Automatically Configurable Smart Bed

K .Venkata Ankith , T. Venugopal

Abstract— Comfort and aesthetics are of paramount importance to a hospital bed that assumes the position or the posture of the occupant in it for better comfort. The probable applications of the proposed smart bed can be implemented in the hospital industry for patient care and the entertainment field for people looking for a higher level of comfort than offered currently. With the human motion as a stimulant, the smart bed assumes a configuration that offers maximum comfort and automatic assistance to the user. The smart bed can be controlled automatically by employing microcontrollers and an array of sensors at a lower cost. Easy operation and low cost of smart bed is important for increasing the prospective market.

Keywords: Smart bed, Accelerometer, Sensors, Actuator, Configuration, Torque, Microcontroller.

I. INTRODUCTION

The in-bed positioning of patients with limited mobility is of major importance in order to prevent the worsening of their health condition and improve their comfort. The lack of autonomy to undertake basic movements and postural changes causes anguish and discomfort in these patients. The manual-handling of patients is reported to cause an outstanding amount of work-related back injuries, with 85% of nurses suffering back injury at some point in their career. These injuries account for 15 billion lost working days each year, bringing about annual cost of approximately 6 billion euros to the European hospitals.

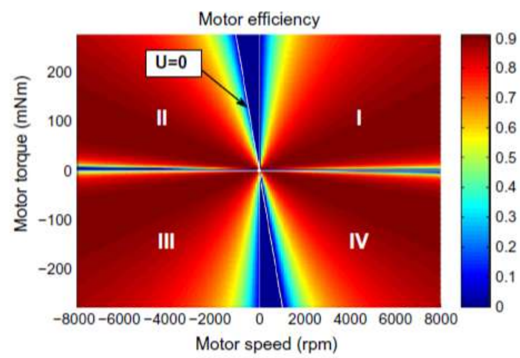
The care of the patient being the top priority safety and simplicity of the project is vital to have an impact in the patient care. Along with the facilitating the hospital staff with an easier access to the patient the smart bed also makes the patient independent with regard to his or her own comfort. While adhering to safety requirements such as brake and steer pedals, battery backup, and side rail design and so on the implementation of this project aims at increasing functionality.

II. LITERATURE SURVEY

A higher level of safety and comfort are of vital importance in the field of health care. An arrangement of sensors and actuation working in cohesion can accomplish the elevated need of the present day customer seeking comfort or a patient seeking control. For the smart bed to work as expected a variety of actuators and sensors are available.

K Venkata Ankith , M-tech Mechatronics, School of Mechanical and Building Sciences, VIT University, Chennai.
(Email : kvenakta.ankith2014@vit.ac.in)
Dr .Venugopal T , School of Mechanical and Building Sciences, VIT University, Chennai (Email :venugopal.t@vit.ac.in)

Study was conducted to understand and explain the relationship between: back-emf v/s angular speed and the torque v/s current characteristics. The study was conducted on a 3 pole DC motor. Simple construction consisting of a stator, rotor and 3 armatures confined in a magnetic field between two permanent magnets. According to Faraday's' law the angular speed of the motor is linearly proportional to the back-emf. Lorentz force law dictates that the torque produced is proportional to the current passing through it [1][3]. The efficiency of a DC motors depends on the type of gears used, gear ratios and also the resistance offered. The torque produced at a high spend would be minimum and vice versa.



Unlike the electric motors (DC motors) servo motors use the feedback via the back-emf to improve the positioning and its exactness. The functioning of a servo motor revolves around the gear, motor, controller transducer and a sensor to provide feedback from the gearing [2].

III. METHODOLOGY

Extensive study pertaining to the rules and standards for developing the hospital bed must be done to ensure safety for the user. The implementation of this project has been done through the following steps: literature survey, design and fabrication and experimentation. Literature survey is very important step in the process of realising this project. The complex nature and variety of practices involved make developing a smart hospital a challenging task. Information pertaining to the specifications of the bed and the details of the average user is crucial. Once the physical dimensions and other details are sorted the focus shifts to the selection of a sensor and actuator. The selected devices must comply with the International Electrotechnical Commission Standards (IEC Standard) which ensure no harm comes to the patient These standards include:

