Advance Smart Bed for Patients

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ABSTRACT: The design, modeling, and experimental testing of a smart hospital bed that is mechanically operated to avoid pressure ulcers in hospital patients are described in this study. The smart hospital bed, or Smart bed, is designed to improve the existing "turning" cycle performed by health care workers, guaranteeing constant patient turning and lowering caregiver labor needs. This describes the bed's mechanical construction as well as its benefits over other Smart Bed products. The Smart bed actuation systems, on the other hand, are dynamic models that are described in depth in line with the constructed single unit and full bed control installations. The powering of one multi-unit bed platform unit is verified using an open user feedback loop, testing of design choices, and hardware upgrades of the bed, and the simplified ultimately control system is assessed in simulation against the original dynamic model.

KEYWORDS: High Pressure, Microcontroller, Smart Bed, Torque Speed.

INTRODUCTION

In recent years, South Korea has confronted the problem of a rapidly aging society. As a result, the care of elderly people is a crucial issue. In addition, a growing number of specialized medical facilities and senior care centers have been created for the elderly (called sanatoria). Nonetheless, the industry's fast development in relation to senior care and the creation of suitable institutions is beset by a slew of issues, including a lack of effective management. When an old person remains in the same position for an extended period of time, whether in a bed or a wheelchair, friction between the skin and the surface disrupts blood flow, resulting in less oxygen reaching the pressure region and cells dying in that area. Pressure ulcers in the elderly may cause significant morbidity and death, as well as putting a significant financial strain on the health-care system. Recent studies have found massive spending on direct medical expenses for domestic injuries (in the United States, more than 1 billion for non-fatal falls in subjects > 65 years of age; in the United Kingdom, 1.2 billion for emergency care and hospitalization; and in Australia, a national expense of US 2.3 million for elderly falls). Surprisingly, hospitalization-related costs account for two-thirds of total medical costs. Falls are by far the most common cause of injury among the elderly.

Every year, one in every three seniors aged 65 and above suffers a fall. These are the main cause of non-fatal and fatal adult accidents, as well as moderate to severe injuries that may result in impairment or increase the chance of mortality by 10 to 40%. Elderly falls are a significant clinical issue with an outgrowing socioeconomic cost in terms of incidence, damage, institutionalization, and total mortality from a healthcare viewpoint. Bedsores and falling injuries among senior patients are common problems, accounting for more than 80% of cases in these care facilities. The Korean Ministry of Health and Welfare has established operational rules for medical institutions, and the latter, in turn, monitors the risk of falling and pressure ulcers by following these laws. Despite this, the number of cases of bedsores and fall incidents continues to rise. The primary reason for this tendency is a scarcity of qualified employees [1]–[3].

These hospital beds, sometimes known as smart beds, are already available on the market and have been for some time. The alternating pressure air mattress (APAM), for example, rotates users side to side by inflating and deflating air-filled cells in the mattress. While some items seem intriguing, their efficacy is insignificant. Three-piece mechanical beds that can incline a person's back and legs have also been created, some of which feature pressure sensor arrays for input and limited turning capabilities for Adams. While they have been shown to decrease the incidence of PUs, current versions cannot turn a patient on their side and relieve pressure on their back without the aid of a medical staff.

The goal of this project is to improve existing smart bed systems by simulating patient turning procedures purely via bed actuation, eliminating the need for a caregiver to exert themselves. We propose a proof-of-concept platform for pressure ulcer monitoring and prevention in this article. The four major elements of a support system, namely data gathering, modeling, machine learning, and action, have been incorporated into this framework. We successfully tested our technology using pre-recorded data and found that it performed well and was accurate. Due to a shortage of space, our debate will be restricted to the system level. The specifics of these algorithms are outside the scope of this article and will be disclosed in subsequent versions.

