November 17, 2011

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440 Design Specifications for a Bed Side Assistance System

Dear Dr. Rawicz,

I have attached a copy of the design specification documentation here titled: Design Specifications for a Bed Side Assistance System. The document enclosed outlines the ideas, methods and requirements that our project is composed of and they will work together. The goal of this project is to create and design a device that will assist a patient which is having difficulties positioning their lower body (leg region) into bed due to other alignments that prevents them from doing so comfortably on their own. The device is designed to allow the patient to start in a sitting position from the bed side and have their legs lifted up and over onto the bed where they are allowed to maneuver themselves as needed for their comfort. The device will then return back to its initial resting place for the next needed use. All of this is controlled by a controller unit which the patient uses to operate the device at their own pace so the patient is not put into a situation where they feel uneasy or uncomfortable during the process.

This document outlines the concepts of our project and how they will be implemented. Being able to lay out the designs and structures will give us an overview look at what will be required to complete our prototype. It will provide us with a base that we are able to refer back to so that we always understand where our direction and focus should be.

AMMA Tech consists of the following members: Michael Quong, Martin Wong, Andrew Yip and Amer Kalla. For any inquires about the company, project or individuals, please feel free to contact us at mqa1@sfu.ca.

Sincerely,

Michael Quong

Michael Quong
AMMA Tech – CEO

Design Specification for a Bed Side Assistance System

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Issue date:
November 19, 2011

Revision:
1.2

Executive Summary

The Bed Side Assistance System is a device that is created to fill a specific role in an elderly user's life. The role which it plays is to assist an elderly individual into their bed easily and comfortably from a sitting position starting at the side of the bed to a sleeping position on the bed. To accomplish the task of transporting the elderly individual's legs from the initial position to the final positioning, we will be creating for them a type of leg lifting mechanism which will provide such a service with ergonomic features in mind. The hope is to be able to grant users the capability to do simple tasks such as getting into bed easier for them from their prospective and the capability to do the task themselves with little guidance from others.

The basis of the system operates in the following manner:

- System will be an attachment that rests on the side of the user's bed.
- It will take a user from the initial sitting position and slowly lift the legs upwards and slowly shift the legs towards the bed simultaneously.
- Once the leg lift system has brought the legs over and on to the bed, it will allow the user to adjust themselves comfortably before the system returns back to its initial starting position.
- All these actions will be controlled by the user through a secured handheld controller with only the most basic controls needed.

The hope of this product is to give the user independence in the most important daily activity people go through in life; having the ability to get into and out of bed safely and comfortably on their own.

In this document, we will be looking at the overall system design at a high level and how each major component is meant to interact with the rest of the system. With each fundamental component, we will go though the design aspects that each component to decipher which parts and materials are used to build a specific section, and the reasoning behind those certain choices.

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Component Terms:

Acronym	**Definition**
FSR	Force Sensitive Resistor
VD	Voltage divider

1.0. Introduction

The Bed Side Assistance System is a device made to help those that are unable to sufficiently bring their legs up and on to the bed under their own power. The reasoning behind their inability to do such an action themselves ranges from permanent disabilities to old age to chronic illness. We want to give these types of users the ability to help themselves in certain aspects in hopes of in stowing some freedoms and liberties that we have taken for granted. Our device for this project is aimed at a low costing automatic method of transporting ones legs from the ground to the patient's bed.

1.1. Scope

In this document, we will be going through the designs of the Bed Side Assistance System and explaining how some of the design features that will be implemented will satisfy the important functional specifications which has be outlined in the *Functional Specification for a Bed Side Assistance System* document shown previously. Information regarding the designs, implementations and requirements of our system are associated solely to the preproduction model or the proof-of-concept prototype only.

1.2. Intended Audience

The intended audience of this document is for the members of the AMMA Tech. team. The design specifications composed here will be used as the team's resource and a place for reference throughout the project creation. It will also serve as a written record of all that is needed and the designs required for the proof-of-concept model. It will also give a basis of how well our progressions have been so far.

2.0. System Overview

This section will describe the fundamental parts of the overall system and how they will interact together to create our desired design. The Bed Side Assistance System is mainly comprised of the following three components:

1. The Mechanical Lifting Arm
2. The Electrical Circuit Control
3. The Support Frame and Attachment System

Each of these components will be described in their own following sections in this report. Those sections will go through the design choices made during the construction of this prototype and why choices were chosen to be this way. They will also touch on how the components will operate and how they will be combined together to create a device that can provide users with an automatic solution to transferring their low body section (mainly the legs) onto their beds.

2.1. High Level Block Diagram

The figure below will show a high level block diagram of the Bed Side Assistance System. It includes all the interaction between each separate component and parts and where they fit in the grand scheme of the project.

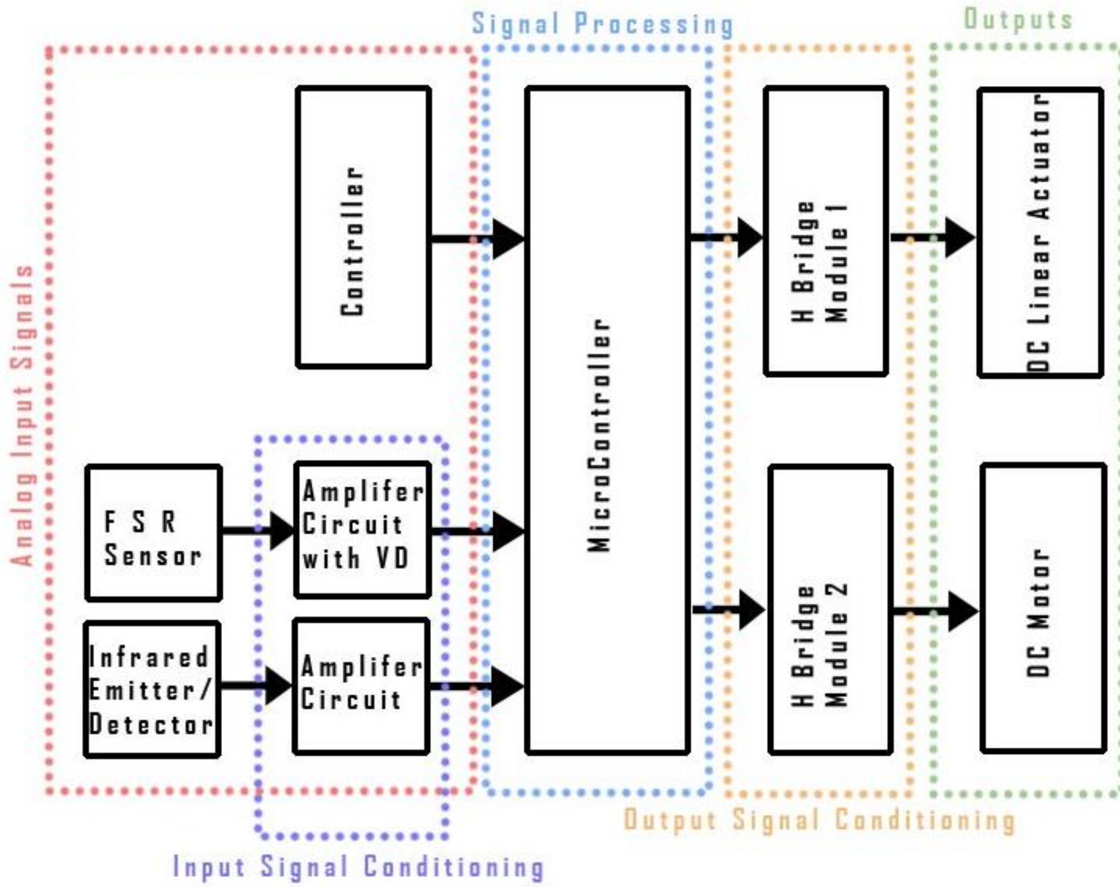

Figure 1: High Level Block Diagram of the Bed Side Assistance System.

