RAFIK HARIRI UNIVERSITY

THE WORKSHOP CHAIR

Done by

RAWAN GHALAYINI

ABDALLAH KAISSI

KHALED ZAATARI

MOHAMAD SAYDEH

Submitted to

DR. HASSAN HARIRI

DR. NADIM DAIB

This senior project submitted in partial fulfillment of the requirements of the
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MECHREF-LEBANON

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Abdallah Kaissi (2011 - 0243)

Khaled Zaatari (2015 - 0041)

Mohammad Saydeh (2014 - 0148)

Rawan Ghlayini (2015 - 0298)

ACKNOWLEDGEMENT

This letter is to give appreciation to all of those who contributed and supported us through-out the Summative Learning Project. Starting with the instructor of the group Dr. Hasan Hariri, all instructors at RHU, especially Dr. Nadim Diab, we would like to thank you for lightening our way towards exploring the future.

Finally, we dedicate this book and our success to our beloved parents who were the major support for us and are the ones who raised us to become better thinkers and performers in the society.

ABSTRACT

This book describes a human controlled workshop chair that relies on Mechatronics Engineering to offer physically disabled people self-mobility. With its sitting, sleeping, standing and leaning postures, it will help increase independence and flexibility for persons who are unable to walk. This chair will provide disabled people especially men job opportunities mainly in the industrial and automotive fields.

The workshop chair consists mainly of three parts: the seat with its back mechanically changing form sitting to sleeping positions; second the scissors mechanism which is the most important part of the chair for its changing in the different positions with balance; and finally the last part including the wheels of the chair where they elongate or collapse to have stable center of gravity

This book describes procedure of building up the workshop chair including full description of system's design and calculations.

TABLE OF CONTENTS

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LIST OF FIGURES

LIST OF TABLES

TIME PLAN

	Task	Deadline	Status
Fall 2018	Literature Review	Week 10	Completed
	Design draft of the system	Week 7	Completed
	Primary stress analysis	Week 13	Completed
	SLP Report 1	Week 16	Completed
	SLP Presentation 1	Week 16	Completed
Spring 2019	Final system design	Week 2	Completed
	Calculation of mechanical properties for the large scale system	Week 8	Completed
	Material selection	Week 10	Completed
	3D printing of parts	Week 6	Completed
	Buying electric components	Week 8	Completed
	Assembly and electric installation	Week 10	Completed
	Progress Report	Week 9	Completed
	Progress Presentation	Week 9	Completed
	Optimization of mechanical and electrical work	Week 12	Incomplete
	Programming the system	Week 13	Completed
	Testing and Tuning	Week 15	Completed
	SLP Report 2	Week 17	Completed
	SLP Presentation 2	Week 17	Completed

Table 1 - Time Plan Table

CHAPTER 1

INTRODUCTION

1.1 – Background Information

Although modern science and technology helped extremely enhance the life style of normal people; yet, there are special groups who have not been able to develop their daily life [1]. On particular, handicapped people with physical disabilities are still living a pathetic life. These people living with disabilities deserve a long lasting developed solution to empower them and to remove all the barriers which prevent them participating in their communities; getting a quality education, finding decent work, and having their voices heard [2]. Therefore, the wheelchair is an essential assisted vehicle for handicapped people to move from one place to another and participate in social activities [3].

The tendency to associate society increased the demands for the wheelchair are more and more [1]. Hence, the standing up [4], sleeping [5], leaning forward [6] and multi-function [7] wheelchairs are made up to satisfy the physically disabled person's need. Figures. 1(a) to 1(d) show the wheelchairs with sitting, standing, leaning and sleeping positions.

Figure 1 Functional wheelchairs

The present network is organizing the height of wheelchair's usefulness and mechanical structure [8]. Wheelchairs have wide assorted variety styles in the present market. Steel, aluminum and lightweight strong are the basic materials utilized in the assembling of wheelchairs. Wheelchairs are likewise named either physically operable wheelchairs or electrical controlled wheelchairs [9].

