DESIGN OF UPPER LIMB EXOSKELETON FOR PARTIALLY PARALYZED PATIENT

An Undergraduate CAPSTONE Project
By

MD. SAKIB HOSSAIN	19-40232-1	Dept: EEE
AL-MAMUN, JUBAIR	19-40276-1	Dept: EEE
HREDOY, MD ATIAR HOSSAN	19-39900-1	Dept: EEE
MONSUR, SHAHRIAR	19-39761-1	Dept: EEE

Under the Supervision of

Mr. Rethwan Faiz
Assistant Professor

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Faculty of Engineering
American International University - Bangladesh

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A CAPSTONE Project submitted to the Faculty of Engineering, American International University - Bangladesh (AIUB) in partial fulfillment of the requirements for the degree of Bachelor of Science in their mentioned respective programs.

1.	MD. SAKIB HOSSAIN	19-40232-1	Dept: EEE
2.	AL-MAMUN, JUBAIR	19-40276-1	Dept: EEE
3.	HREDOY, MD ATIAR HOSSAN	19-39900-1	Dept: EEE
4.	MONSUR, SHAHRIAR	19-39761-1	Dept: EEE

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American International University - Bangladesh

DECLARATION

This is to certify that this project is our original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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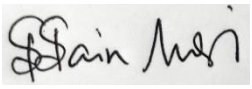
Students' names & Signatures

MD. SAKIB HOSSAIN



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AL-MAMUN, JUBAIR

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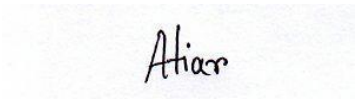
HREDOY, MD ATIAR HOSSAN



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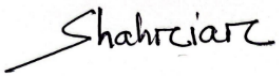

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APPROVAL

The CAPSTONE Project titled **DESIGN OF UPPER LIMB EXOSKELETON FOR PARTIALLY PARALYZED PATIENT** has been submitted to the following respected members of the Board of Examiners of the Faculty of Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in the respective programs mentioned below on **January 2023** by the following students and has been accepted as satisfactory.

1. MD. SAKIB HOSSAIN	ID: 19-40232-1	Dept: EEE
2. AL-MAMUN, JUBAIR	ID: 19-40276-1	Dept: EEE
3. HREDOY, MD ATIAR HOSSAN	ID: 19-39900-1	Dept: EEE
4. MONSUR, SHAHRIAR	ID: 19-39761-1	Dept: EEE

Supervisor
Mr. Rethwan Faiz
Assistant Professor
Faculty of Engineering
American International University-Bangladesh

External Supervisor
Mr. Md. Shahariar Parvez
Lecturer
Faculty of Engineering
American International University-Bangladesh

Prof. Dr. Md. Abdul Mannan
Director
Faculty of Engineering
American International University-Bangladesh

Prof. Dr. ABM Siddique Hossain
Dean
Faculty of Engineering
American International University-Bangladesh

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Chapter 1
INTRODUCTION

1.1 Overture

Human hands are essential in activities of daily dwelling, with a ramification of functions including touching, feeling, preserving, grasping, typing, handwriting, molding, etc. however, disability from stroke or harm remains to be the main purpose of impairment global. medical evidence suggests that repetitive physical activities and strengthening sports are vital to regain motor function and improve the first-class of lifestyles of patients stricken by hand impairments. The hand is part of the extremity of a human positioned at the distal phase of an arm or forelimb. it's far composed of a palm with five palms with the wrist connecting it to the forearm. Human arms are taken into consideration as one of the maximum problematic mechanical structures of the body with 27 bones and 24 levels of freedom. currently, robot exoskeletons had been evolved to help with the rehabilitation method but because of the complexity of the human hand, there is an undertaking to deliver significant manipulation abilities in a small and lightweight package [1].

1.2 Engineering Problem Statement

Our fundamental aim is to build such a synthetic assisting hand to conquer the incapacity hassle of the human hand with the usage of microcontrollers, microprocessors, and motors. in this challenge we've tried to perform our intention the use of FSR sensor, Relay module, equipment Motor primarily based Actuator (excessive Torque) and it can't be viable without amassing intensity understanding approximately these devices. Getting statistics perfectly in time through sensors is a project that we've taken on, and accurate implementation is also a challenge that taken successfully. It must be stated that establishing the vehicles nicely so that they are useful as we want is the hardest undertaking we've got taken [3].
inside the table, its miles defined how our challenge meets the situations of OBE requirement and definition of complicated engineering hassle.

Indicator	Title	Description
CP1	Depth of knowledge required	This project needs deep knowledge of computer programming, microcontroller, Robotics, Circuit design, Transformers, Sensors
CP2	Range of conflicting requirements	The project has to combine the knowledge of mechanical, electrical, computer, data science, and robotics to achieve the needed efficiency and result.
CP3	Depth of analysis required	The data collection and operation of the rover need be thoroughly analyzed

CP4	Familiarity of issues	Movement of human hand and motor operating methods need researches which were lacking in the previous existing rovers.
CP5	The extent of applicable codes	C, C++
CP6	The extent of stakeholder involvement and conflicting requirements	The diverse groups of stakeholders (Patients, Medical Community etc.) of the project has been considered with varying needs.
CP7	Interdependence	The research work will require many component parts or sub-problems like electrical components, robotics components etc.

1.3 Related Research Works

Based on world health organization, over 15 million people suffer from stroke and diseases related to the heart. Among those patients, almost 85 percent suffers from limb impairments. This results in a situation where the patients end up as a burden to the society and family. A 5 DOFs upper limb robot named MARSE-5 was developed by Rahman *et al.*The mechanism is supposed to worn laterally on the limb to support movement of the arm [16].

1.3.1. Earlier Research

Several arm rehabilitation robot devices, each Cartesian and exoskeleton-primarily based, had evolved over the years. some examples include MIT Manus (Krebs et al. 1998; Fasoli et al. 2003), Assisted Rehabilitation and size (ARM) guide (Reinkensmeyer et al. 2000), replicate photo motion Enabler (MIME) (Lum et al. 2002) [8], and one-diploma of freedom (DoF) and corresponding author. Email: a.frisoli@sssup.it two-DoF devices were developed at Saga College (Kiguchi et al. 2001, 2003). The latest survey (Prange et al. 2006) outlines that robot-aided remedy allows a better degree of development of motor manage if as compared with traditional remedy. Nevertheless, no consistent impact on functional skills has yet been found. Exoskeleton robots have recently raised the hobby of the robotic rehabilitation research network. Exoskeletons are robotic structures designed to paintings connected with components (or the complete) of the human body, as shown in parent 1. In preferred, robots are designed for a defined workspace where they carry out duties autonomously (Avizzano and Bergamasco 1999). The layout of exoskeleton structures stems from contrary motivations that intend the robot structure to constantly preserve touch with the human operator's limb. one of these circumstances is required for several packages that consist of using grasp robotic fingers for teleoperation, energetic orthoses, and rehabilitation (Bergamasco 1996) [2].

1.3.2. Recent Research

The authors in [4], attempt to show us an enhanced model of Exoskeletons in upper limb rehabilitation. this robotic exoskeleton, the shoulder vertical and horizontal flexion/extension, and elbow flexion/extension movements are pushed with the aid of pulleys and cable force even as the actuators are placed at the desk-bound frames. whereas, for delivering shoulder internal/external rotation, forearm supination/pronation, wrist flexion/extension, and wrist radial ulnar deviation movements to the robotic, the actuators are mounted on the robotic itself and either without delay connected or via gear power.