LITERATURE REVIEW

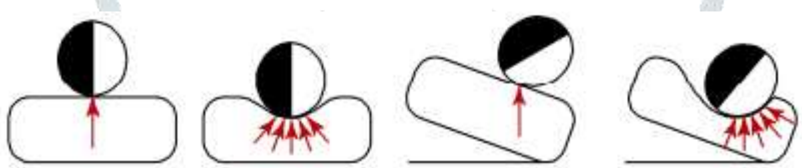
Ignacio Ghersi et al. discussed a review on Smart Medical Beds [4]. Recent scientific accomplishments and technical advancements have brought forth a huge display of new or updated medical equipment, equipped with highly-developed embedded-control capabilities and interactivity. Medical beds have been especially impacted by this rise during the latter decade of the twentieth century, taking on new shapes and functions while accommodating existing characteristics that have become well-known for these equipment. Changes in conceptual frameworks, such as product design and production processes (standards), as well as patient care, have occurred during the last fifteen years (perspectives on patient-care environments and accessibility). This paper provides a state-of-the-art study on electric medical beds, which are part of an increasingly complete patient-care environment and are referred to as "smart beds." Methods: Between 2000 and 2016, a survey and evaluation of market trends, research efforts, and standards in the field of smart medical beds was conducted, encompassing a wide range of public records of intellectual property, models, and related healthcare solutions, as well as relevant research efforts in the field. Contextual issues such as new technology, disabilities, and the reach of healthcare systems were also studied and analyzed, since they were essential for comprehending this subject. The next generation of electric medical beds has been specified, and the projected timetable for these devices has been completed. Functional, aesthetic and interactive features are presented, and the current global market for medical beds and related standards are also assessed. Finally, the possibility for integrating more monitoring and assisting implementations into medical equipment and surroundings is discussed, as well as the increasing difficulties and possibilities for these systems. Conclusions: Based on a thorough, interdisciplinary design approach, smart medical beds are integrated solutions for patient care, support, and monitoring. In the context of global ageing, research in this area is important, and it is fueled by a rise in possibilities for accessible solutions. Smart beds, when seamlessly integrated into the healthcare system, offer a one-of-a-kind potential to help caregivers work more efficiently and provide more responsive settings for patients.

Youn Sik Hong et al. discussed a review on Smart Care Beds for Elderly Patients with Impaired Mobility [5]. The most common types of accidents that occur in medical facilities treating senior patients with mobility issues are bedsores and falls. The shortage of nursing staff is one of the causes for the high incidence of accidents. In this article, we suggest the design and implementation of a smart bed to assist caregivers in nursing elderly patients who are unable to move about freely. Several pressure sensors are installed under the mattress cover in this bed to account for both people's general physical features and the particular body areas where bedsores are more prevalent. The body is split into three vertical and three horizontal regions to control the pressure ulcer area and avoid falls. Each microcontroller unit is in charge of pressure-sensing data in one of the horizontally split body sections. This research presents a real-time pressure-sensing algorithm capable of determining the likelihood of bedsores and falling accidents by taking into account both the intensity and duration of pressure on particular body regions. Our findings show that a prototype smart bed works effectively for a variety of human models of varying heights and weights.

Youngho Kim et al. discussed a review on Monitoring technology in Smart bed [6]. We wanted to assess the viability of omnipresent technology in healthcare since it is a new paradigm in the field. As a preliminary step, we assessed the smart bed's viability. A number of tests were carried out in order to assess the smart bed in this research. Materials and Procedures: Seoul National University created the Smart Bed, which is a continuous ballistocardiogram monitoring equipment. Eleven healthy people took part in the research. For two nights, each participant slept in the smart bed. Noisy portions of the original signal were eliminated in order to quantify significant sleep times. Automatic peak detection, utilizing the AF2 peak detection method, was used to collect the subject's cardiac activity. The practicality of the smart bed was assessed in this research in terms of meaningful sleep durations and automated peak detection accuracy. The results showed that 92.8 percent of sleep time was significant on average. The peak detection algorithm's accuracy was also tested. In contrast to the human findings, the algorithm proved to be 95% accurate; therefore, we notice that 95% of the peak detection results were right. Conclusions: Based on the findings of the experiments, we believe that the smart bed may be a valuable device for long-term monitoring in a variety of healthcare settings.

