International Journal of Advanced Culture Technology Vol.8 No.3 254-259 (2020)
DOI https://doi.org/10.17703/IJACT.2020.8.3.254

IJACT 20-9-32

The Control System of a Robot Bed for Caring Pressure Ulcer

Jungae Kim[1],Youngdae Lee[2], Hyunkyung Cho[3]

Assistant Professor, Department of Nursing, Chodang University, Korea[1]
Research Director, Ninebell, Korea[2]
Assistant Professor, Department of Digital Visual Graphics, DIMA University, Korea[3]
jjosha6615@hanmail.net, *ydlee@ninebell.co.kr, Sharonny69@naver.com*

Abstract

The medical bed developed in this study is an electrically driven segmental keyboard. First describe the instrument of the segmental bed specially designed for pressure ulcer prevention, then the motor control system and pressure ulcer prevention operation of the bed. The main factor of pressure ulcer generation is displayed as body pressure x *time, and when the keyboard falls, the body pressure becomes zero, and the pressure becomes higher than the threshold even if the body pressure is above the threshold, the pressure control algorithm has been developed. Therefore, using the proposed pressure control method, it has no particular ulcer occurred theoretically.*

Keywords: *Body pressure, Ulcer Prevention, Robot Bed, Segmental bed, Motor control system*

1. Introduction

The pressure ulcer refers to the condition of damage to subcutaneous tissue caused by continuous pressure or shear stress on the soft tissue of the body. The pressure ulcer is a common complication that usually occurs in people with circulatory, nutritional disorders, cognitive impairment, sensory disorders, and exercise restrictions, and when it progresses to the bone, it leads to a life-threatening condition with osteomyelitis and sepsis [1]. The occurrence of pressure ulcers in hospitals is mainly occurring in intensive care units with severe movement restrictions. The incidence of bedsores in intensive care units in domestic hospitals is reported at 38.3% [2]. The pressure ulcer not only increases the risk of complications of disease [3], which not only prolongs the length of hospital admission, but also imposes burdens on the patient's family and society because it increases medical costs [4], but also increases the risk of death by making it difficult to recover once it occurs [5].

Therefore, it is most important to prevent pressure ulcers before they occur. Nurses who directly care for patients were studied in various fields to find ways to reduce the incidence of pressure ulcers. A recent study in the field of nursing has been conducted to reduce the incidence of pressure ulcers through careful observation before the occurrence of pressure ulcers [6], [7] and further to develop programs to prevent pressure ulcers [9].

As above, it can be seen that in the nursing field, the emphasis is placed on careful observation, nutrition and skin care to reduce pressure, which is the cause of the occurrence of pressure ulcers. On the other hand, in the

Manuscript Received:July 15, 2020/Revised:August 07, 2020/Accepted: August 18, 2020
Corresponding Author: jjosha6615@hanmail.net
Tel:+82-61-450-1818, Fax: +82-61-450-1801
Author's affiliation :
Assistant Professor, Department of Nursing, Chodang University, Korea

field of biomedical engineering, various risk analysis studies of pressure ulcer generation were carried out to prevent crushing.

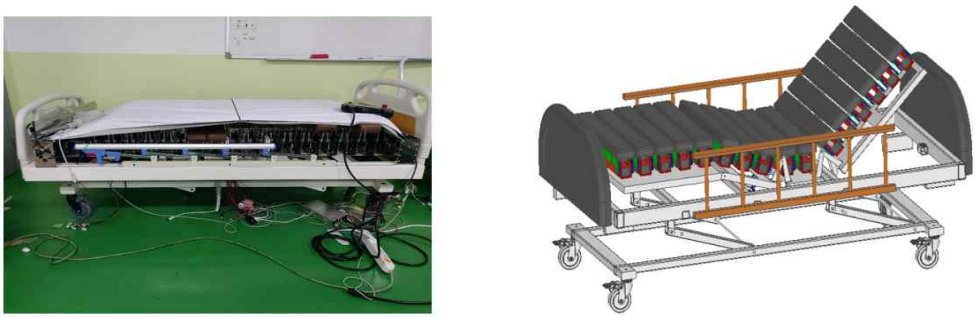
Looking at the biomedical aspects of the pressure ulcer that have been studied so far, Todd and Thacker [10] interpreted the stress distribution of the hip in the wheelchair. [11], [12] studied the risk of crushing by applying contact between the hips and the wheelchair cushion. Furthermore, [13] was studied to measure pressure distribution using pressure distribution measuring devices. As such, the main factors of pressure ulcer generation are focused on the skin continuously, and various technical research and expert analysis are being conducted, such as testing the pressure distribution of pressure-reducing mattresses to prevent pressure ulcers. For the prevention and healing of pressure ulcer, the anti-pressure mattress currently on the market is a passive pneumatic type, which is usually installed on the bed, and an active alternating pneumatic type using a pneumatic pump is also used [14]. Beds made by integrating pressure ulcer mattresses and pneumatic pumps are also developed and used in domestic Sorbed co., ltd, but nobody pressure measurement information is used [15]. Recently, a product called Monitor Alert Protect (MAP) has been developed in Wellsense, which analyzes body pressure sensor data embedded in bed mattresses and raises alarms when pressure ulcers are feared to occur [16]. In addition, the Fraunhoffer Institute has published a technology to reduce user's body pressure by modifying the bed's own posture by measuring the distribution of body pressure through a project called INSYDE, but it seems to be for research purposes that are not easy to commercialize [17].