Slider-crank mechanism was used for compensating CR of the shoulder joint

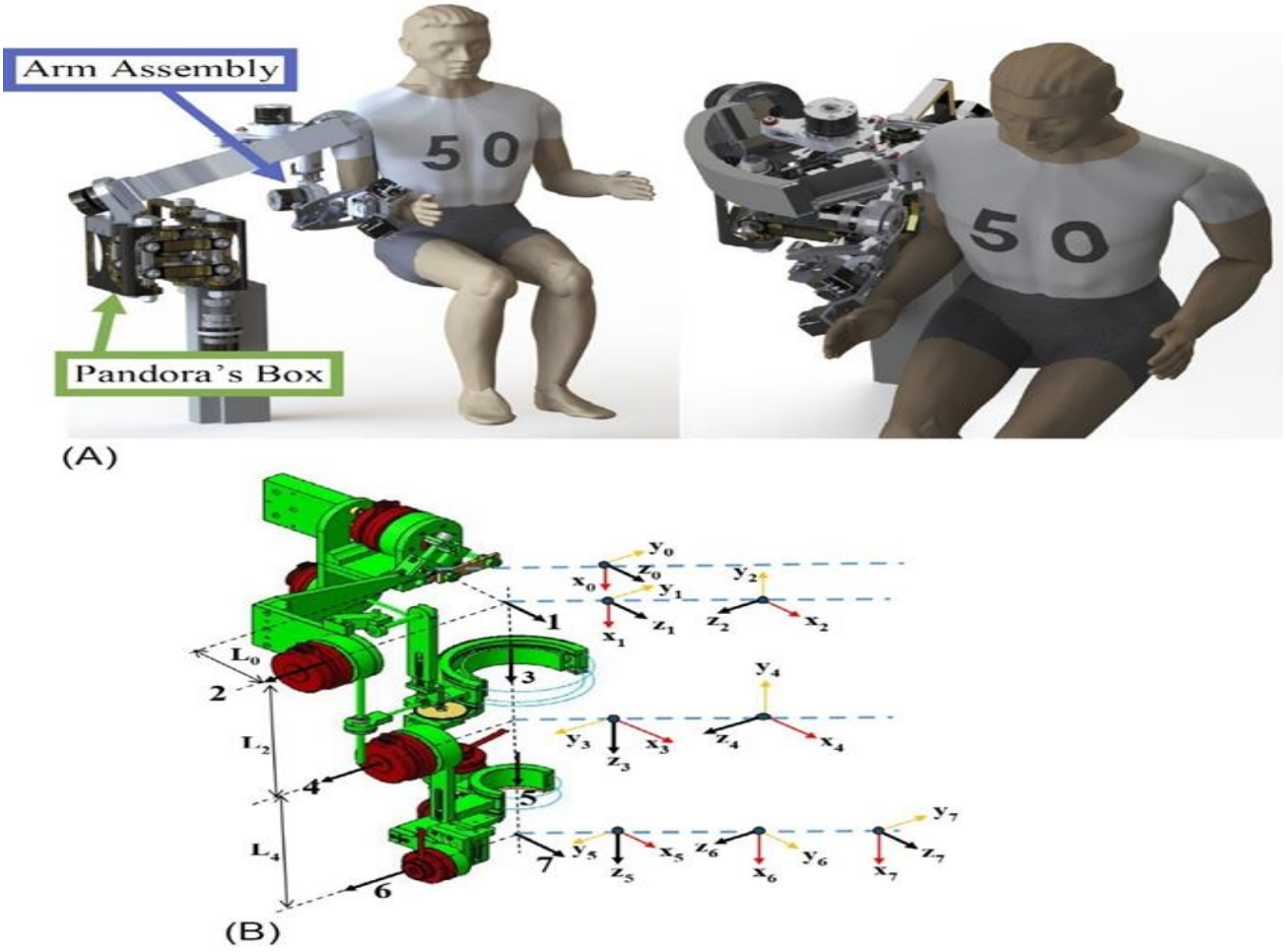

Figure 1: Recently proposed upper limb exoskeletons [4].
A. **BLUE SABINO (Perry et al., 2019);**
B. **U-Rob (Islam et al., 2019, 2020**).

a piece in [6], FLEXO-Arm1 is a top limb exoskeleton robotic advanced by means of Shanghai Engineering studies center of Assistive gadgets and college of Shanghai for technology and technology, as proven in Fig. 1. The exoskeleton has a passive training mode, lively help mode, and teaching mode, appropriate for the treatment of stroke patients at distinctive degrees. And it combines digital facts (VR) to improve the interest and enthusiasm for patients' training. The exoskeleton can educate the shoulder, elbow, and wrist joints. we all realize that the flexion/extension of the shoulder and elbow joints are the 2 maximum essential moves of the upper limbs. Consequently, the flexion/extension of the shoulder and elbow joints of FLEXO-Arm1 is driven with the aid of cars. The exoskeleton has active stages of freedom.

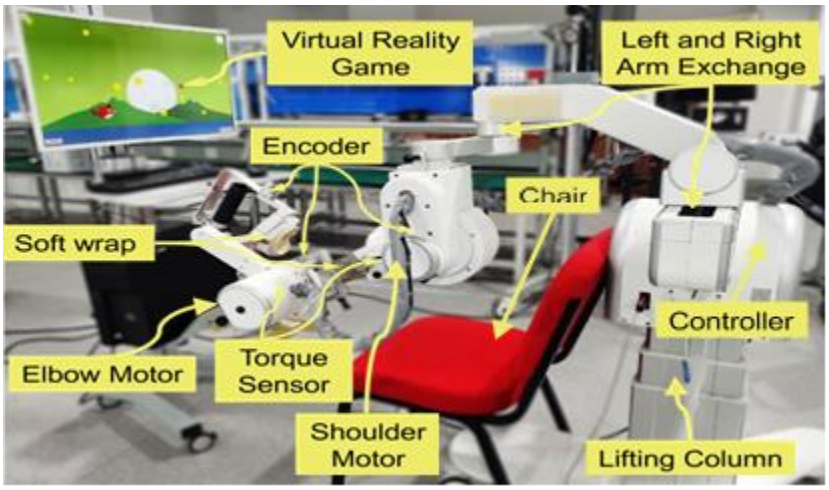

Figure 2: Upper limb rehabilitation robot (FLEXO-Arm1) [6].

1.4. Critical Engineering Specialist Knowledge

The project was constructed by utilizing the concept of robotics to get a better solution for the disabled part of the human body. An exoskeleton, as the name suggests, is an external frame that can be worn to support the body, either to help a person overcome an injury or to enhance their biological capacities powered by a system of electric motors, the frame gives limbs extra movement, strength, and endurance. Exoskeletons are wearable robotics that provides mobility to those who are physically disabled or recovering from injury.

1.5. Stakeholders

The undertaking has been researched and the possibilities had been explored from many exclusive angles in various papers. Many of the projects have very near human interference and are operating perfectly in one-of-a-kind regions of the world. The procedure includes placing the exoskeleton in the human arm which ultimately makes sure the very last product is operating nicely. There are numerous corporations within the world now not the handiest bio-clinical enterprise which can be generating unique sorts of exoskeleton for different parts of the human frame that consists of people in sports or style industry stakeholders [6]. However, there are nonetheless very limited studies on the monetary advantages of robotic rehabilitation devices

against traditional sorts of physical therapy. However, those are existing endorse an excessive potential to provide inexpensive alternatives, thus a more reachable and dependable device, the design and development of a fee-effective robotic exoskeleton for the upper extremities could advantage the subsequent stakeholders:

- **Patients (Stroke, injury, and so forth.) –**because of the number one customers of this device, they may have lesser costs on therapy classes and they could sing their progress in real-time leading to a quicker recuperation fee. This gain shall be focused in the direction of patients inside the developing regions whose get entry to healthcare alternatives is very limited [5].