Looking at the figure above, the section outlined in red is our analog input signals. These input signals primarily come from three main sources:

- Controller inputs from the user, which generates signals to move the lifting mechanism up or down.
- Force Sensitive Resistor (FSR), which is used to detect the presence of weight and types of impacts/obstructions in key points of our system
- Infrared emitter/ detector, which is used to detect and restrict motor motion such that the motors will only be active within a limited range to fit our design.

On the controller, there will only be three main signals that will be sent to the system which the user will be able to use. They are the following:

- Up input: An analog input which the user presses to indicate to the system that they would like the leg lifting mechanism to move upwards.
- Down input: An analog input which the user presses to indicate to the system that they would like the leg lifting mechanism to move downwards.
- Return input: An analog input which the user presses to indicate to the system that they would like the leg lifting mechanism to return back to its collapsed (folded) position.

Since the Microcontroller, shown in the above figure outlined in blue, is capable of reading analog input signals through the provided analog input pins we can connect the controlling unit directly to these pins and have access to analog-to-digital signal conversion without extra additions.

Looking at the Force Sensitive Resistor and being a standalone electric piece, it requires additional circuitry to function properly before outputting the input signal into the microcontroller. The Force Sensitive Resistor will require a voltage divider and op amp combination to generate a sufficient signal that the microcontroller can read. The required circuit will as follows:

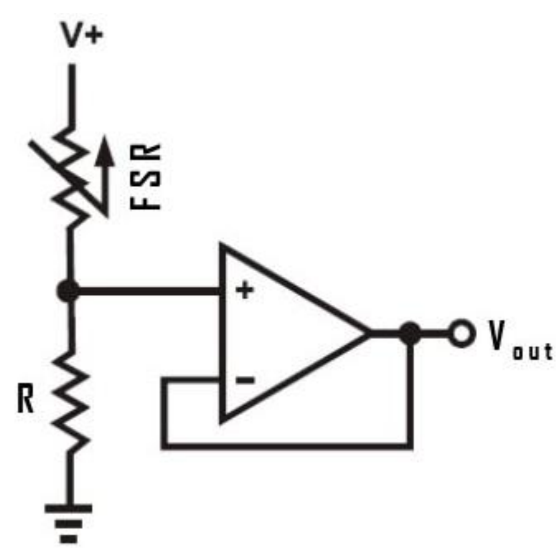

Figure 2: Voltage divider with op amp circuit for the Force Sensitive Resistor connection.

where V_{out} is the output signal of this circuit that is fed into the one of the analog-to-digital pins of the microcontroller and R is a resistance value.

As like the Force Sensitive Resistor circuit, the Infrared emitter/detector is standalone electronic piece that needs addition circuitry to operate and connect the signal it generates to the microcontroller's analog input pins. The infrared emitters and detectors will be placed in situations to create a limitation of where the motors are allowed to operate such that we are able to find out in general where the leg lifting mechanism positioning is at currently. This will allow us to override any user inputs that would cause the leg lifting mechanism to rotate higher or lower than the desired heights of our design. The additional circuit used in conjunction with the infrared emitters and detectors will be as follows:

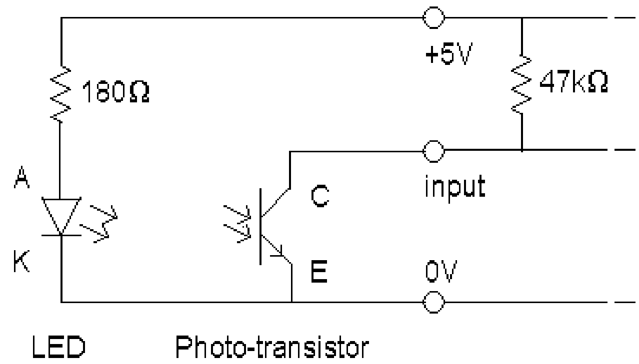

Figure 3: Additional circuit for the Infrared Emitter and Detector module. [1]

To drive the DC motors used in this system, we will need to use H bridges to handle the signals that are outputted from the microcontroller and fed into each of the motors. The H bridges will give us the ability to control certain aspects and how our motors will operate. Such aspects of the motors we are interested in controlling are speed of rotation and direction of rotation. Due to the amount of current required to drive our motors that we will be using here, each motor will be connected through its own H bridge circuit. This will ensures that we do not overheat and run past the H bridges current capacity limitations of 2 amperes. [2]

2.2. High Level Operational Paths

The Bed Side Assistance System controls follow a strict control path to ensure safety and consistency while the user uses the system. The general operations of the system are shown in the follow figure bellow:

