



Smart-bed with Internet of Things for Pressure Ulcer

Taryudi Taryudi¹ , Linlin Lindayani² , Irma Darmawati³ 

¹Department of Electrical Engineering, Faculty of Engineering, Universtas Negeri Jakarta, East Jakarta, Indonesia; ²Department of Medical Surgical Nursing, Sekolah Tinggi Ilmu Keperawatan PPNI Jawa Barat, Bandung, Indonesia; ³Department of Nursing, Faculty of Education and Sports and Health, Univeristas Pendidikan Indonesia, Bandung, Indonesia

Abstract

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***Correspondence:** Taryudi Taryudi, Department of Electrical Engineering, Universitas Negeri Jakarta, East Jakarta, Indonesia. E-mail: taryudi@unj.ac.id
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AIM: The purpose of this study was to develop prototype smart-bed based on Internet of Things that consisted of automatic patient mobilization every 2 h as well as monitoring patients. Stroke patients experience pressure sores that result in increased mortality within 30 days after a stroke. Pressure sores are injuries caused by continuous pressure. Patient mobilization is the primary prevention and treatment technique for patients with pressure sores.

METHODS: The proposed medical bed is designed to resolve both concerns through a revolutionary design that rotates the patient and offers an advanced patient monitoring system. Using an Android smartphone or tablet connected to the Arduino microcontroller through Bluetooth, the caregiver can rotate the bed in either direction to shift the pressure away from the back of the patient and to monitor the critical risk of ulcer pressure.

RESULTS: The bed functions in two modes: manual mode, which engages the caretaker in the rotation process, and automatic mode, which rotates the bed every 2 h. The overall rotation angle is calculated by calculating the patient's weight by means of loading cells distributed across the bed. In addition, the smart bed features sensors for certain vital signs, such as heart rate, body temperature, oximetry, humidity, and blood pressure.

CONCLUSION: A novel, efficient, smart medical bed is presented to ease the lives of patients and caregivers, both of whom have difficulties using conventional beds. The proposed system automatically rotates patients as planned and tracks them for any unexpected changes in their vital signs. The proposed novel bed is fitted with a range of safety measures to ensure proper functionality and prevent any danger to patients. The patients' vital signs are assessed.

Introduction

Stroke is the third leading cause of death in Indonesia and has an impact on the high number of comorbidities and treatment costs [1]. The prevalence of stroke has increased significantly from year to year, by 10.9% in 2018 (up 3.9% from 2013) [1]. Uniquely, stroke patients are no longer synonymous with old age, but many have occurred at productive age starting at the age of 35 years, and the risk of stroke increases at 45 years, with an incidence of 14.2% [1]. Previous studies report that more than 50% of stroke patients experience pressure sores that result in increased mortality within 30 days after a stroke. Pressure sores are injuries caused by continuous pressure [2]. In addition, treatment costs due to pressure sores are very large. For example, in America, treatment of pressure sores reaches USD 500–70,000 per patient per year [2], [3].

Patient mobilization is the primary prevention and treatment technique for patients with pressure sores. Physically, the patient must be positioned on the left and right sides every 2 h. Actions like this require a nurse or family that is full time and labor intensive. However, these actions are rarely carried out either by nurses or families due to difficulties in mobilization,

business (nurse and patient ratio, 1: 10–12). At the time of mobilization of patients can also cause work accidents. Research in the United States in 2014, showed that 56% of nurses suffered back, neck, and spinal pain, caused by lifting, pushing, or pulling [3], [5]. Hence, we need an inexpensive tool, works automatically equipped with the ability to monitor patients in real-time from a distance.

At present, health care facilities have begun to use robots and various sensors to improve service quality and work efficiency. Some devices such as hand robots have been developed to help mobilize [7], [8], [9], a number of manual tools for moving patients, automatic force bed which involve manipulating bed linen [10]. In addition, many beds have also been developed such as air mattresses, alternating pressure mattresses, lateral rotation mattresses to prevent pressure sores [11]. However, it still requires a lot of energy, and time-consuming. There are no mattresses or beds that are automatically able to mobilize patients every 2 h and monitor blood pressure, pulse, temperature, respiration in one system. In the era of the industrial revolution 4.0, the internet of things has an enormous impact on health services, which can monitor patients in real-time remotely. Thus, the purpose of this study was to develop prototype smart-bed -based on Internet thing that consisted of automating patient mobilization every 2 h as well as monitoring patients.