- **Scientific network (Physicians, Therapists, etc.) -** The improvement of this tool shall offer an opportunity option to traditional remedies. Because of the progress in the direction of selling the function of robotic gadgets in rehabilitation, the clinical network shall also adapt to such gadgets. At present, the purpose of this research region isn't always to update the therapist but to automate the procedure so as for them to attend to patients who require more human intervention [1].

- **Instructional network** – This serves as an assignment to researchers, design engineers, and developers because it opens new doors to a place of research in low-cost manufacturing of biomedical devices. as the fashion focuses on the direction of greater state-of-the-art, steeply-priced, and complex structures, a brand-new location is diverged to focus on using the confined resources of a growing economic system [7].

one of the traits in reducing the expenses of biomedical tool production is additive manufacturing or interchangeably known as 3-d printing [3]. This procedure gives the economic advantages of reduced waste and faster production time. Present-day studies suggest that additive production is not pricey whilst completed in small batches. However, those studies tend to be constrained in their scope because of the complexities related to measuring the price effectiveness of 3-d-revealed merchandise. However, the 3-D printing of robotic exoskeletons both for prototyping and distribution is an exceptional goal for new research [4].

1.6. Objectives

People from across industries are taking their mobility know-how and applying it to the medical devices market. there are numerous different things that can come to mind whilst considering medical gadgets consisting of implants, surgical units, drug transport, and greater. Exoskeletons won't be what first come to your mind, but they probably have to be, given the way specialists are pronouncing they are revolutionizing the scientific tool market. To many, exoskeletons are becoming the bridge between the human body and robots [2].

Our preliminary intention turned into creating a simple artificial skeleton with the usage of our engineering know-how that might assist the patient who’s tormented by primary harm in the upper limb of the hand. We set out to build something comparable, which has already ended up a surprisingly popular phrase inside the engineering industry for bringing modern trade. We constructed the tools with a slew of sensors. A microcontroller has been used to run all of the sensors and a microprocessor is there for making a connection between the microcontrollers and

the automobiles. With this gadget, an affected person can move their top limb with a diverse degree of freedom. The machine could be developed with greater features in destiny.

1.6.1. Primary Objectives

- Make a metal frame that can support the upper limb
- Implement the sensors with the microcontroller
- Make a connection between the microcontroller and the microprocessor
- Build a structure of the upper limb to support the hand

1.6.2. Secondary Objectives

- Improve features by adding more sensors and microcontroller
- Increase the degree of freedom

1.7. Organization of Book Chapters

Chapter-1: is entitled "Introduction. It introduces historical background and overview, evolution Technology used in the project. The objective of the project is also described in this chapter.

Chapter-3: Methodology and Modeling

Chapter-4: Implementation of Project

Chapter-5: Results Analysis & Critical Design Review

Chapter-6: Conclusion

Chapter 2

PROJECT MANAGEMENT

2.1 Introduction

Project management is the process of creating, planning, putting ideas into action, and supervising the plan that will be used to carry out the complete project. The goal of this project is to identify patients with upper limb physical disabilities and create an exoskeleton that can help such people regain their ability to move about. A firm grasp of project management is required to assure the project's success. The first step in making sure the job is carried out without incident was to comprehend the numerous parts of exoskeleton and why it is so crucial. Next, thorough planning of the processes, their execution, the resources required, materials needed to complete the project, cost analysis of the project, and most importantly.

2.2 S.W.O.T. Analysis

Strength, Weakness, Opportunity, and Threat analysis of a project is known as S.W.O.T. analysis. Such analysis is required to comprehend the future scopes as well as how the project might be utilized. This analysis assesses a project's strengths and limitations as well as the risk it poses and the opportunity it presents for the near future. Through the study, it is also possible to determine whether the project poses any risks and how those risks may be reduced or addressed. There are numerous approaches to identify areas for improvement, what should be the best working method for a project, and the likelihood that the project will be successful, allowing a group to decide whether to work on the project.

2.2.1 Strengths:

- Environment friendly
- Compact
- Cost effective
- Requires less human labor
- Portable
- Doesn’t require complex codes to run
- Less power consumption

2.2.2 Weaknesses:

- Moving of model is linear
- Electrical connections are complex
- The exoskeleton, if not insulated properly poses health hazards
- The actuators are controlled by the sensors which could cause serious damage if handled without knowing the procedure.

2.2.3 Opportunities:

- Can be improved to be complete
- With so external attachments, it is possible to finish the entire process in a compact space
- Has the potential to become an industry itself

2.2.4 Threat:

- There is a possibility of theft of intellectual property.

2.3 Schedule Management

Schedule management gives the project an organized work method and techniques. A project runs depending on many variables. Schedule management outlines the goals and objectives and organizes them in order. Its setups the pathway to finish the project within required time and budget. In order to run, monitor, control, and finish the project, schedule management is very important.

	Apr 16 – 09 May	9 May	10 May – 20June	21 June – 5 July	6 July – 30 July	31 July – 11 Aug	12 Aug – 31 Aug	1 Sep – 8 Sep	9 Sep – 22 Sep	23 Sep – 22 Oct	23 Oct – 23 Nov	24 Nov– 05 Jan
Topic Selection												
Project Proposal Submission												
Literature Review												
Relative work analysis												
Theoretical Analysis												
Completion of Chapter 1 & 2												
Research and Modification												
Progress Defense												
Attending Final Defense												

Submission of Chapter 1 & 2											
Submission of chapter 1 & 2 Progress Reflection Report											
Final Product Production											
Online Lifelong Learning Report Submission											
Draft Book Submission											
Final Book Submission											
Final Defense											

2.4 Cost Analysis

S/L	NAME OF COMPONENTS	QUANTITY	ESTIMATED PRICE	ACTUAL PRICE
01	Arduino pro	1pcs	700	680/-
02	Relay module	4pcs	1020	980/-
03	FSR sensor	2pcs	2100	1980/-
04	PCB	1pcs	150	100/-
05	Resistor	8pcs	50	10/-
06	Gear Motor Based Actuator	2pcs	15000	13580/-
07	Switch	1pcs	20	10/-
08	PVC	5ft	800	680/-
09	Wire	20ft	350	300/-
10	Glue stick	10pcs	400	330/-
11	Super glue	1pcs big pack	100	130/-
12	Lead		150	100/-
13	Metal Frame		4000	3800/-
14	Power supply (DC)		2000	1890/-
15	2pin Plug		50	40/-
16	Miscellaneous		800	1000/-
	Total		27690/-	25610/-

Standard Deviation

Now, $S = \sqrt{\frac{\sum(X-\bar{X})^2}{N-1}}$

$s =$

$$S = \sqrt{\frac{4326400}{15}}$$

$$S = 537.053$$

Hence the project cost analysis was feasible to implement.

2.5 P.E.S.T. Analysis

Political, Economic, Social, and Technical Analysis of a Project is known as PEST. The PEST analysis can be used to monitor these factors. Macro-environmental features of the projects are evaluated considering the significant influence the project has. Political, economic, social, and technological dimensions are, as the name implies, the most crucial elements in this kind of analysis.

2.5.1 Political Analysis

The project is the result of the team's idea, and it won't require any political or governmental engagement to be carried out. However, concerned authorities should be aware if it becomes necessary to generate significant amounts of the finished product in the future.

2.5.2 Economic Analysis

Since the project implements a complete system to produce a wearable exoskeleton product, logically the hardware setup of the project has a reasonable budget. So, it is unfortunate so say that any students or researchers with very little fund will see barriers to implement the project. But the project itself has the potential to become a profitable medical product, comparatively low amount of capital.