These days, the primary spotlight is on standing wheelchairs [10]. On the off chance that the tolerant client needs to achieve a higher spot or move from wheelchair to another sit in somewhere else, the individual in question will experience a standing up procedure. Along these lines, a standing wheelchair will help their development.

We discovered a few kinds of standing wheelchairs on the Internet, one was the mechanical wheelchair that interest for an arm power while the standing movement [10]. Another we found is the electrical wheelchair, a further developed kind of wheelchairs. However, it doesn't have brilliant structures for remaining; thus, it executes a complex controlling framework in the seat [11]. Besides, we figure all wheelchairs with standing component don't look for individuals' ordinary standing stances.

Along these lines, we need to plan our own standing wheelchair to tackle such issues. We need to consolidate mechanical and electrical parts in our wheelchair to improve the standing wheelchair.

1.2 – Motivation

Because of the expansion of the maturing populace and the increment in interminable wellbeing conditions, for example, cardiovascular maladies, malignant growth and emotional well-being issue coming about because of wars or atmosphere changes, more than one billion people the world over live with some type of inability with whom almost 200 million experience trouble in working [2].

Over the world, individuals with inabilities have less fortunate wellbeing results, lower instruction accomplishments, less financial investment and higher rates of neediness than individuals without incapacities [2]. This is mostly in light of the fact that individuals with handicaps experience boundaries in getting to administrations that a considerable lot of us have long underestimated, including wellbeing, instruction, work, and transport just as data [12].

As per LPHU's insights: 15% of the Lebanese populace live with incapacities. 140,000 people out of the 900,000 crippled has physical disfigurement and utilize the wheelchair for development. An examination was directed on an example of 200 incapacitated individuals matured somewhere in the range of 14 and 40 years. The examination brought about astonishing discoveries were just 91 people out of the 200 were working, 23 of them worked in their field of study, for incredibly low wages and without the assurance of wellbeing and retirement protection [13].

1.3 – Project Aim

We aim to build an automatic mechanical wheelchair with several seating positions to help certain class of handicapped people work in industrial workshops. In this way, we are providing these people job opportunities in which they can build up their lives.

The wheelchair we built has designing structures that can achieve a natural human standing posture. Then, we worked on calculating required power to change the form of the wheelchair operational part. Finally, we attained the design of the controlling system to monitor the motion of the wheelchair. The main design constraints to be taken into consideration in this work are a low-cost, easy to assembled/manufactured, safe-functioning and light weight chair.

Main contribution of this thesis is to design a new mechanical structure. The wheelchair can reform automatically and support the physically disabled technician standing up and leaning over the workshop table. The different positioning of the workshop chair fit the normal human postures. To do so, we had first to consider the wheelchair as a rigid body and study its forward kinematic motion using the joint variables of the links.

CHAPTER 2

PROJECT OVERVIEW

2.1 – Problem Statement

The workshop chair is a personal positioning device uniquely designed for lifting and lowering the human body for work under and around virtually anything. This chair is designed especially for physically disabled millennials who would like to work in industrial and automation fields. Hence, this chair will create job opportunities that will offer them better life styles.

2.2 – Project Description

Repairing a vehicle needs several operations for a technician in different places on different altitudes. Sometimes, the technician needs to lean down a car to inspect and repair. Other times he needs to be standing or sitting to repair the engine for example.

Getting to these 3 positions was never an easy task for a technician especially when he is disabled. This brings us to think, how can we design a wheel chair that can make the disabled technician sit, stand, and lean while operating on a vehicle?

Here is where we contribute, our project is to design a chair that can let the disabled technician to freely move in all positions and directions using a bar mechanism mounted on an electronically controlled rolling wheels.

The system is composed of a set of subsystems; each has its own functionality. The system is multi-disciplinary it has mechanical subsystems, electrical subsystems, and control subsystems.