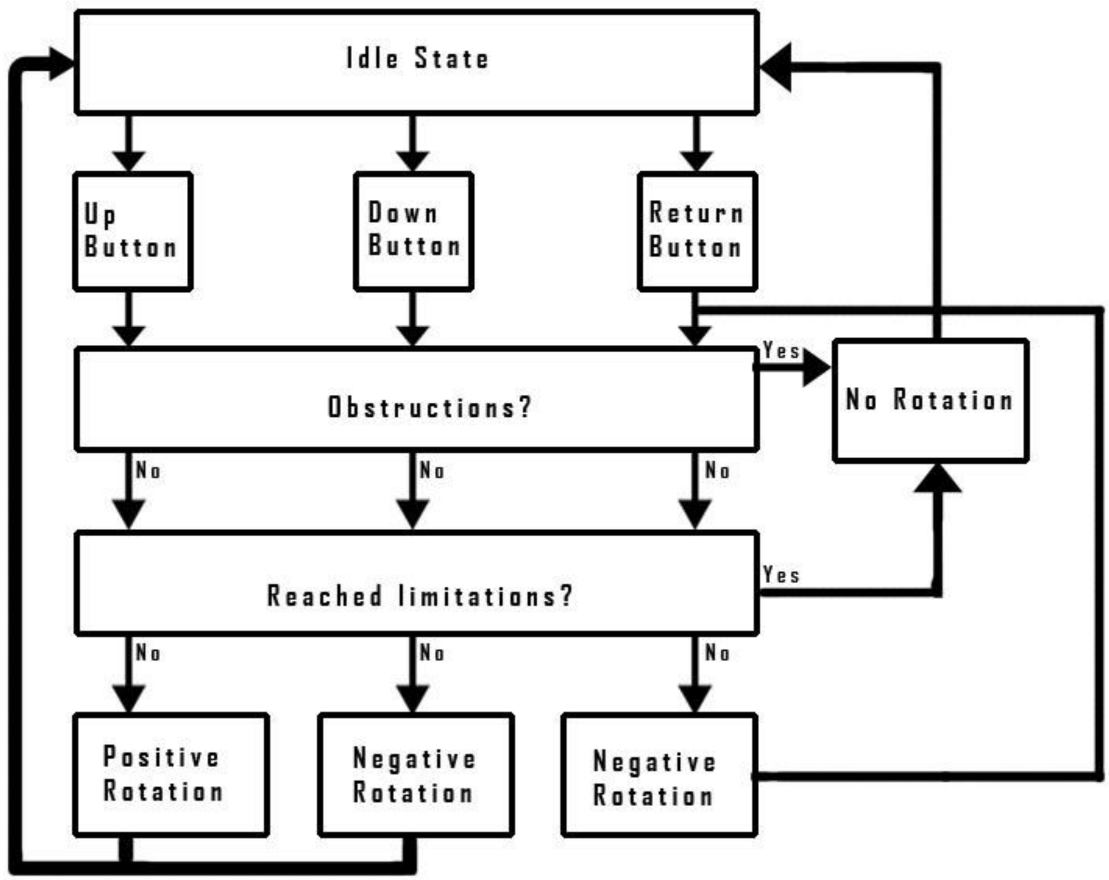

Figure 4: General Operational Behavior.

The system will always begin in an idling state; this state is where the system is actively waiting for signal inputs to respond to. These signal inputs can be occurring from either the controller unit, force sensitive resister module or the Infrared emitter/detector module which are put in place to monitor the system.

The Obstruction block shown is a conditional block which verifies with any of the force sensitive resister modules to check whether or not if there is any objects impeding the progress of the system overall. If there is any interference detected then it immediately stops the motors from moving and will remain fixed in their current locations until the interference is removed.

The Limitation Block is there to check the conditioning whether if the motors are operating out of their restricted limits or not. These limits are set in place so that the motors do not continue to raise or lower the leg lifting mechanism past our desired heights. This prevents from causing any damages to our system while in operation as well as maintaining comfort for the user during usage. If any of these limits are reached, the motors will be held fixed immediately at their current location until they are brought out of those limits. You can do that by using the controller unit to maneuver the leg lifting mechanism manually.

In the design of this system, Positive Rotation which is noted in the figure above refers to the positive rotation of all our motors. The positive rotation of the motor is translated into the raising motion of our leg lifting mechanism which brings the users lower body (legs) up to bed height. Conversely, Negative Rotation refers to the negative rotation of all motors in the system which translates into lowering the leg lifting mechanism to allow the user lower down their lower body (legs) to floor level. Lastly, No Rotation refers to no movement of all motors in either the positive or negative directions and is held immediately in place.

2.3. Detailed Operations Flow chart

With the high leveled design operations mapped out, we are able to go into more detail concerning how our system will operate when various input signals are triggered. This ensures that we know and understand what will be the following steps that the system will take when it is handling these input signals. The following is a detailed flow chart of our systems behaviors:

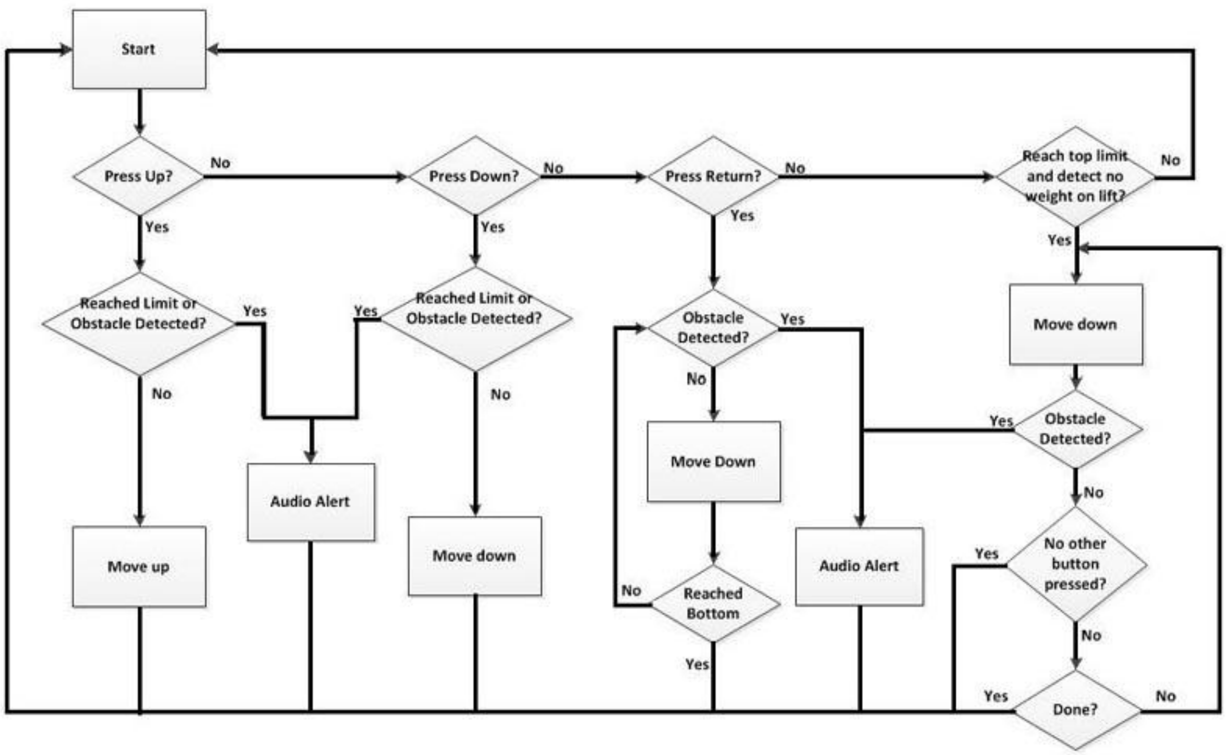

Figure 5: Detailed System Flow chart.

From here the system can now tell based on the type of signal it will be receiving from its inputs whether to raise our leg lifting system upwards, to lower our leg lifting mechanism downwards, to return the leg lifting mechanism to its known home position, or when any of the systems limitations has been reached which cause our system to halt where it is at that moment.

In our Flow chart shown above, we have also included a type of audio alert mechanism which signals to our user when obstructions have occurred on the system or if limitations of the system have been reached. We wanted to incorporate a warning type mechanism in our final product design so that our users are notified and aware of the systems status. However, due to time constrictions and implementation, this feature will not be present on the prototype model but will be mentioned as an additional feature that will be required in the final product.

3.0. Mechanical Design of System

3.1. Motor Specifications

For the lifting process of the device function, we needed a high torque and low revolution motor. These requirements for the motors were set so that we get a safe slow movement for the device at high forces. This was hard finding since all the motors that we found were either too weak or too powerful. We started thinking outside the box and thought of applications that needed similar motors.