2.5.3 Social Analysis

The project runs with the goal to reduce the physical disability from the society which poses the possibility to affect the society in various terms and trends. It also has the potential to build self-confidence to the disable person of the society which may result in a declination of disablement. The project also can be served as a big market for bio-medical industry of Bangladesh which may help country in a good scale if utilized properly.

2.5.4 Technological Analysis

One of the goals of this project is to contribute and make an actual change in the human life as well as in the society. In order to that, it is important that the technology if this project is available and accessible to industries and corporations who can mass produce the product and create the change that is intended. The technologies used in the project are completely domestic and available to most who wishes to utilize the project.

2.6 Professional Responsibilities

It is the responsibility of the implementers of a project that the product or the outcome of their project is accessible and understandable by everyone. It is the job of the engineers to make sure that the method, techniques, setups, and products are safe, usable, and effective. In order to achieve that, engineers must work with good management, communication, and effective teamwork. The most important responsibilities the engineers must heed to be:

- Using comprehensive drawings to draw out plans
- Preparing estimates and budgets for projects
- Defining the scope of the project
- Designing experiments in the field of engineering
- Producing customer-facing technical reports
- Completing safety-related regulatory documents
- On-time and within-budget completion of projects
- Informing clients and coworkers of findings and conclusions from analyses

2.7 Norms of Engineering Practice

The fundamental goal of this effort was to make engineering more accessible. For us, this was a very difficult circumstance. We'll make a PCB board and add sensors to it. As a result, proteus software was used to create it. After that, it's printed. This work took a long time and a lot of thought to finish. How to fit all these items into a little place? It will also be simple to use. With a soldering iron, we carefully scolded the PCB. A soldering iron is a hand-held soldering instrument. It generates enough heat to melt the solder and let it flow into the connection between two workstations. We analyze code part to use the sensor properly with micro-controller.

2.8 Individual Responsibilities

To achieve the successful completion of any project, it is a must to have good group work and teambuilding capacity. But within the group, every member should carry out the individual or personal responsibilities which would ultimately lead to a complete and well-done project. Every member of a group is bound to have different traits and strengths. By playing their strong suits and combining them together a project is compiled. Throughout the project, members of the group had different responsibilities and this portion analyzes their contribution in depth.

Software and Hardware Implementation

Name	ID	Responsibility
MD. SAKIB HOSSAIN	19-40232-1	Hardware
AL-MAMUN, JUBAIR	19-40276-1	Hardware
HREDOY, MD ATIAR HOSSAN	19-39900-1	Simulation
MONSUR, SHAHRIAR	19-39761-1	Simulation

Book Writing

Name	ID	Responsibility
MD. SAKIB HOSSAIN	19-40232-1	Book Writing Lead, Chapter 2,3,4,7
AL-MAMUN, JUBAIR	19-40276-1	Chapter 4,6
HREDOY, MD ATIAR HOSSAN	19-39900-1	Chapter 1,5
MONSUR, SHAHRIAR	19-39761-1	Chapter 1,2

Overall Project Lead

Name	ID	Responsibility
MD. SAKIB HOSSAIN	19-40232-1	Lead book writer, Project Manager
AL-MAMUN, JUBAIR	19-40276-1	Lead Hardware Implementer, Lead designer
HREDOY, MD ATIAR HOSSAN	19-39900-1	Lead of simulation, Lead of communication
MONSUR, SHAHRIAR	19-39761-1	Researcher, Lead of Purchasing

2.9 Summary

The project is the result of the team's idea, and it won't require any political or governmental engagement to be carried out. However, concerned authorities should be aware if it becomes necessary to generate significant amounts of the finished product in the future.

Chapter 3

METHODOLOGY AND MODELLING

3.1 Introduction

The success of a project depends on a lot in designing of the model and the method the project is following. The model can be said to be the backbone of the project. This chapter discusses the methods that were followed to construct the project in depth and the designed models are analyzed. The methods are shown via all the necessary block diagrams. The fact that has to be admitted is that the project still has a long way to go. It still has many potentials to unlock through further upgrade. But in order to upgrade the system, first it is necessary to understand the basic methods and designs which are covered in this chapter. It can be said that the project is a lot industrial and mechanical based which is why all the block diagrams just represent the mechanism and do not show the real-life project.

3.2 Block Diagram

As stated before, the project is made up with two different parts, the Electrical mechanism, and the Mechanical mechanism. Both are vital for the project to run. The best way to understand the working of a project is through the block diagram which gives us a picture in our mind of what the project is. By understanding the block diagram, it is easy to replicate the project to mass produce the system.

3.2.1.1 System Block Diagram

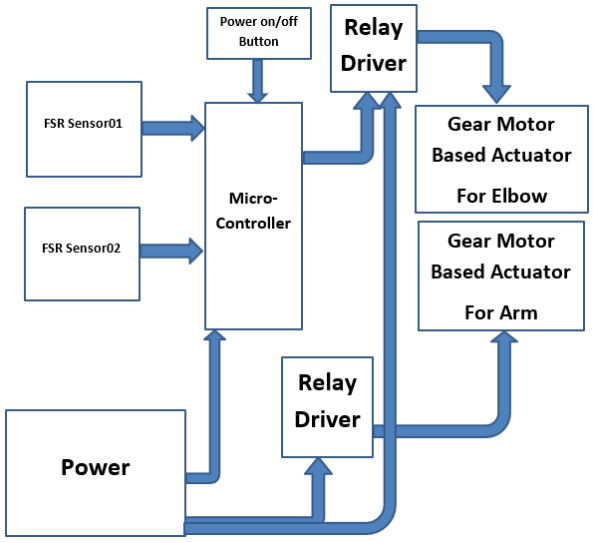

Figure: 3 Block Diagram of the Project

The block diagram shows which part relates to which here, the system is powered by a portable dc power which powers all the components. The microcontroller connects FSR sensor and the actuators.

3.3 Required Tools and Components

The project is constructed by comprising many different parts together. To complete the simulation of the project, proteus simulation tool was used to get a better grasp at how the project is supposed to behave. Then, to construct the hardware part, it was divided in two parts, mechanical setup, and electrical box. The mechanical setup had two Gear Motor Based Actuator and Metal Frame. The electrical box had Arduino pro, FSR sensor, Power supply (SMPS), and relays connected inside. Detailed information about all the tools and components are given below for better understanding.

3.3.1 Actuator

An actuator is a device, or rather a component of a device that uses control signals to transform externally available energy into motion. Actuators allow machines to carry out various mechanical movements, like how hands and legs allow humans to move around and carry out actions.

In this project, two actuators are employed to pull and push a metal frame that has been modified to fit a human arm and elbow. The actuator cannot have a high rotational speed because its goal is to move the metal frame slowly. Otherwise, both the hand and the metal frame will suffer significant harm. A 0.37KW, 0.5HP single phase AC induction motor is used in the project. The output speed is 61 and the gear ratio is 23:1.

Figure: 4 Actuator [11]

3.3.2 Arduino pro

The Arduino Pro Mini is a microcontroller board based on the ATmega328P.It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. A six pins header can be connected to an FTDI cable or Spark fun breakout board to provide USB power and communication to the board.

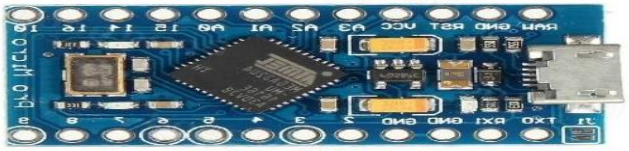

Figure:5 Arduino Pro [12]

3.3.3 Metal frame

Barrel chamber is a hollow cylindrical chamber to hold the screw shaft inside. Barrels for extrusion machines are created to withstand large amount of pressure from inside. In general, the barrels, once heated can feel pressure up to 700-1000 psi in large extrusion machines.

