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Smartbed For Pressure Ulcer Using A Microcontroller

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ABSTRACT

The most challenging factor in health care sector for chronic bed ridden patients suffering from long term illness and to tackle bed sores is a common complication. The paper focuses on how to solve such anissue. The care of pressure ulcer is very expensive. A care taker is needed to turn the patient's body every two to three hours depending upon the patient's condition. In order to avoid the necessity of care-taker,this automated bed system is proposed and implemented and known as Smart Bed. Smart bed consists of air-filled bladders at top with incorporated pressure sensors. The sensors sense the amount of pressure applied on regular basis and commands the microprocessor to regulate the actuators when pressure exceeds the prescribed level.By this combined effort of all parts, we can tilt the patient's body automatically.

INTRODUCTION

Pressure ulcer(PU) is a wound that can develop in a patient who remains in one bodily position for an extended period of time. These wounds can be very painful, may take many months to heal and in extreme cases can lead to amputation, organ failure and death. The constant contact between the body and the mattress creates pressure spots that pinch off the tiny blood vessels, cutting off oxygen and nutrient delivery to the skin. Since most people sleep in lateral decubitus position, they have risk of developing pressure ulcers. Pressure ulcers are commonly found in patients suffering from immobility, spinal cord injury, elderly persons (Braden, B. and N. Bergstrom, 1988; Cullum, N., et al., 1995).

Normal young adults spend approximately 60% of their total sleep time in the lateral decubitus position, 25% in the supine position, and still less time in the prone position(as shown in Fig.2)

As per the survey,each year 2.5 millions patients worldwide experience pressure ulcers (also known as bedsores), representing a truly global challenge to health care providers. Pressure ulcers cost $9.1-$11.6 billion per year in the US. Cost of individual patient care ranges from $20,900 to 151,700 per pressure ulcer. Medicare estimated in 2007 that each pressure ulcer added $43,180 in costs to a hospital stay. About 60,000 patients die as a direct result of a pressure ulcer each year.

Currently, the most common practice to prevent PUs is for nurses or caregivers to physically turn patients over from side to side approximately every two hours (Whitteridge, D., 2012). The goal of the proposed work is to improve current hospital beds by replicating the patient turning processes solely through actuation of the bed without the need for a caregiver to exert themselves.

Existing Design Techniques Of Pressure Mattress:

It is very important to determine the type of mattress to be used for the design. According to study, the patients of Stage 1-2 needs high specification foam mattress with pressure reducing property. The persons with stage 3-4 needs high specification mattress with alternating pressure redistribution property

There are two types of mattresses available to distribute the pressure. They are:

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(I)Constant Low Pressure Mattress(CLPM)
(II)Alternate Pressure Redistribution Mattress(APRM)

Constant low pressure Mattress (CLPM):

Constant low pressure mattress (as shown in Fig.1) is also known as “Static, Reactive pressure reducing mattress”. It does not change the pressure beneath the body unless an external force or load is applied. This reduce the applied pressure through process of “IMMERSION” that includes foams, gel, water and fluidised technology. CLP is best suited to whole body pressure mapping techniques. This increases the surface area over which pressure is loaded and thereby reducing skin mattress pressure.

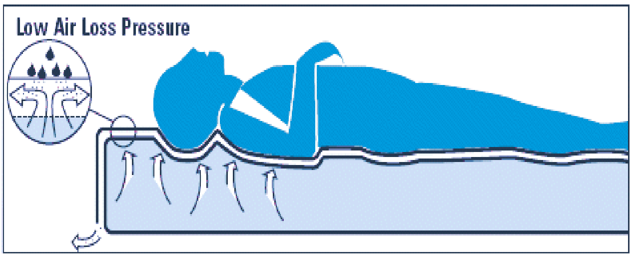


Fig. 1: Constant low pressure mattress

Alternate pressure redistribution Mattress (APRM):

Alternate pressure redistribution mattress(as shown in Fig2) is also known as “dynamic, active, pressure relieving mattress”. This is an externally powered device that systematically load and off-load pressure by inflating and deflating cells and relieve pressure at different anatomical sites for short periods. APRM is best suited to a time based pressure threshold technique. APRM is incorporated with pressure sensors.