We came up with the actuators that move car trunks automatically and window motors. We then managed to get Window Lift Motors, Which have a high torque and low revolution. The motors are originally connected to a window regulator that moves the car window, but we discarded it. Instead we attached the motors directly to our device since our device is going to do the movement regulation itself.

Figure 6: Rotational Motor. [3]

The motor weight 1.435 lb and are powered by a 12 Volts battery originally. We can change the speed of the motor by changing the voltage we feed it. We can also change the direction of rotations by changing the polarity of the input voltage. Since these motors are made by Original Equipment car standards, they are very safe and hard to break or fail.

In combination with our motor which is used to create our vertical lifting motion, we coupled it with a linear actuator to shift the lower body of the user on to the bed.

Figure 7: PA-19-24-150 Track Linear Actuator. [4]

This linear actuator was chosen for our project due to its very strong specifications at a reasonable price and is also available locally here. This linear track actuator is capable of holding forces up to 150 Lbs and moving at a slow pace of 1.30 inches per second. We require the slow movement so that we ensure that the operations of our system are smooth and gentle on the user as possible.

With only a single motor to lift the lower legs of the user, we found that the vertical lifting action that it creates is uncomfortable during certain stage of usage. We noticed this by trying to mimic this vertical lift action on ourselves. Tests were conducted by having a test user sit next to the bed upright in a sitting position as a regular user is intended to do when using our system. Once our test user was in the proper positions, their lower body region (mainly their lower legs) was slowly raised up vertically in the motion that our rotational motor would create in our system.

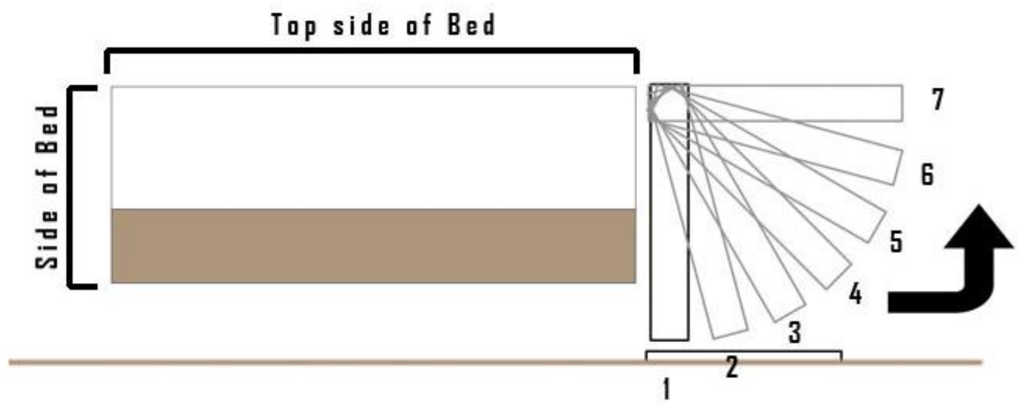

Figure 8: Diagram of the Lift Mechanism Test concerning the strain associated at each level.

For the duration of the test, we asked our test user to signal whenever there was the slightest discomfort and to identify where the discomfort was coming from while their legs were being lifted off the ground.

From our tests, we found that our test user would begin to feel a slight stress around there waist area as their legs were being lifting directly vertically upwards as shown in the above figure. And from the above figure we noticed that they would tend to notify us about some stress occurring around the time where their legs are at the 5th or 6th positions and definitely at the 7th position. To further explore this situation, we asked our test user to lie back naturally as their legs were being lifted off the ground just like they were during the first test. We wanted to observe whether this type of positioning would lessen the strains that the test user was feeling during the first test when they were sitting up straight. During this demonstration, the test user did not notify us of any feeling of uneasiness at the 5th, 6th or 7th positions as they did during the first experimentation. Once their legs were at the 7th and final position, the test user is now resting fully on their back side on top of the bed while their legs stay rested on our leg lifting system.

Thus, we saw that the best way to transition a user from an upright sitting position on the side of the bed to a sleeping position on top of the bed was to not only raise their legs up vertically but to also shift their legs horizontally simultaneously. This places the user into the bed at their comfort since they are about to lie down on their bed while their legs are being brought up to bed level comfortably.

4.0. Electrical Design of System

4.1. Microcontroller

For our project, we have chosen to use an Arduino Uno Microcontroller.

Microcontroller Board Name	Arduino Uno
Microcontroller	ATmega328
Input Voltage	7 – 12 V
Number of I/O Pins	14
Pin Voltage	5 V
Pin Current	40 mA
Flash Memory	32 KB
Clock Speed	16 MHz

Figure 9: The Specifications of the Arduino UNO Microcontroller. [5]

The reason we chose this microcontroller was because it was inexpensive, easily accessible, and user friendly to work with. In addition to being inexpensive, the board has a small dimension (6.9 x 5.3 cm) which makes it easily hidden away and usable for mass production of the final product. The board has 14 input/output pins for connecting with the motor driver, sensor, and user input. Each pin has a voltage of 5 V and a current of 40 mA. This is enough for the sensor but we will need a motor driver to control the motors. The board can be powered through an USB connector or an external power supply. The USB connector can be used to program the board using Arduino IDE software provided at their official site. The Arduino IDE use a C/C++ library called “Wiring” that is used to controls it I/O pins. There is 32 KB of flash memory to store the user program on.