Figure: 6 Metal frames [15]

3.3.4 Portable DC power supply

A Direct Current (DC) Power Supply is a type of power supply that exclusively and constantly supplies DC voltage.

3.3.5 Relay module

A power relay module is an electrical switch that is operated by an electromagnet. The electromagnet is activated by a separate low-power signal from a micro controller. When activated, the electromagnet pulls to either open or close an electrical circuit.

Figure: 7 Relay modules [13]

3.3.6 FSR sensor

Force Sensing Resistors, also known as Force Sensitive Resistors or FSR. They are basically a sensor that changes its resistance depending on the amount of pressure, force or stress applied to it. In this project, we are using this sensor to control the actuators by applying force.

Figure: 8 FSR sensors [14]

3.4 System Model

The model of a system is vital to understand how the project is supposed to look like. Most of time the hardware doesn't resemble the model exactly but without the model, it cannot be compared to verify the mistakes and scopes for further upgrade.

3.4.1 3D Model

After the primary modeling, it was easy to create a 3D model of the system which is capable of giving an idea of the project and gives an edge for further upgrading

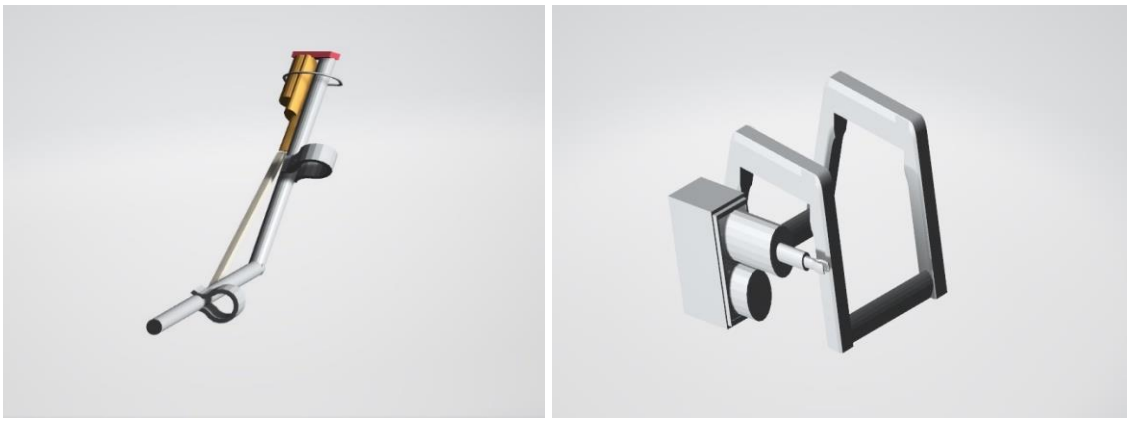

Figure 9: 3D Models of the project

3.5 Summary

The chapter successfully provides the method to create the entire system. Via the block diagrams, the working principle is thoroughly understandable and possible for anyone to recreate. The model of the system provides the exact parameters needed for the project.

Chapter 4

Project Implementation

4.1 Introduction

The current situations of Bangladesh, there are many patients whose can greatly benefit form a project that takes about the disability problem. The project is constructed mechanically by consisting of two metal frames. As the disabled patients cannot move their arms, frames will support the upper arm and the elbow. In order to implement the project, both parts had to be constructed differently and then merge together to get the desired output.

4.2 Construction of the Metal frame

The complete exoskeleton model is completed by dividing the work in two steps as mentioned before, the mechanical part and the electrical part. The mechanical part of the project is constructed with intensive and advance metal which was done in a workshop and the electrical part was compiled completely by hand.

4.2.1 Construction of the metal frame for Elbow

The pieces of different size of metals are the main parts that were constructed in workshop. there are two metals connected with a screw so that it can move freely in order to maintain the proper movement of elbow and two parabolic shape metal are adjusted to both of the metals in order to hold the elbow of the body. An actuator is attached on the upper part of metal so that it can pull up as well as pull down the lower part of the metal. An external small metal is used to connect the piston rod of actuator and the lower part of the metal.

Figure: 11 construction of the metal frame for Elbow

4.2.2 Construction of the metal frame for upper hand

To ensure the movement of the upper part of the hand there is an actuator attached to a customize metal frame which is made of two types of metals, soft metals and hard metals. The soft metals are bend to a parabolic shape as the frame is design as wearable prototype. Two hard metals are used to interconnect the both soft metals. One of the soft metals is bearing the actuator. A cup shape hard metal is joined to the piston rod of the actuator to ensure the proper movement of the upper hand.

Figure: 12 construction of the metal frame for upper hand

4.3 Construction of the Electrical Part

The electrical part of the project is fully separate from the metal frames.

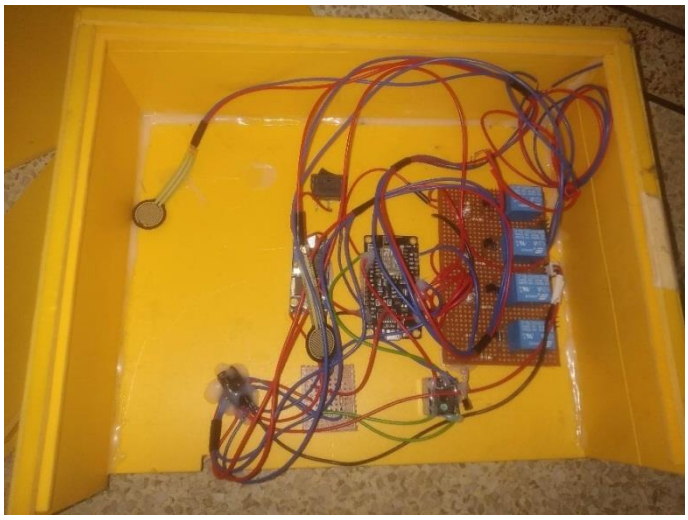

Figure: 13 Electrical connection of the project

The electrical part is comprised of the Gear Motor Based Actuator, FSR sensor, portable DC power supply and the electrical box that has Arduino pro, Relay module, resistors, and connection wires inside.

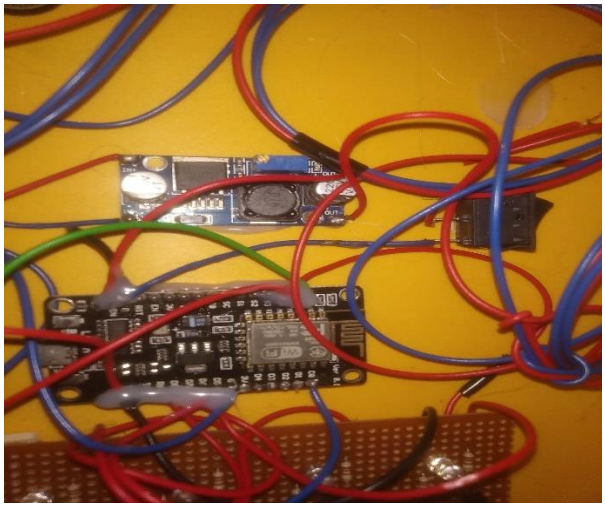

Figure: 14 Electrical connection of the project

The FSR sensors are used to control the actuators. As the function of the FSR sensors, it controls the actuators movement by sensing the force difference. The soft pressure on the FSR sensor make sure the forward movement of the piston rod in the actuator. There is an Arduino pro to controlling the actuators and receiving command from the relay modules. Relay modules are used for multiplexing the FSR sensors data and forward the data to Arduino pro.