2. Robot Bed System

2.1 Mechanism

The figure shows the appearance of the developed bed-robot, which is made of a keyboard, applies a parallelogram link mechanism made as shown in Figure 1 to perform a four-bar driven movement (4 bar motion). Section 4 drive motion has a phase inversion problem, so to solve this problem, a phase offset has been placed and a mechanism has been designed to smoothen the motion [18][19][20]. Figure 2 shows a keyboard-structured bed equipped with 16 such mechanisms, which is a medical powered bed for pressure ulcer prevention, automatic seat exchange and patient transport. Figure 3 shows the control system of keyboard motors.

Figure 1. Developed Quadrant motion Link



(a) Picture **(b) 3D model**

Figure 2. The Appearance of the robot bed

The medical robot control system developed consists of 16 motor drivers driving a keyboard link, a main controller connecting them to a car area network (CAN) communication, and a Teach Pendant that directs the operating mode of the bed, as shown in Figure 4.

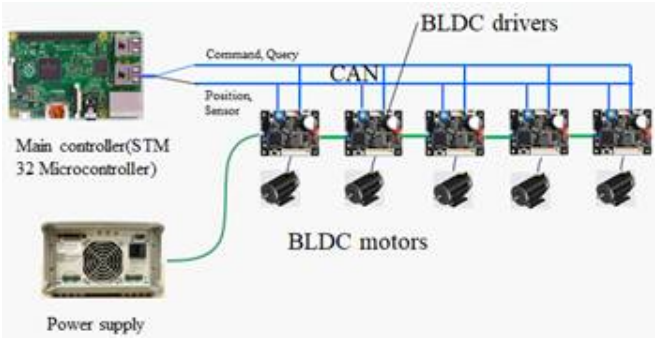


Figure 3. Control system of keyboard motors

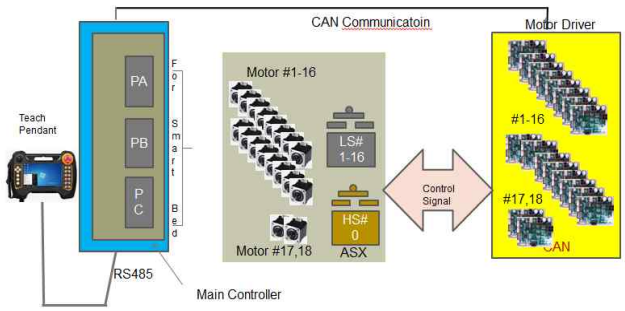
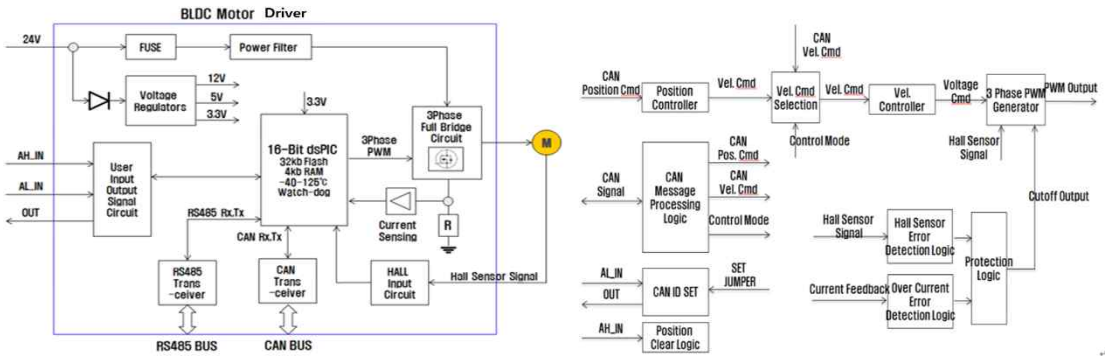


Figure 4. Composition diagram of the entire control system

As shown in Figure 3, servo drivers controlling BLDC motors on the keyboard and STM32 microcontroller, which is connected by CAN (Car Area Network) communication and provides two CAN ports, are used as main controllers. The main controller transmits the motor's position and speed instruction information to the servo driver and the servo driver transmits the current position, speed and sensor information to the main controller. In addition, a dedicated servo driver is provided with input contacts, and the motor origin detection signal is received from the servo driver and transmitted to the main controller as shown in Figure 4. Figure 5 shows the hardware block diagram (a) and software control block diagram (b) of the developed BLDC motor servo driver.