METHODOLOGY

Because contact with the hospital bed is the leading cause of pressure ulcers, a smart bed may serve as the first line of defense in preventing them. With this aim in mind, the hospital bed may be seen as a source of bio-signal data gathering, since patients spend a significant amount of time there. In general, the goal of this research is to improve the bed's intellectual and physical skills so that it can offer cognitive assistance to medical personnel. A smart bed will be created by combining a sensor network, artificial intelligence, a morphable, tiled floor, and computer control to provide staff assistance that will significantly enhance therapy, epidemiological research, and pressure ulcer prevention. The smart bed cuts down on the number of people required to turn patients around. This allows the nurse to spend more time at the bedside evaluating problems or adverse events rather than requesting assistance in rotating the patient. The smart hospital bed proposed in this research improves on existing designs by including an actuation system that can regulate the bodies of patients without requiring physical assistance from a caregiver. While this eliminates the need for assistance in turning the patient, it is not intended to be used without the supervision and care of a nurse—the Smart bed is a tool designed to alleviate one of the caregivers' more time-consuming and labor-intensive tasks rather than completely replacing their presence.



a) High Pressure b) Low pressure c) High Pressure Tilt d) Low Pressure Tilt

Figure 1: Manipulation of Mattress

According to the doctor, cyclic loading is desirable if not essential for the entire avoidance of PUs, as it removes pressure from every area of the patient's body on a regular basis. The Smart bed must also be able to redistribute forces on a patient's body, allowing for full off-loading of forces on all areas of the body at different periods. Nonetheless, the goal is to complete this job without causing possibly damaging shear pressures due to the patient's wide mobility. Repositioning and Inflation/Deflation are used in the Smart bed to achieve this. Figure 1 shows how this procedure works. In Figure 1a, the mattress is under a lot of strain. At a single level, the body's weight is supported by a powerful force, as seen by the up arrow. Figure 1b shows how when the mattress is deflated, the surface deforms at each contact point, providing for force distribution and reduction. However, when the skin sinks into the mattress, it may expand, creating shear tension. Furthermore, the usual force still affects the point of contact in Figure 1a, and it may not recover quickly enough. A stiff surface for repositioning is shown in Figure 1c.

The peak point of force travels across the surface as the body rotates. The force is still significant, and the body may move away from the intended position, as when the patient is physically rotated. The lesser, redistributed forces resulting from simultaneous repositioning and deflation of the mattress are shown in Figure 1d. The skin may heal since no force is applied at the initial contact site in Figure 1a. During rotation, body movement may help to reduce skin strain and shear stress. In most cases, the body remains in the end position and does not travel as far from its initial position as seen in Figure 1c. While the mattress has been turned significantly, the body has not moved far from its initial position. Moving the forces from one side to the other on a regular basis allows for 5 skin regeneration on each side, giving the impression of turning with tiny rotations. Deflates the pneumatic and mechanical actuation and tilts the flexible framework connected to the stiff, as shown in Figure 1. These concepts may be extended to obtain the basic tile concept illustrated in Figure 2, which consists of a stiff parallel mechanism with an air bladder connected.

SVM, a learning algorithm that generated state-of-the-art results on a number of tasks both within and outside the healthcare sector, was used to train this risk assessor. Each instance in our training set refers to data received from a particular body part of a patient at a certain time period and is represented as a vector containing the characteristics described in the previous chapter. A health care practitioner may give an instance mark that is either a simple binary categorization (i.e. whether the patient is at high risk of getting illness or not) or one of three levels (i.e. extreme, moderate, low risk). Because of this training set, the author may use an SVM and a variety of kernels to assign one of the risk levels to a test instance (if the label is one of the three classes) or a classifier to identify whether a patient has a high risk of getting ulcers (if the label is binary). One might argue that the binary choice a classifier gives isn't very helpful in reality since most people want a real number that reflects the likelihood of getting ulcers. In reality, this actual value may be readily calculated using an SVM classifier. As a result, the author creates a risk function that assesses the risk associated with a test instance based on its distance from the hyperplane in SVM, with the greatest (lowest) risk value being assigned to the instance in the positive (negative) area that is furthest from the hyper plane [7]–[9].