Design and Implementation

The bed implementation consists of both hardware and software. The hardware part is shown Figure 1 comprises Iron, that builds a bed frame, 12 V DC, and 10 motor jacks are being used to move the bed. The Arduino Microcontroller is used to monitor the motion of the jacks and to collect calculations from vital signal sensors and load cells. These measurements are powerful in autonomous transmission.

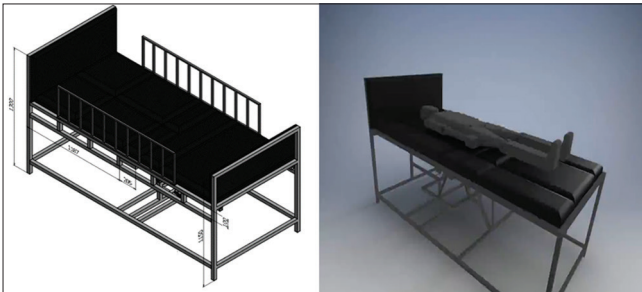


Figure 1: Hardware structure design

The user will start a software application on an Android smartphone that is linked to the Arduino through bluetooth. This software includes a user guide that enables the user to monitor the movement of the bed. It also displays all measurements from the sensors of vital signs and the load cells. A CCTV camera linked to a Wi-Fi network is installed for additional protection. This camera, that is installed to the bed itself, could be paired to the smartphone of the caregiver so that he/she could monitor the patient periodically.

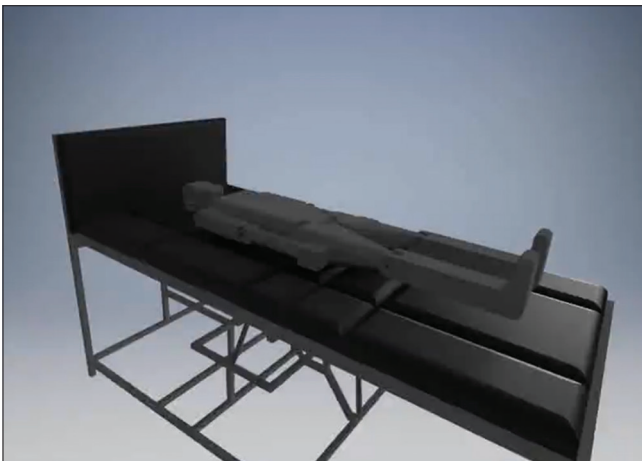


Figure 2: Normal position

Hardware System Description

There are five major positions to help both patients and caregivers. These positions allow patients to stop getting back ulcers. The first role is the usual

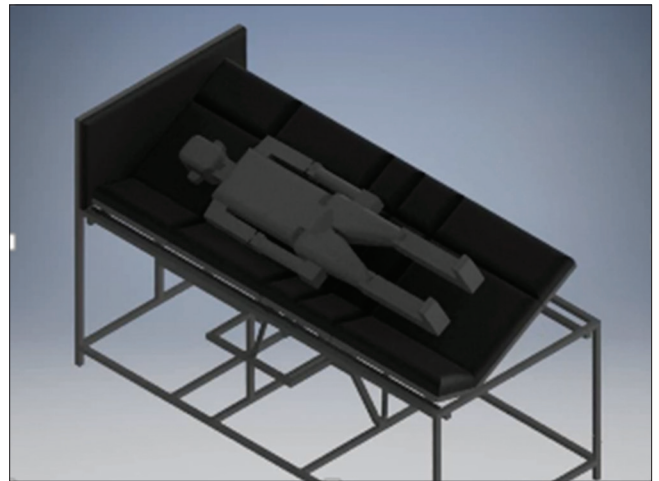


Figure 3: Rotated to left

one where the mattress looks normal bed, as seen in Figure 2. In the second position, the bed rotates to the right, up to 40°, from 20° to 40°, enabling the patient to convert the tension from his or her back to the correct sides of his or her body as seen in Figure 3. In the third, the bed rotates to the left, up to 30°, enabling the patient to transfer the strain of his or her back the other way side of his or her body as shown in Figure 4. The patients also could set their position head up to 90 degree (Figures 5 and 6).