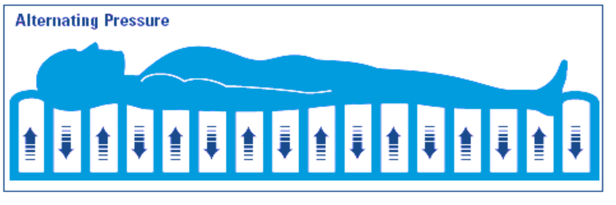


Fig. 2: Alternate pressure redistribution mattress

Litrature Survey For Necessity Of Smart Bed:

The costs of stage IV pressure ulcers and related complications are extremely high. In this study, we emphasize that in calculating costs, the amount spent on treating associated medical complications of pressure ulcers must also be included. Our cost estimate in this study represents only a fraction of the total economic burden of pressure ulcers. There are also expenses of long-term care, such as nursing home and home health care, outpatient visits, social services, and patient transportation, all of which are not accounted for. Other indirect costs include time lost from work, forced early retirement, patient pain and suffering, impact on the patients’ families, and expenses associated with morbidity and mortality. In addition, malpractice suits associated with the development of pressure ulcers, averaging $250,000 per settlement and reportedly accounting for a total of 65$million, were not included in our calculations. It is widely accepted that prevention of pressure ulcers decreases associated morbidity, mortality and health care costs. One study showed that the implementation of a comprehensive prevention program decreased the incidence of all pressure ulcers by 87% At a monthly cost of $519.73 per patient, preventing pressure ulcers would be significantly less expensive than treating stage IV pressure ulcers and associated morbidities, as exemplified in this study.

Although initially more expensive, providing the best quality care from the onset of treatment reduces healing time and is by far the most economical approach. Despite appropriate care, pressure ulcers may not be preventable in certain patients. An alternative approach to reducing morbidity and mortality from pressure ulcers is early detection and treatment to halt progression to stage IV ulcers. Our clinical experience in treating patients with pressure ulcers has shown that while prevention may not be feasible in all cases, halting progression is a feasible goal for all pressure ulcers, except in patients receiving palliative care. A comprehensive program of early recognition and treatment should be implemented to prevent these high costs as well as to reduce morbidity and mortality. The Wound Electronic Medical Record (WEMR) is an essential tool to synthesize the complex clinical information required to manage patients with pressure ulcers because it captures all the critical clinical information on one page, so that appropriate medical decisions can be made[24].

Furthermore, the WEMR allows all clinicians to view the wound, the variables that affectwound healing, and the wound area, thus facilitating change in real time.

Calculation of prevalence and Incidence factors:

PREVALENCE measures the number of patients with pressure ulcers at a certain point or period in time: The numerator will be the number of patients with any pressure ulcer (count for both any ulcer and Stage II or greater).

- Just count patients, not the number of ulcers. Even if a patient has four Stage II ulcers, he or she is only counted once.
- The denominator is the number of patients on your unit or in your facility during that month.
- Divide the numerator by the denominator and multiply by 100 to get the percentage.

Example: 17 patients with any pressure ulcer ÷ 183 patients = .093 X 100 = 9.3 percent

INCIDENCE measures the number of patients developing new pressure ulcers during a period in time Just count patients, not the number of ulcers. Even if a patient has Divide the numerator by the denominator and multiply by 100 to get the percentage.

Example: 21 patients with a new pressure ulcer ÷ 227 patients = .093 X 100 = 9.3 percent.

Proposed Concept:

The proposed concept of smart bed consists of a microcontroller part and motor part. The microcontroller run by a program which includes the basic program setup, input/output pin configuration, and all of the code required to control the mechanism

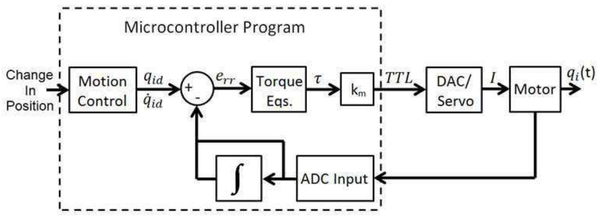


Fig. 3: Control diagram for the mechanical actuators in each tile

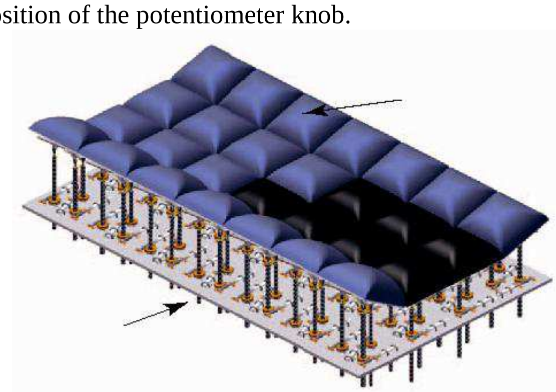
The control functions of the microcontroller program are setup as follows:

First, a desired bed shape is inputted into the microcontroller, indicating which position(right-side lateral, left-side lateral, flat, or semi-Fowler) the patient should be changed to (as shown in Fig. 5).

Next, the desired positions of each tile are found to create the desired bed shape. Trajectory equations then determine desired operational space positions over time, comparing this to the tile's actual position and velocity to generate control errors. Digital signals are produced and sent to a digital to analogy converter (DAC).