4.4 Implemented Model

To complete the project, both simulation model and hardware model are needed. The simulation model gives an idea whether the project would work as desired and not before implementing the hardware model. And the hardware model could be said as the real-life implementation of the project which would give us a workable output.

4.5 Simulation Model

The simulation for the project was done in proteus simulation tool. The required software is proteus 8.6.

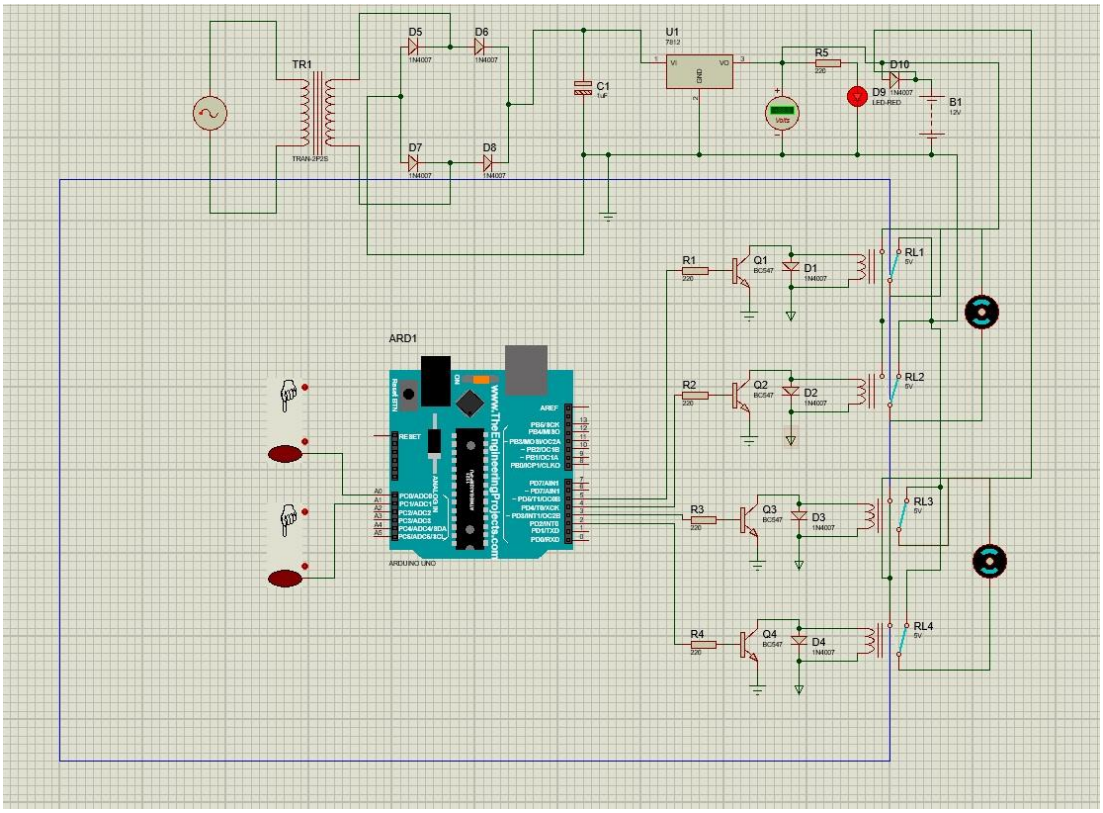

Figure: 15 Simulation Model

The simulation shows two FSR sensors, two actuators and relay modules are connected to the Arduino Pro.

4.6 Hardware Model

Figure: 16 Complete Setup of the model

Once all the parts of the machine are put together, the entire project runs smoothly and as it is shown is figure 23, the entire system is constructed on a steel stand that supports all the parts.

4.7 Summary

With the help of the simulation model, it was assured that the hardware model would work, and the design is based on that. After compiling all the components together, the project took shape, and the endeavor became a success. In order to run the project, combination and understanding of all components are a must.

Chapter 5

RESULT ANALYSIS AND CRITICAL DESIGN REVIEW

5.1 Introduction

The objective of the project was to achieve proper movement of the disable upper hand and the model which was constructed is capable of achieving that goal. With actuators and FSR sensors, the metal frames can move properly as a result the hand will move with the metal frames.

5.2 Result Analysis

Disability of body parts is a very real and ever occurring problem that threatens the balance of the nature. The goal of this project was to ensure the proper movement of human hand. The project is successful in developing movement of hand. When it reaches the desired force in the FSR sensors and the relay modules sent the data to Arduino pro after multiplexing. Then the actuators move as they have enough force on the FSR sensors as a result it makes sure the movement of the upper hand. So, it can be said that the objective of the project is reached, and the goal of the project is achieved.

5.3 Result of the Simulation

A simulation of the FSR sensor was done on Multisim platform to understand the workings of the FSR sensor and the result of the simulation gave the project its confidence to move forward.

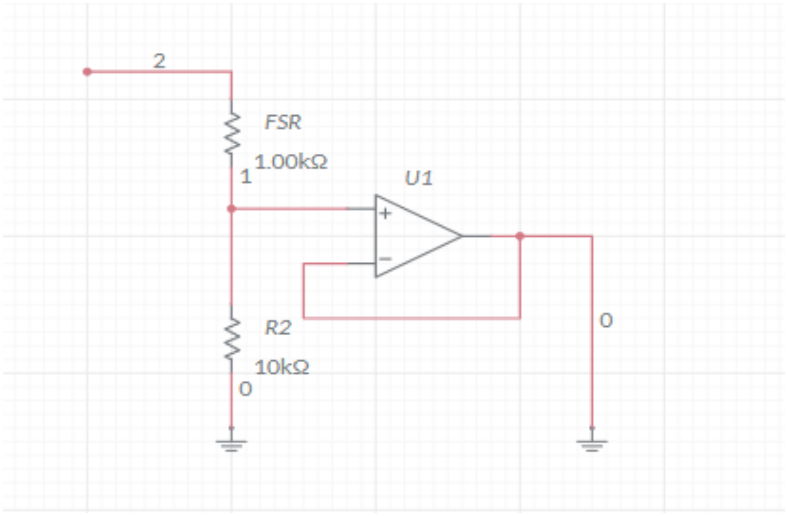

Figure: 18 FSR sensor circuit

The simulation shows whether the FSR sensor will run or not and as it is shown in figure: 19 that if connected properly not only the FSR sensor will run, it is also very much possible to control the actuator.

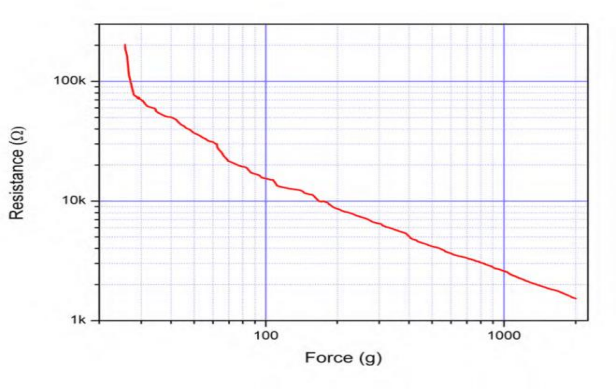

Figure: 19 FSR sensors Simulation Output

5.4 Hardware Result Analysis

After the completion of the hardware, the project runs successfully.