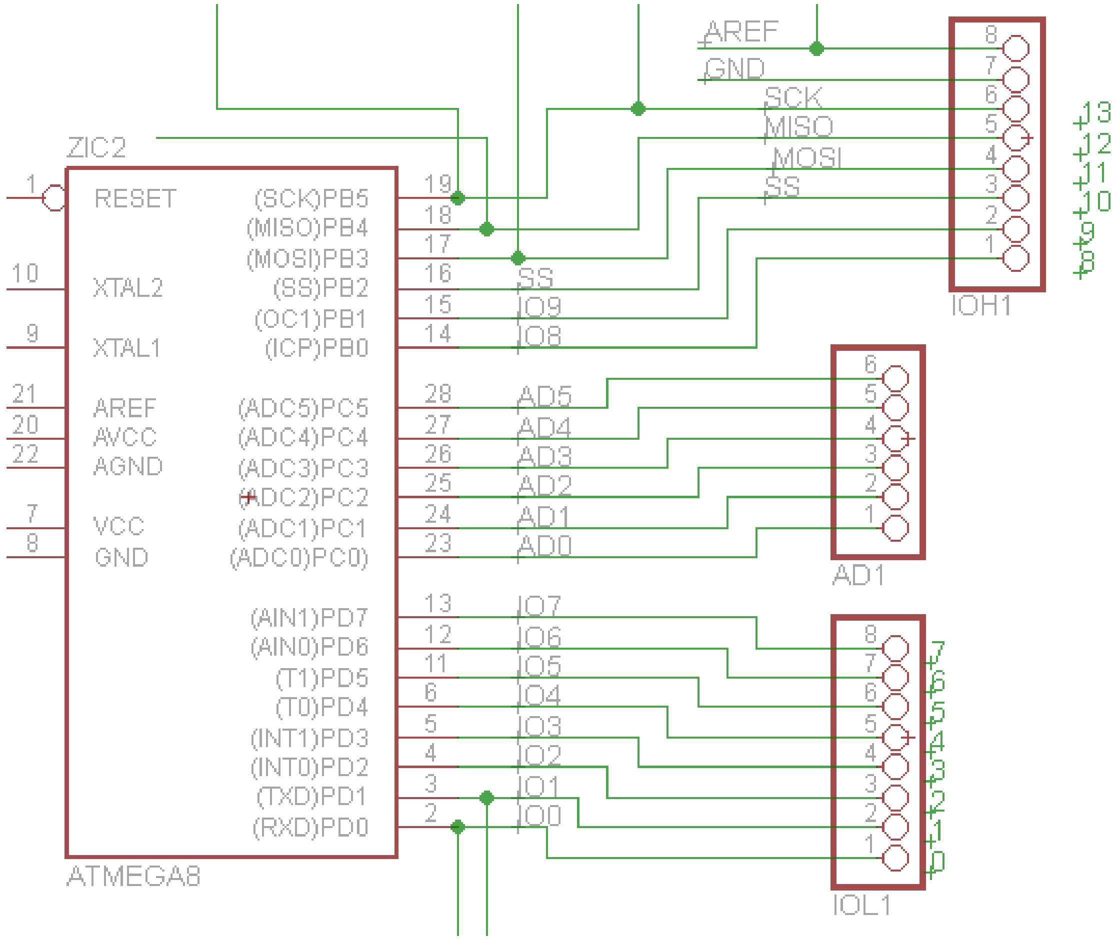

Figure 10: Arduino UNO I/O Pin Layout. [5]

Figure 9 shows how the I/O pins of the microcontroller are layout. The 14 I/O pins are numbered from 0 to 13. Pins 0 and 1 are used to receive (pin 0) and transmit (pin 1) TTL serial data. Pin 2 and 3 are used for external interrupts. Pin 10, 11, and 12 are used with the SPI communication library. For our project, pin 3, 11, 12, and 13 will be used for the motor driver to control the 2 DC motors. Pin 2 will be used by various sensors to trigger interrupts. Pins 4 to 10 will be used by the various sensors in our project.

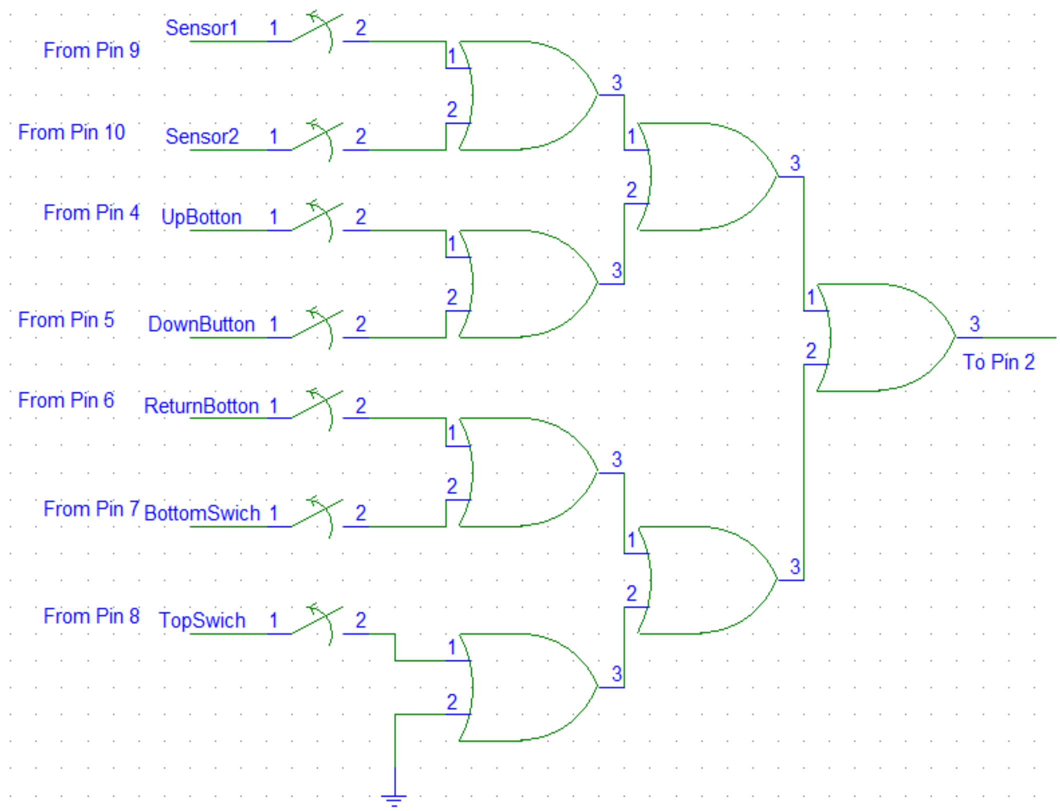

Figure 11: Representation of Sensor Schematic.

Figure 10 shows how the sensors will be hooked up to and from our microcontroller. The microcontroller will send out a signal from each pin and check if it any of the switches causes an interrupt. If a switch triggers an interrupt for pin 2, the microcontroller will determine which pin cause the interrupt and react accordingly. From Figure X.X, pins 0 and 1 will be used for IR sensor, pins 4, 5, and 6 will be used for the remote control options, and pins 7 and 8 will be used for limit switches.

4.2. Sensors and Detection

For this project, a couple of different sensors will be needed. They will be use to detect if there is any obstruction in the way of the lift and when the lift has reach limits on the top and bottom.

Part Name		GP2YoA21YK
Input Voltage		5 V
Output Voltage	0.4 V	No Object Detected
	2 V	Object Detected
Average Current		33 mA
Range		20 – 150 cm

Figure 12: Sharp GP2YoA21YK IR Proximity Sensor. [6]

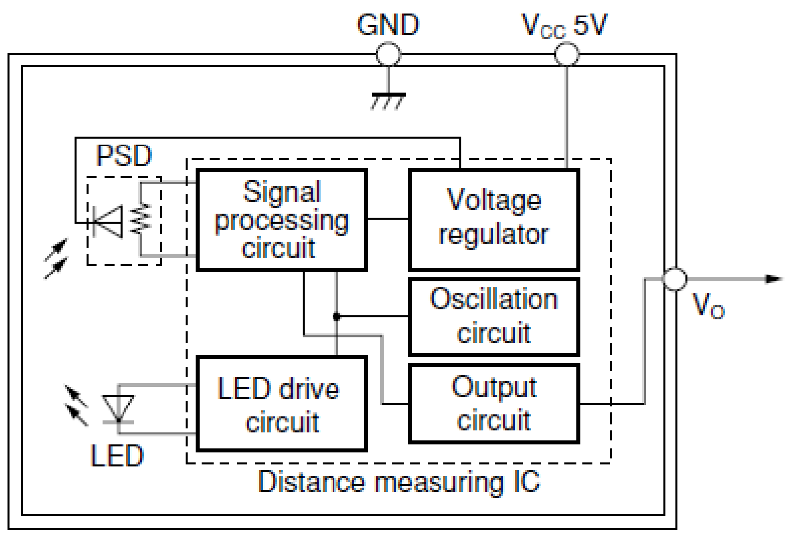

Figure 13: Sharp GP2YoA21YK IR Proximity Sensor Internal Block Diagram. [6]