The air bladder on top is provided to distribute force away from high-risk PU regions to places with less severe pressure. The heels, hips, sacrum (lower spine), and coccyx are examples of acute regions where bony prominences lie immediately under the skin tissue (tailbone). PUs may also form on the gluteal muscles (buttocks), especially when the body and head are raised in the semi-Fowler posture. Pressure dispersion occurs as a result of the air cushions' capacity to deform across an unlimited number of degrees of freedom. The cushion may withdraw at high-pressure spots if the air pressure is kept constant, spreading the pressure on the same tile to adjacent regions. Furthermore, each bladder's pressure is changeable, thanks to air pumps that supply unique air to each bladder. By measuring and balancing the forces on all tiles, this pneumatic actuation, in conjunction with a pressure sensor array on top of the bladders, produces a force-based servo system. The top sensors and air bladder design and control are presently beyond the focus of this research, but these elements of the project have been addressed in the creation of the mechanical hardware and control described.

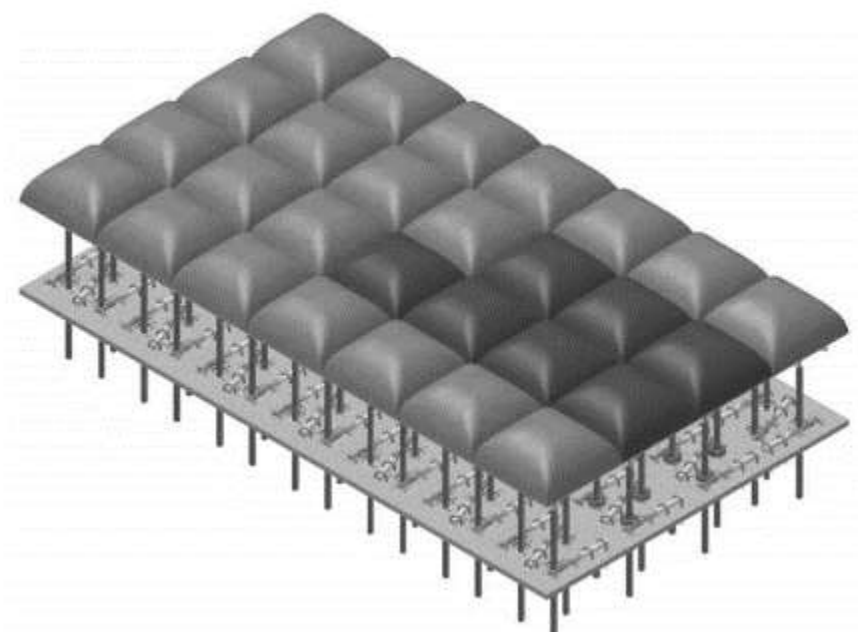


Figure 2: The above Diagram shows Smart Bed

The general design of the bed is a segmented or tiled surface, with each tile working alone or in tandem with the others. It creates a fluid surface on which a patient may be controlled without having to hold him or her. Figure 2 shows a rough sketch of the bed, as well as a close-up of a single tile. It is made up of 1-foot x 1-foot pieces that create a bed that is approximately 7 feet long and 4 feet broad and may fit a variety of patients. It is intended to treat individuals weighing up to 315 kg, including bariatric patients. Other configurations are conceivable since each system consists of a parallel mechanism with an air bladder connected to the top [10].

DISCUSSION

From the deformable bladder on top, every system has three degrees of freedom (DOFs) and an unlimited number of DOFs; the actual bladder would have a more rectangular, flatter surface with greater room. To give force input to the motor controllers, pressure sensors are placed into the surface and/or beneath the air bladder. In addition to the other characteristics of the bed, a tile will currently tilt to a maximum of 610 degrees, which should be sufficient to accomplish the same effect as rotating the patient.

The "ideal" mechanism is used in simulation because it is based on the following assumptions:

• Before the control system takes over, all 13 joint space locations and at least three velocities are known or quantifiable.

• Each rod's exact location in relation to an inertial reference point is known or always quantifiable.

• The controller has adequate memory to house the control software and is powerful enough to execute the computations required and transmit each motor torque signal in real-time.

In reality, such positions are often only given as a relative measurement from an encoder, friction and other nonlinearities in actuation are frequently important, and laboratory computers have trouble handling the complete complexity of an accurately computed torque control scheme, let alone in real-time. Such problems must be addressed before the optimal control system can be applied to the Smart-bed hardware. The uniqueness of this study is in the application of this control system to real hardware; although previously computed torque control equations based on this parallel framework have been generated, no one has yet completed the necessary steps to apply these equations to the built system.