The DAC sends analogy signals to three servo amplifiers, one each for the three motors. Each motor then produces a proportional torque, and the motor's rotational velocity is read through a digital encoder. This encoder signal is combined with a known positional set-point when the mechanism is fully down to produce the position and velocity feedback and finally read by the microcontroller through an analogy to digital converter input (ADC Input).The selected motors are used to approximately 2A of current to move the plate.

The voltage output of the potentiometer is between 0V and 5V, sent into the microcontroller through an analogy input on the microcontroller docking station. This control signal is divided into three regions: clockwise movement, brake(no movement), and counter-clockwise movement, allowing the plate to be raised, lowered, and stopped by adjusting the position of the potentiometer knob.



Bed Surface

The above model uses a combination of 84 rods and 28 air bladders. Each tile of the bed uses 3 rods for the movement.

Bed base

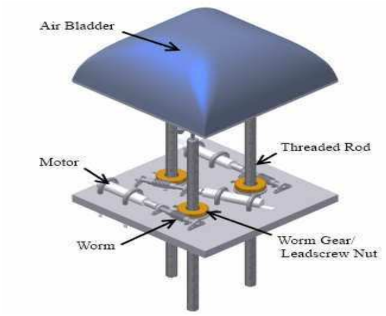


Fig. 5: Overview of a single tile

Scope Of The Smart Bed:

The smart bed proposed in this work includes actuating mechanism capable of manipulating patient's body without physically assisted by the care-giver. The smart hospital bed, *Smart bed*, proposed in this work improves upon the designs of currently available products by including an actuating mechanism capable of manipulating patients' bodies without being physically assisted by a caregiver. While this will eliminate the need for assistance in turning the patient, it is not meant to be utilized without a nurse's care and supervision—the Smart bed is a tool designed to remove one of the more time and labor intensive tasks of caregivers as opposed to replacing their presence all together. Hence a complete or nearly complete removal of pressure on every area of patients' bodies byperiodic, cyclic loading is desirable if not necessary for the total prevention of PUs. Therefore, the Smart bed must be capable of redistributing the forces on a patient's body so that total off-loading of the forces on all areas of the body at different times can be accomplished. However, the goal is to perform this task without performing large movement of the patient that creates potentially damaging shear forces. In the Smart bed this is accomplished using a combination ofrepositioning and inflation/deflation of an attached APRM.

This blend of mechanical and pneumatic actuation creates a surface with a high number of DOFs capable of performing complex manipulation of a human patient.

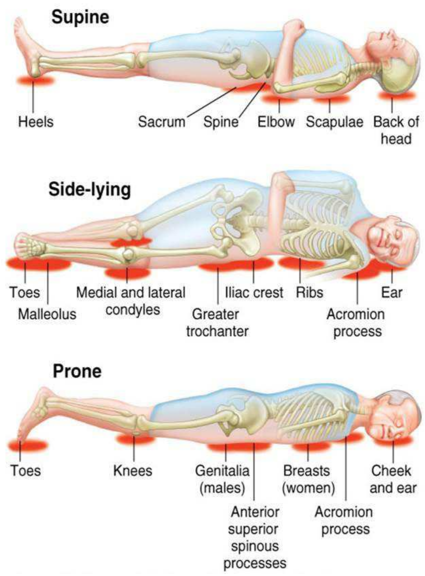


Fig. 6: Three main positions and pressure spots

The supine position is a position of the body:lying with the face up, as opposed to the prone position, which is face down, sometimes with the hands behind the head or neck. When used in surgical procedures, it allows access to peritoneal, thoracic and pericardial regions as well as head,neck etc.

The word *decubitus* is used to mean 'lying down'. It is derived from the Latin verb *decumbere* 'to lie down'. When medical professionals use this term to describe the position of a patient, they first state the part of the body on which the patient is resting followed by the word decubitus .For example the right lateral decubitus is known as lying right sideways.

The word "prone," meaning "naturally inclined to something, apt, liable," has been recorded in English since 1382; the meaning "lying face-down" was first recorded in 1578, but is also referred to as "lying down" or "going prone". It is in 180 degrees contrast with supine.