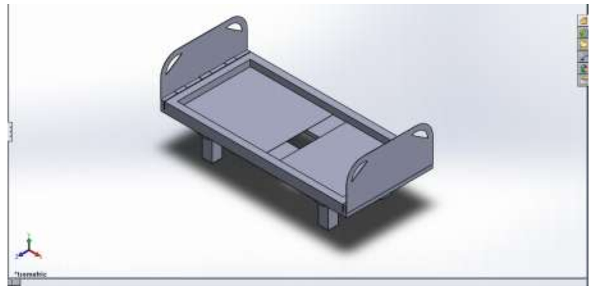
1. IEC 60034 Rotating electrical machinery
2. IEC 60038 IEC Standard Voltages
3. IEC 60041 Field acceptance tests to determine the

hydraulic performance of hydraulic turbines, storage pumps and pump-turbines
4. IEC 60083 Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC
5. IEC 60086 Primary batteries
6. IEC 60479 Effects of current on human beings and livestock
7. IEC 60559 Binary floating-point arithmetic for microprocessor systems
8. IEC 60601 Medical Electrical Equipment
9. IEC 60947 Standards for low-voltage switchgear and controlgear
10. IEC 61828 Ultrasonics - Focusing transducers - Definitions and measurement methods for the transmitted fields

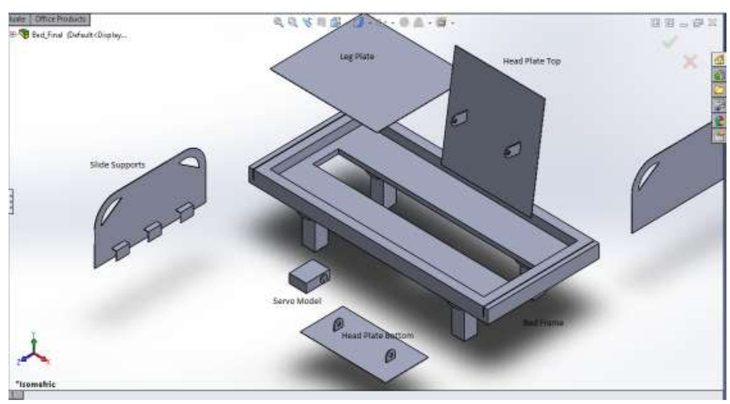
Complying to the sad standards the technical specifications considered in designing the full scale bed are:

- Bed Length with Standard sleep deck: 90.0" (228.6 cm)
- Bed Length with Special sleep deck: 87.0" (221.0 cm)
- Width (with side rails up): 43.7" (110.9 cm)
- Width (with side rails down): 36.6" (93.0 cm)
- Height of Sleep Deck (in low position): 18.3" (46.5 cm)
- Height of Sleep Deck (in high position): 30.1" (76.5 cm)
- Under-bed Clearance: 5.5" (13.9 cm)
- Head Section Articulation: 0 through 72.5º
- Knee Section Articulation: 0 through 25º
- Caster Size: 5.0" (13.0 cm)
- Safe Working Load: 450 lbs. (204 kg)
- Operable Temperature Range: +10º C to +40º C.

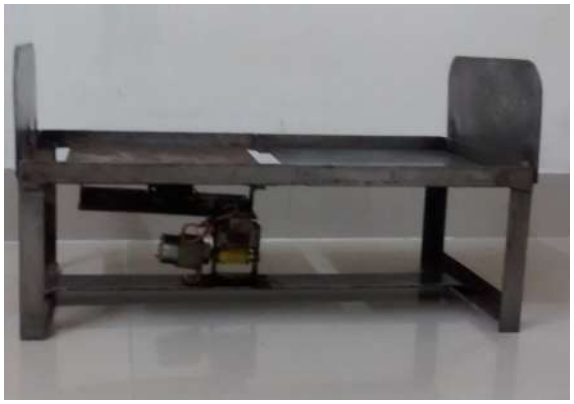
The three dimensional virtual model was created by using SolidWorks 2014. The dimensions for the design of the bed were considered by following guidelines of a standard hospital bed to which the necessary alterations were made [7]. Provision of slots and guides facilitate the various configurations which are otherwise not included in the standard equipment. In addition to the functions of a standard hospital bed, this smart bed provides some advantages such as articulation of the head section in multiple degrees, pull away head and foot rests, removable sections of the bed, etc. The smart bed provides a feature available only in high end commercial hospital equipment. The smart bed is capable of configuring itself in an upright seated position from the zero or the flat position as well as an approximate 15 degrees of angular articulation laterally i.e. about the horizontal axis. The ability to provide an inclination of 15 degrees on each of side adds to the list of advantages. The unique features discussed thus for making this setup a more feasible and practical solution.