- The mechanical subsystem will be responsible to handle the weight of the individual, as well as perform the "scissor mechanism" for lifting. In addition, the variation of the center of the gravity depends on the extension of the base to ensure that the individual will not tip upon standing and tilting. The back support will be adjustable; In order to fulfill the basic positions in this project, the back support should be flexible and be adjusted to a certain angle in which comfort can be provided for the user.
- The electrical subsystem are the set of actuators and sensors (if present). The actuators can be divided into 2 parts in this project. The first part is the linear actuator, which is responsible to adjust the back support for the system, perform the scissor mechanism, and adjust the base to variate the center of gravity. The other part is the regular motors which is responsible for motion. The motors are to be controlled using 2 set of analog joysticks. One joy stick is used to control movement, and the other is used to adjust the positions. A button will be used to adjust to a position directly, where multiple actuators will function at once.
- The control subsystems will be using the Arduino Micro-Controller to control the system, and manage to adjust the inputs (joystick and buttons) and the outputs (actuators) to ensure smooth motion and stability for the system.

CHAPTER 3

STANDING MECHANSIM DESIGN

3.1 – Standing Mechanisms

According to Tianxiang Mo, Yufeng Sun and Yonghao Yang, they summarized 2 different types of standing wheelchair mechanisms as follow:

3.1.1 - Standing wheelchair using the principle of folding chairs

For patients be able to stand up, turning the seat up in order to push up is the least demanding and generally utilized arrangement. It is seen that rotatable seat is in all respects generally connected to one sort of seat in our everyday life. That is the lawn seat. Be that as it may, the majority of the lawn seats turn on the backwards bearing and its legs will get shut while collapsing the seat. So turning around the heading turned into the issue to unravel and the arrangement is as pursued. This standing seat comprises of four principle parts including the base, situate, back and handrail. The base is a flat board with four seat legs or four wheels whenever utilized as wheel seat. The seat is pivoted at the front of the base board, with the goal that the seat part can be turned on the base. The back is pivoted at the back of base board. There are two bars stretch out from the base of the back part. Poles are functioning as a pole of the sleeves of the handrail part. Clearly, the back part will pivot if torque connected on the poles. The handrails are pivoted at both side of the base. One side of the handrail is a half-circle which is simpler for pushing. On the opposite side, a sleeve is introduced. These sleeves are gathered to fit the bars of the back part. To play out a standing movement, it has a few stages. To start with, drive the handrail forward. The sleeve will turn then again and drive the bars of the back pivot. The back pivots and pushes up the seat. Seat slide on the outside of the back. The movement of the seat and the back will fit the standing conduct.

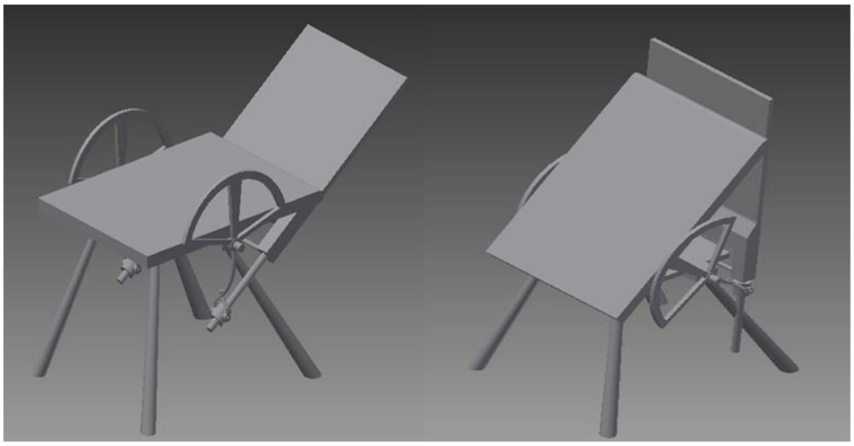


Figure 2 - Standing wheelchair using the principle of folding chairs

3.1.2 - Standing wheelchair using hydraulic control system

Compared with other ordinary mechanic structural control standing wheelchair, the key word has been changed from “push” to “support”. If the wheelchair was so designed that the chair pushes the patients up, then the gravity will always be the obstacles to overcome. One way to make gravity our friends instead of foes is to create a new concept which different from moving the central gravity point up to make patients stand up. So this solution was to make the seat rotate down slowly so as to put patient’s foot on the ground and they can stand naturally. By doing so, we need only to consider about how to lift the patients upper body up. Lifting up things vertical is much simpler. What's more, the gravity would be the power supply to work the whole system. It is also much easier to restore the wheelchair to sitting condition because after the patients stand up all we need to lift up is the weight of the seat which is not too much contrasted to human's weight. The main part of this solution is the damping system, shown in Figure 3. It decreases the speed of patient to get down with the seat. So it may have two properties. First, control the speed of flow in a certain interval. Second, this damp only happens in the working process. No resistance in the restore process.