(a) Hardware Block Diagram (b) Software Block Diagram

Figure 5. The Block Diagram of the Developed Servo Driver

The CPU unit of the main controller is STM32F105 CPU with Cortex-M3 Core, which has 2 CAN communication ports, 5 UART communication and I2C, and has USB and I2C to communicate with the servo motor drive by CAN and RS485 with the Teach Pendant.

4. Control System

4.1 Automatic Ulcer Prevention Control

Figure 6 shows the basic flowchart of pressure ulcer prevention. The bed robot performs a pressure ulcer preventive action at the home position, and the even and odd keys move alternately. For the control of body pressure, the duration of body pressure was much shorter than normal body pressure (2 hours) when the keyboard was lowered to zero or when the keyboard was raised to prevent pressure ulcers from occurring in principle. The raised keys automatically fall again after the critical duration, resulting in a corresponding partial contact body pressure of zero.

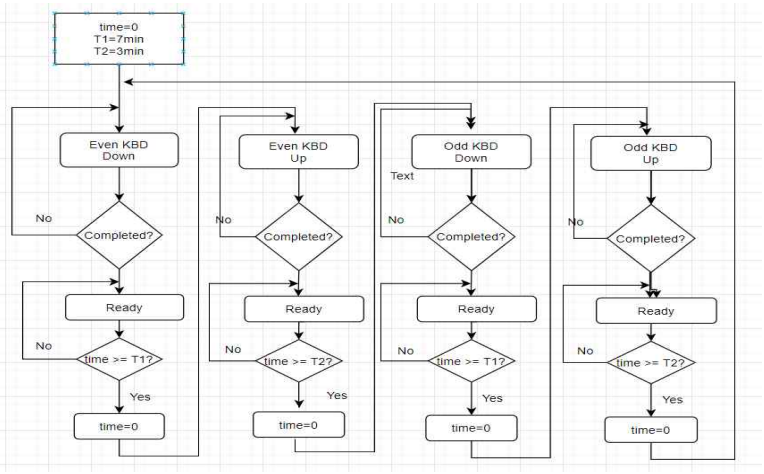


Figure 6. Flow chart of pressure ulcer prevention control

In principle, it is known that the change in body pressure takes less than two hours, but the shorter the time to prevent the occurrence of the pressure ulcer, so the pressure control program has been designed to repeat every T_1+T_2 (=10minutes) that the unidirectional keyboard falls during T_1 (=7minutes) and the flat bed keyboard is maintained during T_2 (=3minutes). The rationale for programming the body pressure change cycle to 10 minutes was that the pressure applied to the skin would change from 100mmHg to 30 minutes, as in the literature [18]. Therefore, the change of body position cycle was set up once every 10 minutes, shorter than the 30 minutes at which the change in body pressure occurred, so that there would be no change in skin tissue. T_1, T_2 has been enabled to be set in the Teach Pendant so that the pressure ulcer prevention cycle can be changed and needs to be set optimally for patient comfort and effective pressure ulcer prevention.

4.2 Teach Pendant UI

Figure 7 shows the UI of the Teach Pendant. (a) has manual mode and automatic mode for pressure ulcer prevention, and in manual mode, the odd number of keys is moved up and down, and in automatic mode, T_1 and T_2 are entered to limit the number of keys. (b) raise the odd number of keys and lower the even number of times, place the supporting bar across the patient's base through a special bed railing in an even number of empty spaces, and lower all the keys. The seat located at the head and foot of the bed is then rotated to replace the seat. (c) is a menu that moves the patient from the center of the bed to the edge of the bed by rotating the

keyboard left or right. (d) rotates three motors on the base of the bed to control the patient's posture, and has the function of knee up and down, back up and down and leg support.

(a) Pressure Ulcer Prevention Menu (b)Sheet Exchange Menu

(c)Patient Transport Menu (d)Posture Change Menu

Figure 6. The UI of the Teach Pendent

5. Conclusion

This study describes the medical robot bed system and control algorithm developed for pressure ulcer prevention and healing. Currently, commercial pressure prevention mattresses operate manually and the residual body pressure exceeds the pressure threshold, so there is always room for pressure ulcer generation, but the bed system developed in this study uses an active electric drive keyboard system to reduce the pressure of the bed to zero when the keyboard falls, so no pressure of the bed does occur. Even if the keyboard of the bed rises and exceeds the pressure of the pressure ulcer threshold, the instrument and control system are configured to keep the duration within the critical time of the occurrence of the pressure ulcer, so the occurrence of the pressure ulcer does not occur. Therefore, the newly developed medical bed means a robot bed that can be commercialized. The motors on the bed keys are equipped with medical-fit BLDC servo drivers and are designed for easy use with a simple overall appearance and communicate with each other in a car area network (CAN) manner. The new system is a medical robotic bed that is effective in preventing pressure ulcers, so it will be available to many patients suffering from pressure ulcers.