Part Name	OPB704W
Diode Input Voltage	2 V
Diode Current	40 mA
Output Photodetector Voltage	5 V
Photodetector Current	25 mA

Figure 14: Active Bag OPB704 IR Sensor. [7]

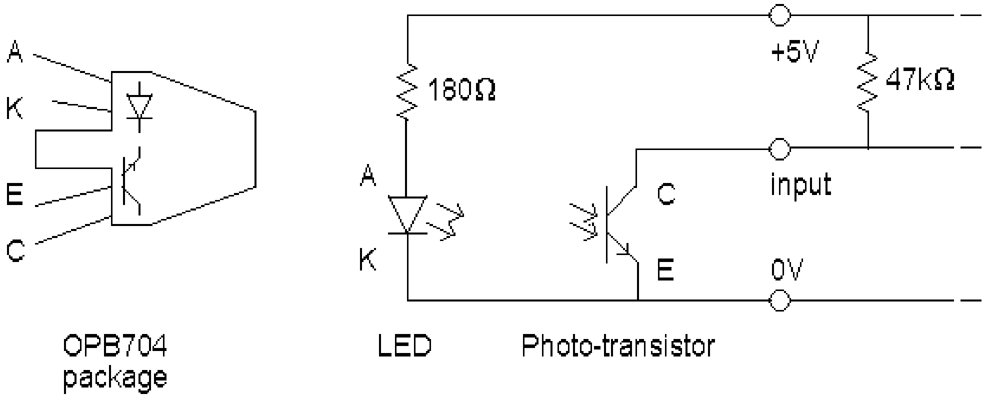

Figure 15: Active Bag OPB704 Circuit Diagram. [7]

For proximity sensors, we are planning to use the Sharp GP2YoA21YK IR Proximity Sensor. This sensor is simple to use, has a sufficient range for our product, and is relatively inexpensive. Our second choice for sensor would be the Active Bag OPB704 Reflective Object Sensor. The OPB704 has a shorter range than the GP2YoA21YK but is sold at a local supplier, so we can obtain it very easily if we are not able to obtain a GP2YoA21YK sensor in time for the construction. Beside their range, the two sensors have different input and output configurations. The GP2YoA21YK require an input voltage from the microcontroller, a ground and one pin for output voltage. It acts like a switch which requires an additional ground input. The OPB704 (shown in Figure 13) uses 4 pins, 2 for an IR LED that emit IR signals and 2 for a photo-transistor to detect those IR signals after they reflect off of an object. The photo-transistor acts like a switch and will lower the voltage at the “input” (see Figure 14) to less than 1 V when it detects a signal from the IR LED. These sensors work by emitting an IR signal from their own built-in IR LED and using a detector to detect if the IR signal is reflected back to the detector.

Other detectors we are using are for the limits of lift and to detect if there is weight present on it. For limits, we are planning to use push button switches (see Figure 15), so that when the lift reached the bottom or the top, it'll hit a switch which will send a signal to the microcontroller that a limit has been reached and prevent the motors from operating past those limitations.

Figure 16: Push Button Switch. [8]

For detecting if there is weight present on the lift, we are using a force sensitive resistor square (see Figure 16).

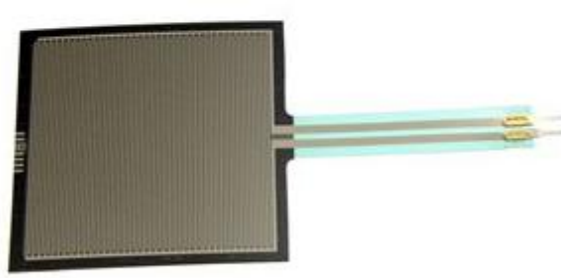

Figure 17: Force Sensitive Resistor Square Component. [9]

These resistor change resistance when a physical force is acting on them changes which will give our system the ability to determine if a user is operating our system at the moment.

4.3. User inputs and Controls

The whole system will be controlled using a remote control that is connected to our microcontroller through an attachment wire.

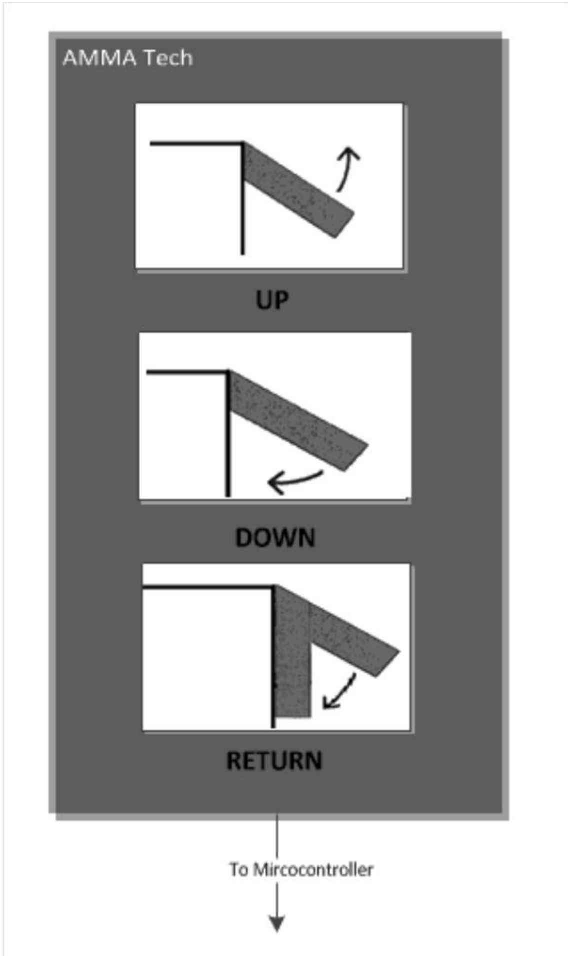

Figure 18: Layout of Remote Controller Unit.

This will be the current layout of our Remote controller unit which the user uses to operate the system. The input signals will be triggered by push buttons and each button will be labeled by either illustrations or by text to inform the user what each button does.

Figure 19: Example of type of buttons that will be used. [10]

There will be an "Up" button to raise the lift, a "Down" button to lower the lift, and a "Return" button to return the lift to the bottom.

4.4. Providing Power to System

The Arduino Uno board we are using has a max output voltage of 5 V which is not enough for our motors. Due to this, we will need to connect the board to a motor driver to power the motors. We decided to use the Ardumoto Motor Shield which is sold at a local supplier. There are a couple of different motor shield for Arduino boards, the main difference between them is the H bridge chips they use. The Ardumoto motor shield uses two L298 H bridges (one for each motor) that are able to support up to 50 V and 2 A. This exceed the values needed by our motor and leave room for safety.