Ten jacks are used to reach the past five positions. Each jack is powered by a 10 V DC. Jacks are used in this design as they are seen as being sufficient to perform the required job (which is to move the bed to the desired position). One jack is used to lift up to 150 newtons and to reach positions with a speed of about 6 mm/s in order to avoid the impact of fast movement (dizziness) [2] and [3], 4 jacks are used to enter an appropriate height (two at each side as seen in Figure 6). Electric jacks are not too costly and work clean (without oil). Electric jacks are used at this stage of the project to illustrate the concept of shifting the bed, but if the concept were to be applied for industrial use, another moving device could be used.

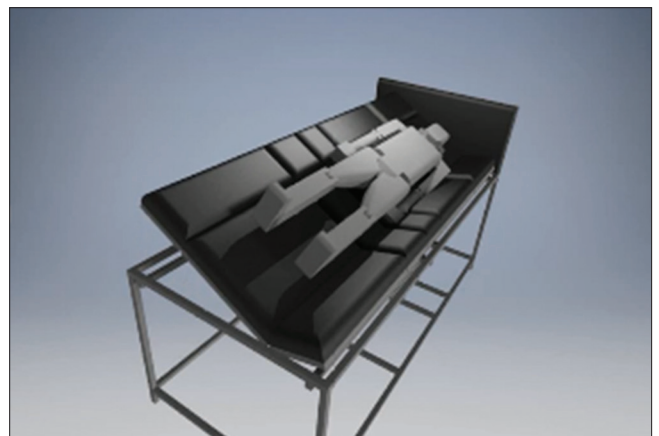


Figure 4: Rotated to right

Because automated modes are often used if nobody is involved directly in controlling the patient's



Figure 5: Head up position

rotation process, the bed can cause any discomfort to the patient. For example, a feeding or breathing tube may be blocked, that may cause significant harm to the patient if proper care is not taken on time. As a protection measure, a software is mounted on the Arduino to force the bed to return to position [1]. The same software initiates a warning to attract the attention of those nearby to make the requisite changes. The data collected from vital sign sensors are a crucial component in assessing whether or not anything is going wrong. Any source where a patient's distress triggers a rise in heartbeat or breathing rate (or both). If either of these two reaches a certain amount, the bed shall behave as stated above.



Figure 6: Legs up position

Software and Interfacing with Arduino

The key program used for this prototype is Arduino IDE. Its purpose is to control each jack motor. As far as the jacks are concerned, they have their own protection mechanism (not to be broken when closed

completely or fully opened). Transmission modules are used to be enabled to use this protection mechanism. Two active low 8-channel transmission modules are being used to replicate the “up” and “down” buttons of each jack and one active low 2-channel relay module is used to monitor the left part of the bed. They are programmed to turn the engines left or right, based on the movement required. In order to calculate the patient's weight, the load cell is applied across the bed and to link it with Arduino, the HX711 24-bit analog to the digital converter module is used. The load cell is attached to a single HX711 module. Vital signs (except the blood pressure sensor) are directly related to the Arduino Microcontroller.

Android application software supported by Google is used to create the Android app that controls the bed. The software first initiates a bluetooth module to the Arduino microcontroller and has several screens (activities); each display is responsible for a particular feature of the bed. For example, there is a “Manual Mode” screen, an “Auto Mode” screen, a Vital Sign Measurement screen, etc. The app sends instructions (to monitor the bed) and receives information (to calculate the sensors) in a friendly user interface.

Bed Movement

As described above, Arduino Mega is accountable for any motion of the bed, is configured to receive feedback from the user and move as desired. In addition, input from vital sign sensors is designed to contribute to the automatic mode of the bed. The user (i.e. the caregiver) may be able to communicate with/control the bed via a smartphone or tablet. This smartphone is the main control device in the bed. The app has the following main features:

- Choosing mode of service (manual or automatic)
- Shift the bed to the desired location and set time for each movement
- Showing measurements of vital signs in real time.