CONCLUSION

The actuation mechanism for a smart hospital bed intended to prevent bedsores from developing was developed, modeled, simulation, and open-loop tested in this study. The methods required to develop an incomplete, immobile prototype of the mechanism using theoretical models and practical analysis are shown, and the resultant mechanism control software and hardware are given. First, based on torque-speed restrictions, a dynamic model of the system is created to choose the motors and associated components for each motor provided by the manufacturer. The model is then used to generate control equations that allow the platform to follow the required operational space trajectories. After then, the computations are reduced to make them usable, taking into consideration the microcontroller's speed, memory, and processing capacity. The ability of these reduced control equations is tested in simulation after additional adjustment of the equations to better reflect the actuating mechanism.

Finally, to qualitatively evaluate the hardware's functioning, an open-loop examination of the hardware structure and specific parts of the microcontroller code is performed. With the completion of these testing, all elements of the mechanism and control system designs are deemed successful, with just the encoder feedback and closed-loop control feedback equations remaining untested on the prototype.

The uniqueness of this study consists in the effective application of an ideal control system created in simulation to an actual mechanical system. The dynamic modeling and calculated torque equations are transformed from a simple academic exercise into a functioning, realistic control system by using polynomial curve fitting methods, trapezoidal velocity propagation, and leadscrew dynamics in the model. Position sensing implementation, more sophisticated user input, and closed-loop feedback regarding the system will be the focus of future development on this project. Additionally, the pneumatic system must be modelled and built to account for the air bladders on top of each plate. Eventually, a control system will be needed to merge the 84 rods and 28 air bladders into a single patient-manipulating Smart-bed system.

REFERENCES

[1] P. Oberlin and M.-C. Mouquet, "Number of hospital beds in 2030: projection with national French case-mix data," *BMC Health Serv. Res.*, vol. 8, no. S1, Dec. 2008, doi: 10.1186/1472-6963-8-s1-a6.

[2] B. D. Rohanta, B. A. Ashish, P. P. Niraj, and P. P. Ganesh, "Smart Bed System In Hospital," 2017.

[3] Y.-S. Hong, "Smart Care Beds for Elderly Patients with Impaired Mobility," 2018, doi: 10.1155/2018/1780904.

[4] I. Ghersi, M. Mariño, and M. T. Miralles, "Smart medical beds in patient-care environments of the twenty-first century: a state-of-art survey," *BMC Med. Inform. Decis. Mak.*, vol. 18, no. 1, pp. 1–12, Jul. 2018, doi: 10.1186/s12911-018-0643-5.

[5] Y. S. Hong, "Smart Care Beds for Elderly Patients with Impaired Mobility," *Wirel. Commun. Mob. Comput.*, 2018, doi: 10.1155/2018/1780904.

[6] Y. Kim, S. Yoo, C. Han, S. Kim, J. Shin, and J. Choi, "Evaluation of unconstrained monitoring technology used in the smart bed for u-health environment," *Telemed. e-Health*, 2011, doi: 10.1089/tmj.2010.0211.

[7] T. Banerjee *et al.*, "Monitoring Hospital Rooms for Safety Using Depth Images," *AAAI Fall Symp. Ser. - AI Gerontechnology*, 2012.

[8] Y. K. Jan and D. M. Brienza, "Technology for pressure ulcer prevention," *Topics in Spinal Cord Injury Rehabilitation*, vol. 11, no. 4. p. 30, 2006, doi: 10.1310/26R8-UNHJ-DXJ5-XG7W.

[9] Z. Chen *et al.*, "Unobtrusive sleep monitoring using smartphones," in *Proceedings of the 2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops, PervasiveHealth 2013*, 2013, pp. 145–152, doi: 10.4108/icst.pervasivehealth.2013.252148.

[10] S. Ajami and L. Khaleghi, "A review on equipped hospital beds with wireless sensor networks for reducing bedsores," *Journal of Research in Medical Sciences*. 2015, doi: 10.4103/1735-1995.172797.