Sl.No	Component Name	Numbers
1	Bed Frame	1
2	Head Plate Top	1
3	Head Plate Bottom	1
4	Leg Plate	1
5	Slide Supports	2
6	Supports	4
7	Servo Motor	1
8	DC Motor	1
9	Arduino Uno	1
10	Accelerometer MMA 7455	1
11	HC SR04 Ultrasonic Range Sensor	1
12	Gears	2



The use of sheet metal allows to use smaller actuators as compared to the full scale devices that are required. Sheet metal aids in reducing the overall weight of the apparatus while the thickness selected prevents the material from bending and slacking off. Mild Steel (MS) of thickness 1.4mm was considered for fabricating the smart bed apparatus [on what basis]. The required clamps and mounts were then designed and welded. Cross links and supports were fashioned for additional rigidity of the structure. The various parts of the bed can be disassembled for repairs, maintenance or inspection.



Parts for the diagram. Choosing the appropriate equipment is not only required but mandatory for implementation. Assuming the human motion voluntary or involuntary as a stimulus there are a wide range of sensors which require examination and understanding. Whereas the selection criteria of the actuator system is a cumbersome process as the interaction of the moving parts and actuating mechanisms increase the risk to the patient in the case of malfunction. For the selection of an actuation system each possibility must be cross checked with all the IEC Standards for safety. A variety of motors and other mechanical systems pose a potential options for the purpose of actuating the bed. While fluidics i.e. hydraulics and pneumatics can be ruled out due to inherent risks and shortcomings, an assortment of motors are still a viable option. To accommodate for the wide angle of actuation required for this setup a DC motor was considered for the linear actuation of the smart bed.

The DC motor is considered for the linear actuation of the Head Plate. Since the actuation of the head section doesn't require a precise value a DC motor fit the constraint. Through the use of an L293D a motor driver circuit it is possible to run the motor in both forward and reverse directions. L293D is used to control multiple motors simultaneously. Depending on the signal received by the accelerometer the motor is run. Although the torque of the motor is a constraint the speed of the motor can be traded in for a higher torque rated motor. The torque of a DC motor can be calculated by the following formula.

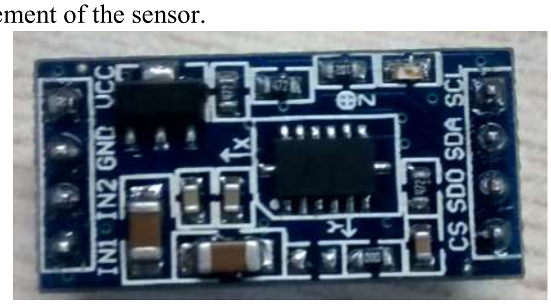
$$\tau_{\mathrm{m}} = \frac{k_{\mathrm{m}} V}{R} - \frac{k_{\mathrm{m}}^2}{R}\omega \ .$$

Where k_m is a constant, V is voltage applied and R is the resistance ω is the speed of the shaft. Form the formula it is apparent that the torque generated is directly proportional to the current and practically it can be seen that the speed of the motor is directly proportional to the voltage.

Considering the sensor front of this setup, the following equipment were implemented: MMA-7455 Accelerometer and HC-SR04 Ultrasonic Range sensor. The accelerometer detects 'g' forces it experiences. A range of 1g to 8g, 1g being the acceleration due to gravity, a wide range of input signals can be considered. The acceleration detected by the sensor is produced by the patient. Based on the principle of capacitance the sensor detects the 'g' forces depending on the value of capacitance.

$$C = \frac{A \times \varepsilon}{D}$$

Where C is the capacitance, A is the area of the beam, D is the distance between the beams and □ is the dielectric constant. The change in the distance between the beams caused by a tilt in the sensor. The change in the capacitance is measured along all 3 axis. Input from the sensor is transmitted in the form of 10 bit data which is converted in to 8 bit data which contains information of the Gravitational Forces (or G Forces) in each x, y and z axis [4]. Based on the input signal the actuation system is triggered to adjust the bed panel. The 'g' forces measured by the sensor are mapped in order to control the on/off of the actuators. An appropriate delay (specify number), made possible by programming, can ensure minimal accidental movements of the actuators caused by movement of the sensor.



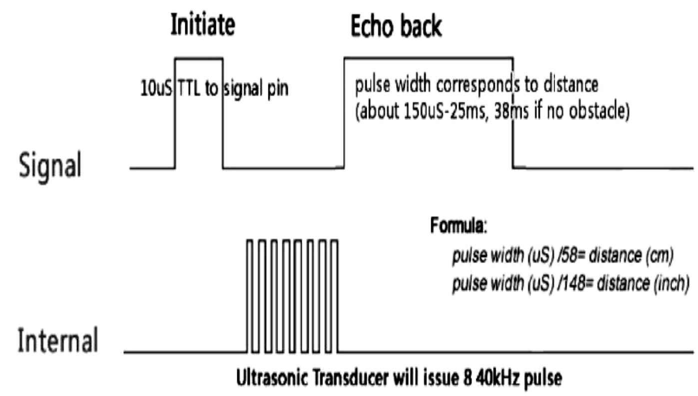
The Ultrasonic sensor (Model-HC SR04) is used as safety check and to limit the movement of the actuator. The HC SR04 is ultrasonic range sensors that detect any obstacle in its path. In order to configure the bed in a horizontal alignment it is necessary to detect the position of the Head Plate. Since the movement of this plate is actuated by a DC motor a feedback is required. This feedback is generated by the ultrasonic range sensor. When the bed panel starts to level out the signal from this sensor seizes its motion. The working parameters are as given below.