Figure: 20 Hardware Model for elbow

Figure: 21 Hardware Model for upper limb

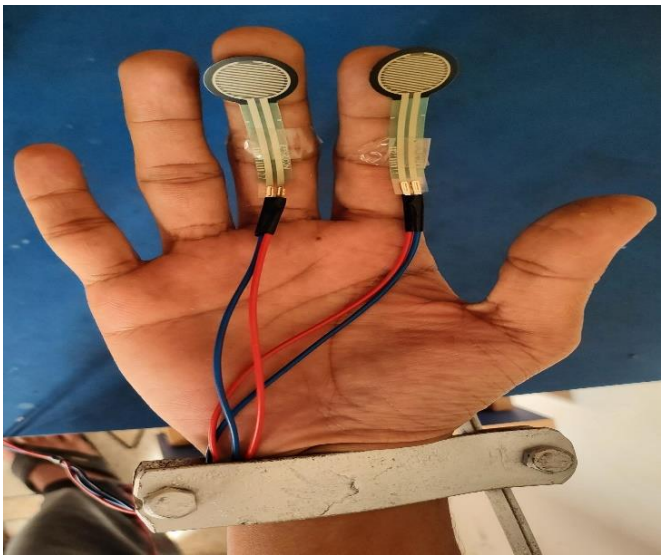

Figure: 22 FSR connection on finger

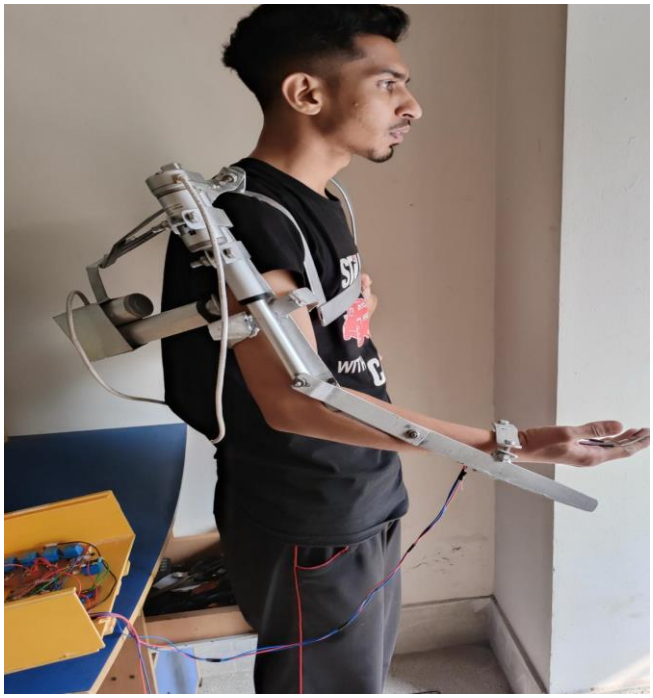

Figure: 23 Practical Demonstration of the Project

The hardware of the project once put together all runs simultaneously.

5.5 Comparison of Results

The hardware and the simulation of the project both showed very promising results. After proper examination, it can be said that the project is functioning properly. The simulation showed that when the force increases the resistance decreases which is exactly what was found while implementing in hardware. The output result that was found after various experiments were usable and within expectation. The complete model as it joins altogether runs smoothly beyond expectation. One of the noticeable features of the project is, almost every component of the machine is detachable which makes it easier for transportation.

5.6 Summary

The study of this project result takes a very thorough look at the systems components and its functioning. After completion it was found that the project was successful and produces a workable output. The objective of the project was to develop a model that can support disabled upper hand as well proper movement. The goal of the project is to reduce disability problem from the society as much as possible. As the model itself is very compact and very easily transportable, it won't be an overreach to say that goals of this project are very much achieved.

Chapter 6

CONCLUSION

6.1 Summary of the Findings

Mother Nature provides the humans with an environment to live. But disability problem courses human life badly. One of the major disability problems are hand upper limb disability and the hand is a part of the body that we need to use our daily life. So, the only way to tackle this problem is to make an exoskeleton that not only support hand but as maintain the movement of hand.

6.2 Novelty of the Work

The goal of this research is to create an exoskeleton that not only supports the hand but also keeps it moving. Although the project's concept is not entirely original, its methodology is. There are some biomedical firms that make exoskeletons for various body parts in some industrialized nations across the world. Even though they produce a lot, the producing procedure requires some powerful machinery.

In this research, force sensing is used to create a movement exoskeleton as well as an upper hand. Being able to assist others in overcoming their limitation makes the project itself a novel work. The project consumes very low power to run and it is completely detachable parts – first of its type. The costing of the project is also preferable. Additionally, this model is compact, durable, universal design.

6.3 Cultural and Societal Factors and their Impacts

The project is based with keeping the cultural and social situation of Bangladesh. Since Bangladesh is a developing country and the biggest import of the country is petroleum and oil. But in the recent days, the biomedical sector is growing very fast and this major sector of the country is facing decline as the country doesn’t have any industry to support the sector with raw materials. This project can support even in a small scale this large sector by producing medical equipment.

Bangladesh is a heavily populated country. due to this reason, the unemployment rate of the country is also high. This project can create a new sector by introducing machines for startups so that the unemployment rate of the country can go down.

Their environmental effect of this project must be mentioned as the project tackles the environmental pollution problem head on. The disability problem is very huge in this country and by implementing this project disability can be solved even if by a small scale.

6.4 Cultural and Societal Factors Considered in Design

Innovation of new technologies makes our lives easier and creates a better environment for us to live on. This project introduces a completely new design of an exoskeleton model to tackle the disability problem. The exoskeleton model design is much more compact compared to the existing technologies. This makes the machine more suitable for startups which is very much important in a country like Bangladesh that has a high unemployment rate.

The project is also designed in such a way that every major parts of the machine is detachable. This makes the machine easy to transport. The costing of the machine is also very low so that it can be reached to everyone.

6.5 Proposed Professional Engineering Solution

In order to design this project, it is necessary to have advance level metal hardware skills. The mechanical part of the project was mostly done in the workshop. Then, it is necessary to understand advance level circuit implementation to create the entire electrical connection. And lastly, it is important to have knowledge about the FSR sensor so that accident can be avoided.

6.6 Limitations of the work

Although the project is successful, it is not without limitations. The metal frame that is used in the model is needed to be less heavy. But unfortunately, the weight of the metal frame was not achieved. Two different models are used for controlling elbow and upper hand. The prototype is not water resistance and there is no feedback mechanism to ensure the speed of the arm rotation. Additionally, the FSR sensor also has some limitations.

6.7 Future Scopes

Development of an exoskeleton could be a very promising machine with lots of scopes to further development. As the project has the potential to help the disabled human, it is very much possible that in near it is going to the biggest biomedical industry.

The machine as it is now, can only move the upper hand. But with further improvements, it is possible to create an entire system that will be capable to control different parts of body.

- more sensors can be introduced to get better performance
- a single exoskeleton model can be made for controlling both elbow and upper arm
- carbon fiber can be used to make prototype light weight
- better gear motor-based actuator can give more stable outcome

6.8 Standard requirements and Ethical Concerns

The project was completed with the utmost regard for any ethical issues. Privacy is the primary ethical issue in this situation. Ensuring environmental safety is a moral obligation. Future users of this system will be able to rest easy knowing that everything about it is risk-free. However, this work benefited significantly from a number of other articles included in the reference section. It doesn't harm the environment or the human body. The Faculty of Engineering at American International University-Bangladesh (AIUB) followed the correct safety protocols while completing the project. This project was a reasonable creation and model that the group members' research produced.

6.9 Related Code of Ethics and Standard Requirements

The Code of Ethics basically plays a big special role for all projects. The Code of Ethics has many rules and conditions. This project satisfies all requirements of the Code of Ethics.

- Everyone has an equal right to greatest extended degree of basic liberties, in a way that incompatible with other having the same right.