H Bridge Used	L298
Number of Motors	2
Number of Input Pins	4 (2 per motor)
Input Voltage	5 or 3.3 V
Maximum Output Voltage	50 V
Maximum Output Current	2 A

Figure 20: Ardumoto Motor Shield. [11]

5.0. Frame Design of System

The system is designed with wood and two different motors. One motor is a linear actuator that is attached to the "arm" of the system and responsible in moving the user's legs. The other motor is a rotational motor that is attached to the "leg" of the system and can only rotated 90 degree from initial position. The system contains four main parts: the "arm," the "legs," the "head," and the "body." The reason for dividing the system into four main parts is that it makes the system portable and easy to assemble. As shown in Figure 20, the front and right views of the system is designed to be no more than 2 inches from the bed. The height of the system is no more than 24 inches from the floor and the length of the system is no more than 43 inches.

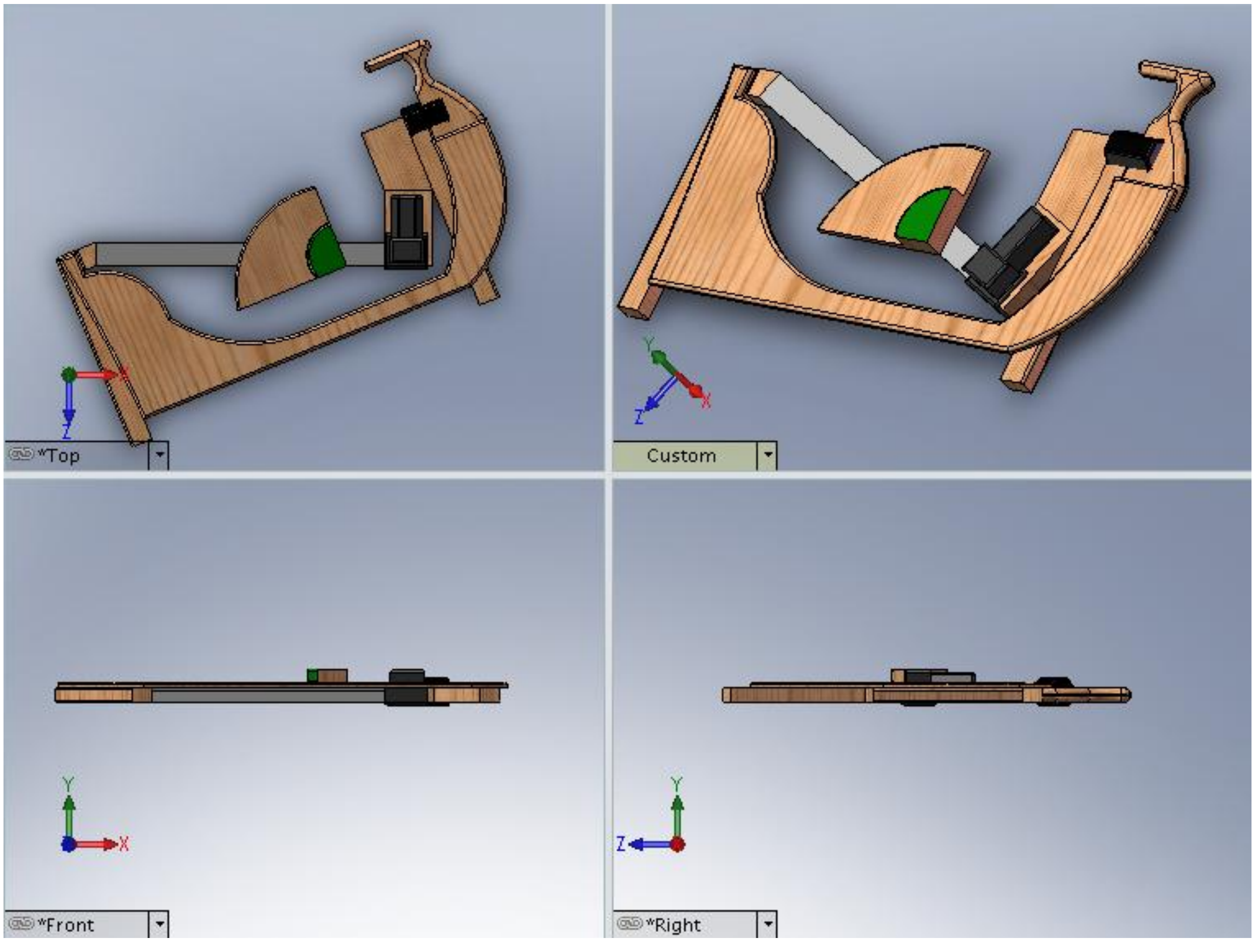

Figure 21: Four different view of the system.

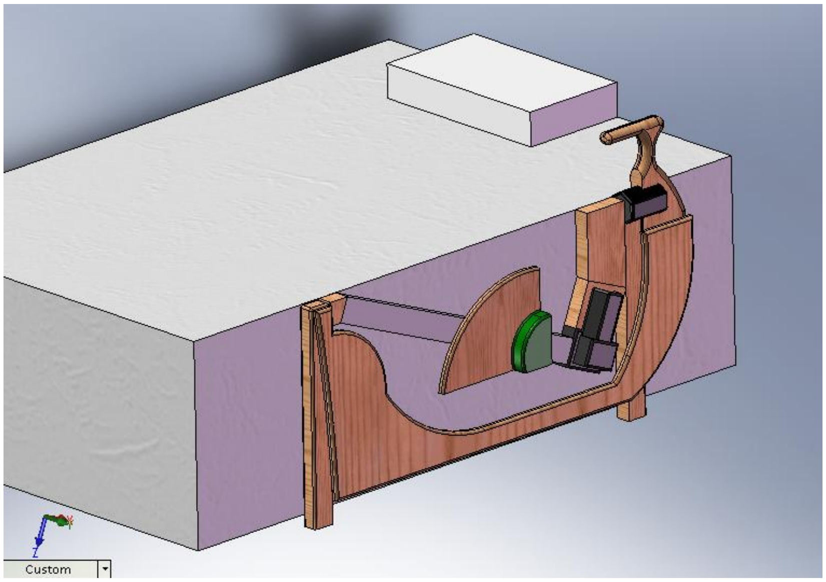

Figure 22: The view of the system on a bed.

In Figure 21, it shows how the system looks like when it is attached to the side of the bed. In Figure 22, the system's "arm" has raised 90 degrees from Figure 21. In the final stage of the system, the system will not be made out of wood; instead, it will be made out of strong, soft plastic.

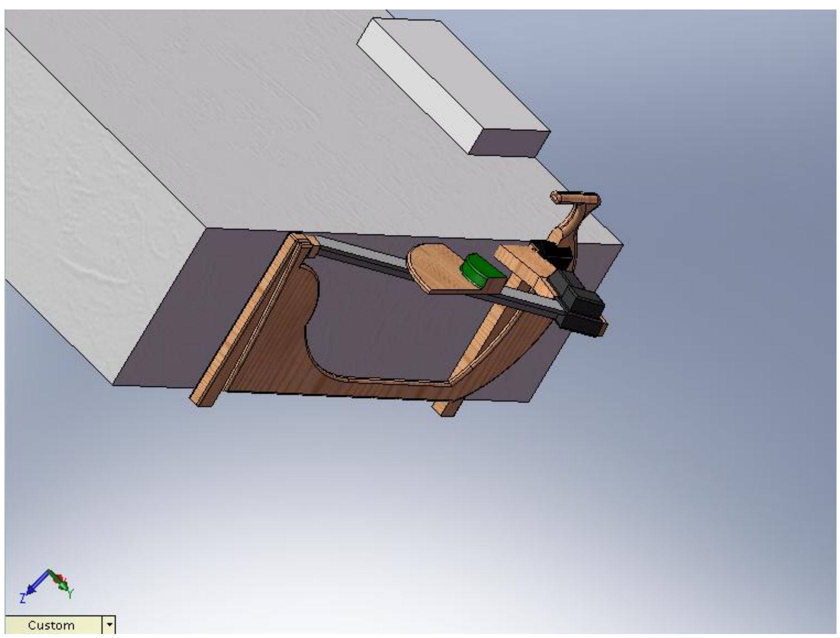

Figure 23: The system with the "arm" rotated 90 degree upward.