Acknowledgement

This research was supported by a grant (code D191970) from Gyeonggi Technology Development Program funded by Gyeonggi-do.

References

[1] YH Kim, Musculoskeletal Modeling, Finite element Studies on soft tissue and Pressure Measurements with BION(Bionic Neuron) functional Electrical Stimulations for Pressure Ulcer Prevention, 2005 year Report on the Research Results of Research Support Project for Overseas Visits of University Students, 2005.

[2] YK Kim, Evaluation of a pressure ulcer risk assessment too. The Korean Academic Society of Adult Nursing. vol.9, no.2, pp.272-285, 1997.

[3] Higgins N. Management of a pressure ulcer in the presence of arterial disease and MRSA infection. Wound Practice and Research, vol. 16, no. 4, pp.166-168, 2008.

[4] Bennett G, Dealey C, Posnett J. The cost of pressure ulcers in the UK. Age and Ageing. vol. 33, no. 3, pp. 230-235, 2004.

[5] Russo, C. A., Steiner, C., & Spector, W. Hospitalizations related to pressure ulcers among adults 18 years and older, 2006 (HCUPStatistical Brief #64). Rockville, MD: Agency for Healthcare Research and Quality, 2008.

[6] HJ Na, Consistency among measurers of pressure ulcer risk assessment and pressure level classification using Braden scale of nurses in small and medium hospitals, master's thesis, Chonnam National University, 2018.

[7] JE Choi, A Comparative Study on the Estimation of Risk Assessment Guards in Trauma Patients, Master's thesis, Pusan National University, 2018.

[8] YH Yang, WS Kim, The Effect of the Risk Factors and Nutrition on the Desiccation of Inpatients in the Intensive Care Unit, Journal of the Basic Nursing Society Vol.5 No.2, pp. 280-292, 1998.

[9] YH Kim, JN Jang, MJ Song, MG Oh, YM Lee, Effect of Integrated pressure ulcer nursing program for pressure ulcer prevention and management, Journal of the Korean Data Analysis Society Vol.17 No.2, pp. 1015-1029, 2015.

[10] Todd B and Thacker J, Three-dimensional computer model of the human buttocks, in vivo, J Rehab Rec Dev, vol. 31, pp. 111-119, 1994.

[11] Chow C and Odall E, Deformations and stresses in soft body tissues of a sitting person, J Biomech Eng, vol. 100, pp. 79-86, 1998.

[12] Oomens CWJ, Bressers OFJT, Bosboom EMH, Bouten CVC and Bader DL, Can loaded interface characteristics influence strain distributions in muscle adjacent bony prominence?, Computer Methods in Biomech & Biomed Eng, vol. 29, pp. 1-10, 2003.

[13] GH Rheu, GW Lee, SB Park, YH Kim, Characteristics of Pressure Distribution of Hips in Sitting Position, Collection of Papers for Spring Conference of the Korean Society of Biomedical Engineering, vol. 21-1, pp. 224-225, 1999] [Kath M, Bogie D, Phil., Steven I, Reger, and Simon P. Levine, Electrical stimulation for pressure sore prevention and wound healing, Asst Technol, vol. 12, pp. 50-66, 2000.

[14] YD Lee, MS Choi, et al., Research on the Development of Automated Multifunction Integrated Motion Bed, IIBC, vol. 18, no 5, pp. 215-222, 2018.

[15] https://www.youtube.com/watch?v=wh56qajNYR8 &feature=youtu.be.

[16] https://www.zdnet.co.kr/view/?no=20130726151317.

[17] https://www.iis.fraunhofer.de/en/pr/2016/ 20161109_BMT_Dekubitus.html.

[18] YD Lee, MS Choi, et al., Research on the Development of Automated Multifunction Integrated Motion Bed, IIBC, vol. 18, no 5, pp. 215-222, 2018.

[19] YD Lee, CY Kim et al., Enhancement of 4 Bar Parallelogram Linkage for a Medical Bed JCCT, vol. 6 , no. 1, pp. 615-620, 2020.

[20] YD Lee, MS Choi, et al., A Study on the Automatic Sheet Exchange for a Hospital Bed, JCCT, vol. 5, no. 4, pp. 361-366, 2019.