To summarize the above we can say that Bed rest as a medical treatment refers to staying in bed day and night as a treatment for an illness or medical condition, especially when prescribed or chosen rather than resulting from severe prostration or imminent death. Even though most patients in hospitals spend most of their time in the hospital beds, bed rest more often refers to an extended period of recumbence at home

Types	No. of Pressure sores	Percentage
Occipital	8	6.06
Back	5	3.79
Sacral	63	47.73
Gluteal	28	21.21
Ischial	4	3.03
Knee	2	1.52
Thigh	4	3.03
Ankle	5	3.79
Heel	10	7.58
Others	3	2.27

Fig. 8: Statsitical chart

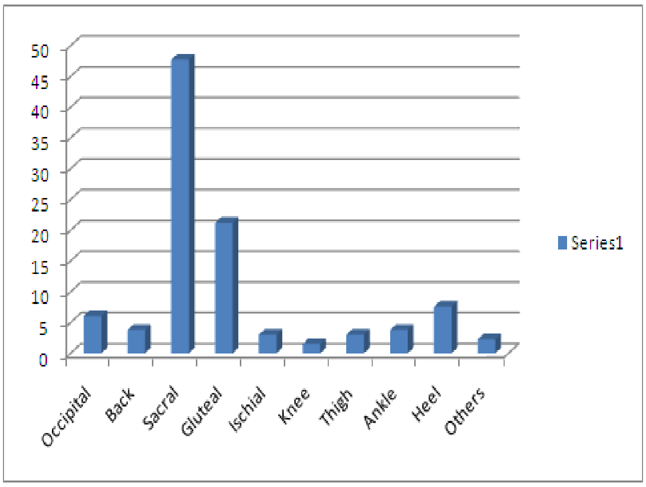


Fig. 9: Pressure sores and their percentage

Mathematical Model For Rotation Of The Bed:

The general coordinates q = [q1 . . . q13]T are used to fully describe the structure's kinematics, and mass and inertia properties are added to each body according to estimations determined from solid models of each part.

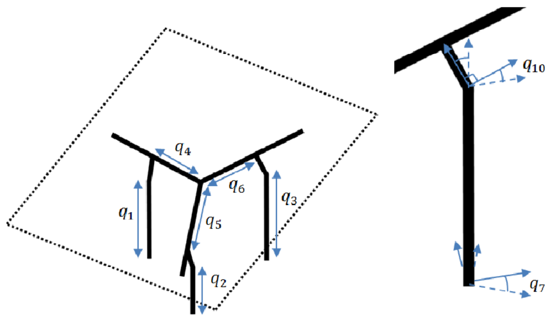


Fig. 10: Generalized coordinates of the mechanism.

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An additional pair of coordinates for each leg and one representing the rotation of the plate body with respect to one of the joint frames are not shownwhere q˙ and q¨ represent each coordinate's generalized velocityand acceleration. The termM(q) □ □13×13 is the massmatrix, b(q˙, q) includes the Coriolis and centrifugal terms,g(q) represents gravitational force, and □(q˙, q) denotes allother external forces acting on the mechanism. Since this is athree degree of freedom (DOF) system, kinematic constraintsare used to relate the velocities of ten dependent coordinatesto three independent coordinates (the extension of the threerods, q1, q2, and q3). The analysis and modeling of thesedynamic systems is based on Kane's method.This dynamic simulation is then used to determine controlsystem equations using the computed-torque method. Sincean accurate model of the system dynamics is known becauseof the previously described dynamic modeling, the externalforcesin (1) are equivalent to the actuator torque.

Using dynamic decoupling, also called feedback linearization.

This assumes a unit mass system according to the definition. Now, the following control law with control constantsk$_p$ and k$_v$ can be included.

The simplified model assumes that the three operationalspace variables, θ1, θ2, and h3 can be approximated by theequations:

System efficiency is given by,

ηls =tan(λ)/tan(φ + λ)=tan(4.9◦)/tan(9.1◦ +4.9◦)= .34ηtot = ηlsηmotor = .34(.80) = .27 (18)

Finally, the direction of friction is taken into account bymultiplying the previous equations by the function sgn(q˙n),where n refers to threaded rod 1, 2, or 3, since friction always opposes motion.

In summary, the dynamics of the actuating system aretaken into account by combining the gravity and inertia termsin the equations of motion, multiplying them by an efficiencycoefficient of 0.27, and then finally selecting the sign basedon their direction of motion. In addition, the tiny reflectedinertia of the motor and gear train is ignored, which shortens and simplifies the final control equation

Conclusion:

This work explains the design, modelling, simulation, and open loop testing of the actuating mechanism for the development of a smart hospital bed to prevent the bed sores. The steps are taken to create a prototype of the mechanism with the use of theoretical models and practical analysis.

The novelty of this work lies in the successful application of an ideal control system in an actual mechanical device. Further work on this project would be focused on the implementation of position sensing, more complex user input, and closed-loop feedback on the mechanism. In addition, modelling and design of the pneumatic system is necessary in order to account for the air bladders on top of each plate. Finally, a control system would have to be developed to combine the 84 rods and 28 air bladders into one coordinated patient-manipulating Smart bed system. With this complete design, the bed could be built entirely and move on to test the patients.

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