provide pressure information for a plurality of areas of a body support surface;
   b. a display that displays a plurality of regions corresponding to areas of a body that applies force to the support surface; and
   c. a processor that determines display attributes for each region of the display, wherein each region of the display is a graphical display of cumulative patient risk having reduced dimensionality with respect to pressure information.

2. A body monitoring system as claimed in claim 1 wherein the processor stores a user profile and determines display attributes for each region of the display representative of cumulative patient risk based on the user profile and pressure information for each respective region.

3. A body monitoring system as claimed in claim 1 or claim 2 wherein the processor maps pressure sensors to respective display regions based on an interpretation as to which body parts of a patient correspond to which pressure sensors based on the overall pressure distribution of all sensors.

4. A body monitoring system as claimed in any one of the preceding claims wherein cumulative patient risk is determined by the processor using a measure of change in risk.

5. A body monitoring system as claimed in claim 4 wherein the processor includes a neural network to calculate the change in risk.
6. A body monitoring system as claimed in claim 5 wherein the pressure information is input to the neural network.

7. A body monitoring system as claimed in claim 6 wherein a temperature sensor provides information regarding the temperature of the support surface and supplies this as an input to the neural network.

8. A body monitoring system as claimed in claim 6 or claim 7 wherein a humidity sensor provides information regarding the humidity of the support surface and supplies this as an input to the neural network.

9. A body monitoring system as claimed in any one of claims 5 to 8 wherein the processor stores a user profile for a patient and supplies this as an input to the neural network.

10. A body monitoring system as claimed in claim 9 wherein the user profile is based on measured parameters obtained during training with the patient.

11. A body monitoring system as claimed in any one of the preceding claims wherein the risk for each region is calculated based on accumulated factors relating to increasing and decreasing risk.

12. A body monitoring system as claimed in claim 11 when dependent upon any one of claims 5 to 10 wherein the change in risk affects the rate at which the current risk increases or decreases.

13. A body monitoring system as claimed in any one of the preceding claims including four display regions divided into quadrants.

14. A body monitoring system as claimed in claim 13 wherein the colour of each quadrant indicates the level of risk.
15. A body monitoring system as claimed in claim 13 or claim 14 wherein a symbol is displayed in each quadrant to display a level of risk.

16. A body monitoring system as claimed in any one of the preceding claims wherein the display includes a region displaying global risk which is calculated by the processor based on an accumulation of the risk for all other regions.

17. A body monitoring system as claimed in claim 16 wherein the colour of the global risk region indicates the level of risk.

18. A body monitoring system as claimed in claim 16 or claim 17 wherein a symbol is displayed in the global risk region to display a level of risk.

19. A body monitoring system as claimed in any one of the preceding claims wherein the display displays historical data for global risk in graphical form.

20. A body monitoring system as claimed in any one of the preceding claims wherein the display displays fault information.

21. A body monitoring system as claimed in any one of the preceding claims wherein the processor monitors patient presence by monitoring pressure sensed by the pressure sensors.

22. A body monitoring system as claimed in claim 21 wherein the processor monitors patient wellbeing by monitoring the combination of presence and that the temperature of the support surface is within an acceptable range.

23. A body monitoring system as claimed in any one of the preceding claims wherein the display is a screen of a portable communications device.
24. A body monitoring system as claimed in claim 23 wherein the processor is incorporated in the portable communications device.

25. A body monitoring system as claimed in claim 23 or claim 24 wherein the portable communications device sends risk information to a remote monitoring device via a wireless link.

26. A body monitoring system as claimed in any one of the preceding claims wherein the support surface is a seat of a wheelchair.

27. A body monitoring system as claimed in any one of the preceding claims wherein the support surface is a bed.

28. A patient support control system including a body monitoring system as claimed in any one of the preceding claims and an active support surface responsive to risk information generated by the body monitoring system to control support attributes of the active support surface.

29. A patient support control system as claimed in claim 28 wherein the active support surface includes compartments in which the level of support may be differentially adjusted.

30. A patient support control system as claimed in claim 28 wherein the active support surface includes means for differentially elevating a surface supporting the support surface.

31. A patient support control system as claimed in any one of claims 28 to 30 including a cooling system responsive to risk information generated by the body monitoring system to control the temperature of the support surface.
32. A body monitoring system including:

a. a pressure sensing system that measures the force applied to areas of a body support surface;

b. a display that displays a plurality of regions corresponding to the regions of sensed pressure; and

c. a processor that stores a user profile and determines display attributes for each region of the display representative of cumulative patient risk based on the user profile and information supplied by the pressure sensing system for each respective region.
Figure 5
Figure 6
Figure 7
### A. CLASSIFICATION OF SUBJECT MATTER

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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)

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)

EPDOC and WPI and IPCs A61B5-, A61G7/057, G06T15/00, G06Q50/22, G06Q50/24, G06F19/26, A47C27- and keywords and phrases such as: pressure, force, deflect, reacting, sensors, map, region, zone, area, bedsore, pressure, ulcer, display, graphic, image, user interface, neural network, monitor, manage and the like.

Google Patents search with keywords such as: pressure, sensors, mapping body, risk assessment or management, monitoring, display, pressure sores, pressure ulcers, 3D graphic, display and neural networks, pressure sores and management and the like.

Searching EPO's ESP@cenet advanced search option and the fields "inventor(s)" and "applicant(s)" were searched.

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Documents are listed in the continuation of Box C

| X 1 | Further documents are listed in the continuation of Box C | X | See patent family annex |

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  - 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

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### INTERNATIONAL SEARCH REPORT

**International application No.**

PCT/NZ2014/000128

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