- Group related project has to do their work properly, and if there any ethical issue, they must be punished.
- If any member of the group steals or discloses any information, they will face consequence.
- For people need to arrange seminar, tv program or writing in newspaper so that they can adopt to new technology.

6.10 Economy, Environment and Sustainability

In order to create a machine that is sustainable in the current economic environment of Bangladesh, it was made sure that the costing of the project doesn't get too high. It can be announced with the greatest pleasure that such a complicated project can be replicated completely with just expending a total of 25,700 BDT. All the components of the project are also available in the local market which makes it very sustainable and easy to repair and duplication.

6.11 Conclusion

A compilation of mechanical and electrical knowledge in a single project gets somewhat complex and that is exactly what has been done in this project. The metal frame was constructed via advanced hardware workshop and the electrical connections were done successfully because of the knowledge provided throughout many courses of Electrical and Electronic Engineering. The project not only provides a solution of the disability problem by introducing a comparatively new method of exoskeleton, it also creates a new startup sector for the unemployed of the country. In order to complete the project, extensive research was done to gain knowledge about the project and the mechanism of the workings. A comprehensive study based on the hardware and simulation was done to understand the process. and finally, the machine is successful in producing a workable output while achieving the goals and objective of the project.

The project aimed to create and implement exoskeleton for Upper Limb of a partially paralyzed patient. This exoskeleton will give the disabled hand a motion. After implementing the exoskeleton both elbow and the upper hand can move properly. By introducing a more effective programming approach data can be utilized more efficiently. The main focus of the following development will be on improving the performance of the system and increasing the device's degree of freedom

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Appendix A

Source Code for Arduino Pro:

```
int Mpin1=D5;
int Mpin2=D6;
int Mpin3=D7;
int Mpin4=D8;

int trig=D0;
int fsr1;
int fsr2;

void setup()
{
Serial.begin(9600);
pinMode(A0,INPUT);

pinMode(Mpin1,OUTPUT);
pinMode(Mpin2,OUTPUT);
pinMode(Mpin3,OUTPUT);
pinMode(Mpin4,OUTPUT);

pinMode(trig,OUTPUT);



}

void loop()
{
digitalWrite(trig,HIGH);
delay(50);
fsr1=analogRead(A0);
delay(50);
fsr1=analogRead(A0);
delay(50);

digitalWrite(trig,LOW);
delay(50);
fsr2=analogRead(A0);
delay(50);
```

```
fsr2=analogRead(A0);
delay(50);


Serial.print("FSR 1: ");
Serial.println(fsr1);
Serial.print("FSR 2: ");
Serial.println(fsr2);



if(fsr1>=100 && fsr1<=800)
{
digitalWrite(Mpin1,HIGH);
digitalWrite(Mpin2,LOW);

}

else if(fsr1>=801 && fsr1<=1024)
{
digitalWrite(Mpin1,LOW);
digitalWrite(Mpin2,HIGH);

}

else
{
digitalWrite(Mpin1,LOW);
digitalWrite(Mpin2,LOW);
}


if(fsr2>=100 && fsr2<=800)
{
digitalWrite(Mpin3,HIGH);
digitalWrite(Mpin4,LOW);

}

else if(fsr2>=801 && fsr2<=1024)
{
```

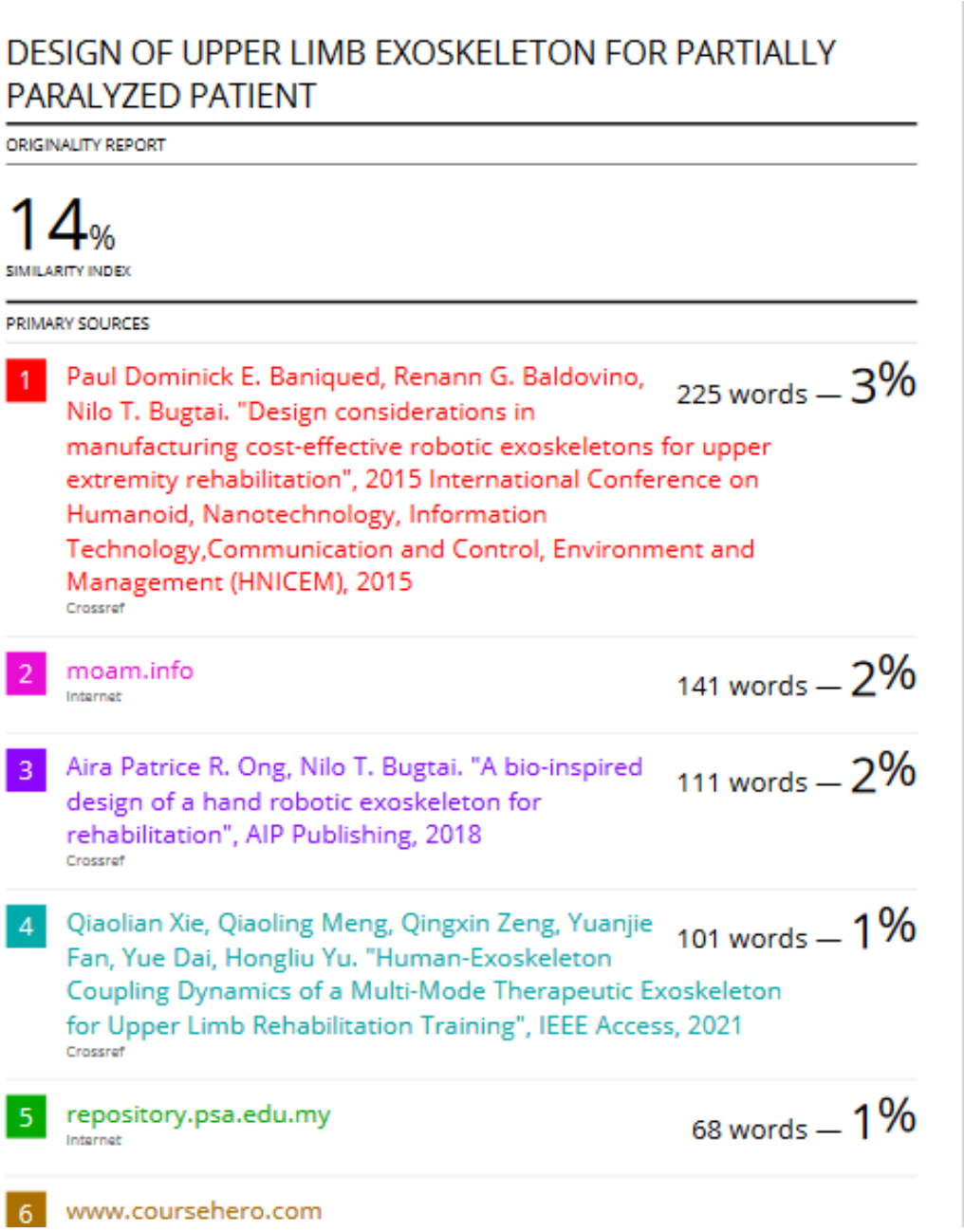
```
digitalWrite(Mpin3,LOW);
digitalWrite(Mpin4,HIGH);

}

else
{
digitalWrite(Mpin3,LOW);
digitalWrite(Mpin4,LOW);
}

}
```

Appendix B



DESIGN OF UPPER LIMB EXOSKELETON FOR PARTIALLY PARALYZED PATIENT

ORIGINALITY REPORT

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PRIMARY SOURCES

1	Paul Dominick E. Baniqued, Renann G. Baldovino, Nilo T. Bugtai. "Design considerations in manufacturing cost-effective robotic exoskeletons for upper extremity rehabilitation", 2015 International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM), 2015 Crossref	225 words — 3%
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