The bed is controlled in two modes: manual mode and automatic mode. In manual mode, the app displays buttons to allow the user to shift the bed to any desired position or height (Arduino is designed not to reach a certain height in order to prevent any accident or harm to the bed). The buttons disappear in automatic mode and the positions allowed are only positions [1], [2], [3]. The bed keeps its place for 2 h, and then rotates to the next place. This function is extremely helpful at night, as caregivers are no longer forced to wake up every 2 h to rotate the patient, as the bed does the job automatically.

Sensors Overview

Vital signal sensors are connected to the Arduino microcontroller through a direct link to the Arduino microcontroller. Figure 7 Display the complete set. Each sensor is attached to the top of the Arduino Super and all data collected by the sensors is analyzed in the Arduino Microcontroller and sent to the Arduino Mega. As far as data are concerned, it is due to two things: first, it is shown on the smartphone or tablet, and second, it is an essential part in autonomous mode.

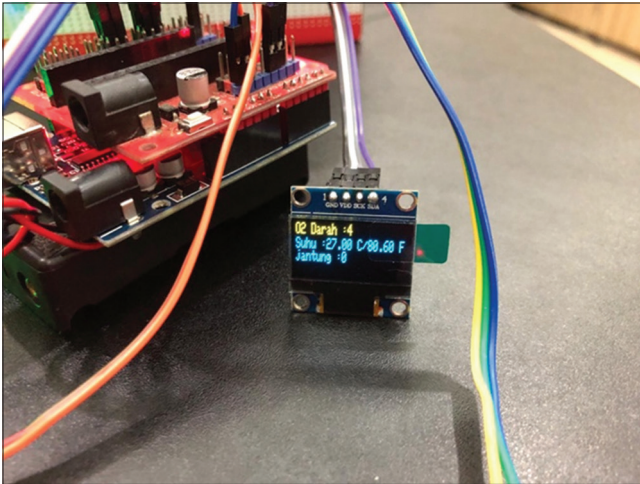


Figure 7: Complete kit sensors

In the proposed device, five different types of sensors are shown in Figures 8-10, are used to calculate the vital signs and weight of the patient and contribute to the smart functions of the bed. The five sensors are as follows:

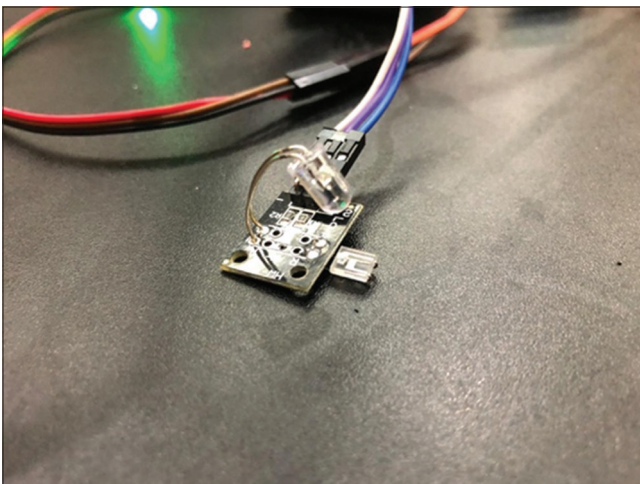


Figure 8: Oximetry sensor

1. Sensor for blood pressure
2. Sensor for humidity (Figure 9)
3. Sensor for body temperature
4. Sensor of heart rate (Figure 10)
5. Loading cell
6. Sensor for oximetry.