5.1. Structural Makeup of System

The system is made of 4 main parts: the “arm,” the “legs,” the “head,” and the “body.” These parts make the assembling task much easier.

Arm Section:

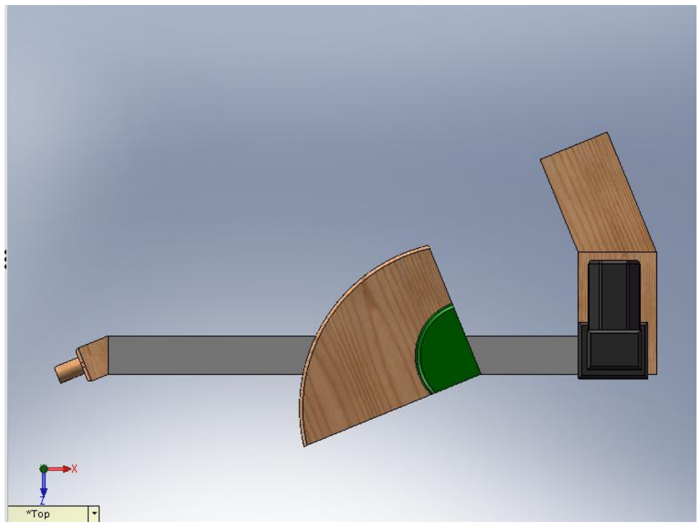

Figure 24: The “arm” of the system.

The “arm” of the system is consisted of a linear motor, a leg rest, and wooden frame. The “arm” rotates from the axis of the top two ends of the wooden frame and it is intended to rotate at most of 90 degrees. The linear motor can move at most of 24 inches, however, in the design, the motor only needs to move 15 inches so the leg rest can push on the mid-lower portion of the user’s legs. The green object on the leg rest is a soft padding to soften the push on the legs.

Leg Section:

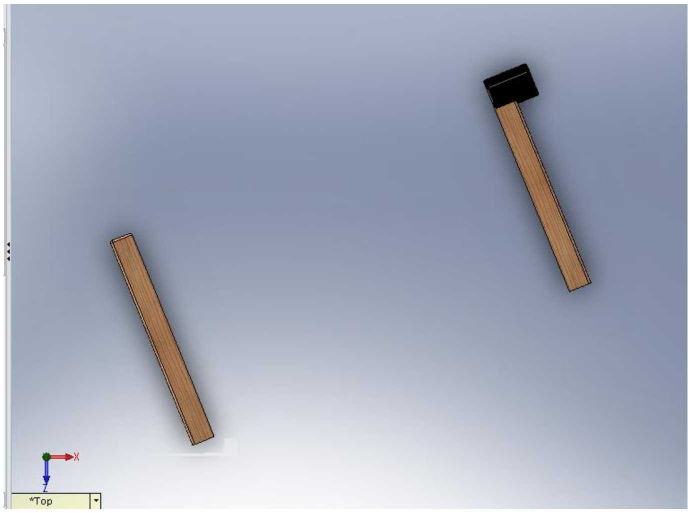

Figure 25: The "legs" of the system.

The "legs" of the system is consisted of a motor and two wooden sticks. Only one of the legs holds the motor and the other leg is there to hold the *arm* in place for the motor to rotate the arm. In the final stage of the system, the legs will be able to adjust the height of the system to match different height of beds.

Head Section:

Figure 26: The "head" of the system.

The "head" of the system is consisted of a wooden handle bar. It is intended to support the user on while they are trying to balance their body while the user operates the systems leg lifting mechanism. In the final stage of the system, the handle bar will be made of plastic.

Body Section:

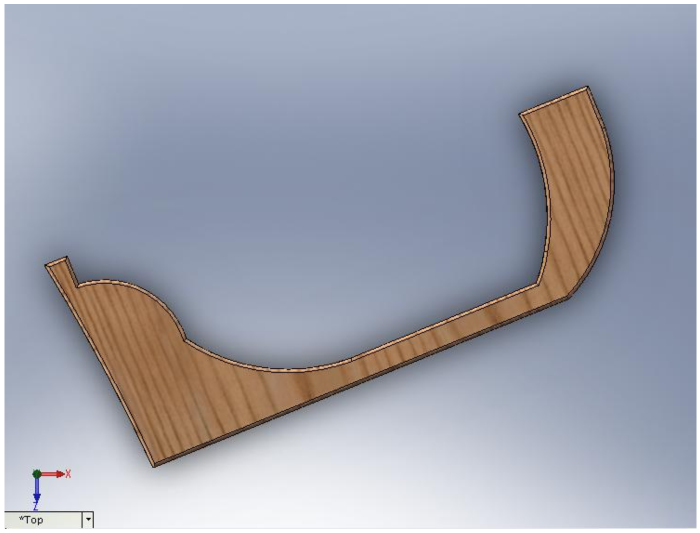

Figure 27: The "body" of the system

The "body" of the system is consisted of a wooden frame that covers all the other parts of the system. The "body" is the important part of the system because it gives the whole system stability and connects everything together. It is also made to cover any small gaps to prevent anything from getting caught. The final stage of the product will be made out of plastic.

5.2. Bed Attachment Mechanism

The system is placed along the side of the bed. For the system to stay on the side of the bed there will be two belts that go under the mattress and hooks around the mattress. The belts will be attached on the "leg" of the system. The belt will be made long enough to cover any sizes of beds and will have a retractor at the end of the belt to recoil any excess length of the belt.

5.3. Safety Precautions

Safety is the most important issues among engineering designs. To ensure the safety of the system of this prototype, the edges of the system's frame are smoothened and there will be no shape edges. The "body" of the system will act as a cover to cover any gaps that could get the user caught. Another safety aspect, the motors of the system will move slowly to give the user a gentle push.

6.0. Conclusion

These are the current proposed design elements which makeup our Bed Side Assistance System. These design choices and considerations are strictly toned towards a prototype model of our system and a full scale production unit will require more research and development progress. The assembly of the system is in their initial stages starting from the mechanical perspective and the electrical proportion is still under the testing phase. We want to take much care and precautions when dealing with the electrical pieces when testing them due to the limited time left to complete the project the difficulty to reacquire damaged pieces. We are confident that the choices we made in this document were in the best interest of our project and for the potential user that will be operating our device.

7.0. References

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