Features:

- Power Supply : +5V DC
- Quiescent Current : <2mA
- Working Current: 15mA
- Effectual Angle: <15°
- Ranging Distance : 2cm – 400 cm
- Resolution : 0.3 cm
- Measuring Angle: 30 degree
- Trigger Input Pulse width: 10 µs
- Dimension: 45mm x 20mm x 15mm

The HC SR04 Ultrasonic Range Senor is equipped with 4 pins: Vcc, Trig, Echo and GND. An input voltage of 5V is provided to the Vcc pin and GND is the ground pin. To measure the distance to the obstacle the Trig pin must receive a 5V signal for the duration of at least 10 µs (microsecond). When the trig pin receives an input signal an ultrasonic burst at 40 kHz is generated. The transmitted signal is the received by the sensor and is sent to the Echo pin [6]. The duration of the pulse at the Echo pin determines the distance of the obstacle from the sensor. Although the HC SR04 is capable of sensing a distance of 0.3 cm the sensitivity depends on the object being sensed. Harder materials reflect the ultrasonic burst much faster than softer materials.

Parameter	Min	Typ.	Max	Unit
Operating Voltage	4.50	5.0	5.5	V
Quiescent Current	1.5	2	2.5	mA
Working Current	10	15	20	mA
Ultrasonic Frequency	-	40	-	kHz



IV. CONCLUSION AND FUTURE SCOPE

The complex and multitude of standards set in place for the implementation of hospital bed is done for the safety and comfort of the patient. Complying with these standards is not only a must but also necessity for achieving the objective of providing a higher order care for patients at affordable prices. The notion of patient is more salient through the process of realising this project. Operation and functioning the various actuation systems was understood.

The model obtained as a result of careful consideration of safety and standard for hospice care can be a feasible and efficient replacement for the current hospital equipment. The ability to articulate around more than one axis is a remarkable advantage when compared to the traditional design. The use of an accelerometer MMA 7455 is lucrative addition to the proposition. The ability to detect G forces along all axis yields a more accurate result. The actuators considered, namely: Servo and DC motors, are simple yet sturdy devices to incorporate to the experimental setup. The provision of an in-built feedback of the servo motor helps accurately control it. Low RPM DC motor creates a high to account for the weight of the smart bed itself and also the occupant. For testing of the bed sheet metal proved advantageous to manipulate and manufacture. The control system is based on a user friendly Arduino platform. The simplicity of the experiment is a significant advantage.

The smart bed idea can be used in medicine as well as entertainment field. With the added ability of controlling the apparatus without a physical controller is an appealing option in this field. The Smart bed provides the occupant independence to set his or her own posture. The idea of an intelligent bed can be further be extended with the help of devices for data communication which would also facilitate doctors to remotely assess the patient and make decisions based on the information available.

REFERENCES

[1] Ravi, Harish, and Rajesh B. Khaparde. "Understanding DC motors through experiments." *Resonance* 15, no. 6 (2010): 561-572.

[2] Kotov, K. Yu, A. S. Mal'tsev, A. A. Nesterov, M. A. Sobolev, M. N. Filippov, and A. P. Yan. "Development and identification of a servo model based on experimental data." *Optoelectronics, Instrumentation and Data Processing* 6, no. 49 (2013): 561-568.

[3] Verstraten, T., G. Mathijssen, R. Furnémont, B. Vanderborght, and D. Lefeber. "Modeling and design of geared DC motors for energy efficiency: Comparison between theory and experiments." *Mechatronics* 30 (2015): 198-213.

[4] Fisher, Christopher J. "Using an accelerometer for inclination sensing." *AN-1057, Application note, Analog Devices* (2010).

[5] Semiconductor, Freescale. "2g/±4g/±8g Three Axis Low-g Digital Output Accelerometer." *Doc-Nr MMA7455L. Rev* 10, no. 12 (2009): 2009.

[6] Freaks, E. L. E. C. "Ultrasonic Ranging Module HC-SR04." *Elek Freaks* (2013).

[7] Travis, Stephen C. "Patient exit detection mechanism for hospital bed." U.S. Patent 5,276,432, issued January 4, 1994.