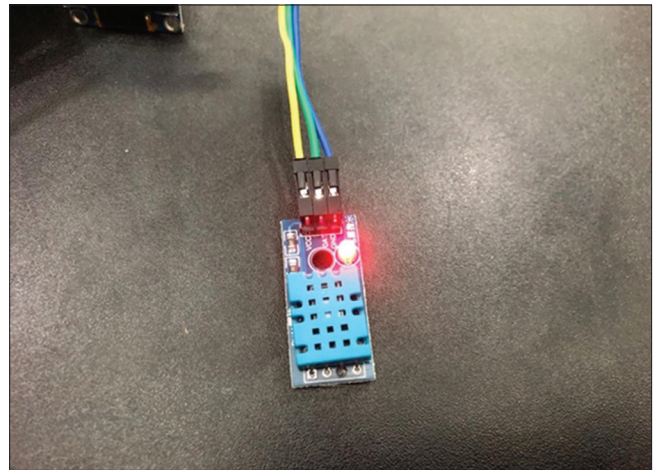


Figure 9: Humidity and temperature sensor

Discussion

There are currently few solutions for controllable/smart medical beds such as MedBed [13], 4-Way Fold Care Bed [14], Freedom Bed by ProBed Medical [15] and Novel Medical Bed [16]. The proposed MedBed [13] does not involve patients with locking-in syndromes. It allows patients who can travel in a smart way using IoT the ability to take care of themselves without relying on the nurse.

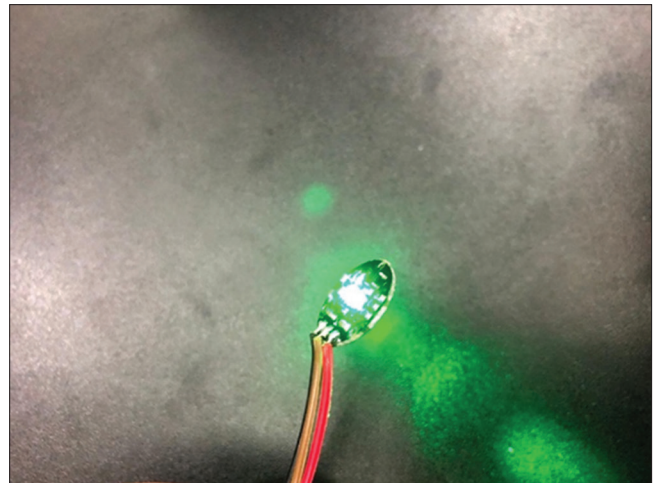


Figure 10: Heart rate sensor

The 4-Way Fold Care Bed [14] needs significant intervention by the caregiver and the pillows to help the patient, while our proposed new bed needs minimal maintenance and no pillows are required. In addition, by using an android tablet connected to the Arduino microcontroller through Bluetooth, the caregiver can rotate the bed in either direction to move the pressure away from the back of the patient and to monitor the sliding washroom to start cleaning. The bed functions in two modes: manual mode, which engages the caretaker in the rotation process, and automatic mode, which rotates the bed every 2 h. The overall rotation angle is calculated by calculating the patient's weight by means of loading cells distributed across the bed. In

addition, the smart bed features sensors for certain vital signs, such as heart rate, body temperature, air flow, and electrocardiography signals.

The proposed smart medical bed outperforms the 4-way fold care bed by enabling automatic mode. This function allows the bed to work without the need for interference by the nurses, making it incredibly beneficial at night, as it is no longer important to wake up every 2 h to rotate the patient, as the bed does the job automatically.

The proposed smart medical bed outperforms both the 4-way fold treatment bed [14] and the Freedom Bed by ProBed Medical [13] with the following features:

1. Vital signs sensors: Our solution includes a vital signal sensor that is incorporated into the activity of the bed, provides input, and performs as stated above if anything goes wrong
2. Measuring weight: The bed is fitted with 12 loading cells distributed along with the mattress. These cells provide accurate measurement of the patient's weight, and this function is useful for tracking the overall health status of the patient.

Conclusion

A novel, efficient, smart medical bed is presented to ease the lives of patients and caregivers, both of whom have difficulties using conventional beds. The proposed system automatically rotates patients as planned and tracks them for any unexpected changes in their vital signs. The proposed novel bed is fitted with a range of safety measures to ensure proper functionality and prevent any danger to patients. The patients' vital signs are assessed. The new scheme seeks to contribute to society by improving the conditions of treatment of patients, wherever they are in hospitals or their homes.

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