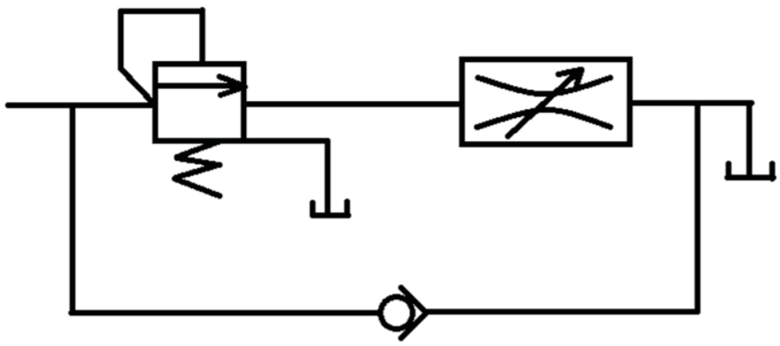


Figure 3 - Standing wheelchair using hydraulic control system

3.2 – Scissors Mechanism

Hence, already designed mechanisms of wheelchairs pay much attention on the movement of the back. In the sitting position, it is 90° between the seat and back or maybe a little bit larger than that to make person sit more comfortable. While standing, the back cannot be always perpendicular to the seat. It need to, at least at final standing position, be vertical and then the patients can stand up. To solve this problem, variety of solution has been designed, like a series of connecting rods and electrical control the back. There is a simpler structure to solve this by using the scissors mechanism.

CHAPTER 4

CHAIR’S DESIGN

4.1 – Chair’s Targeted Postures

For the patient to have full flexibility while working under or over a machine or a vehicle, he/she needs to have an active wheelchair. The workshop chair, hence, replicates human postures in sitting, sleeping, standing and leaning over. Figures 4 (a-d) demonstrate CAD drawings for our designed workshop chair in the different positions mentioned. Note that in the standing and leaning positions, the center of gravity will still be located between the front and back wheels.

Figure 4 (a) - Sitting

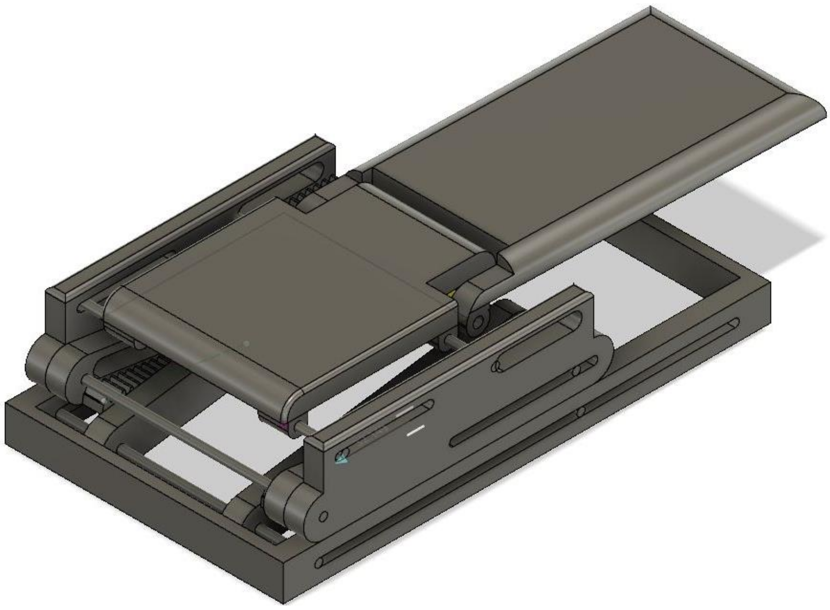


Figure 5 (b) - Sleeping

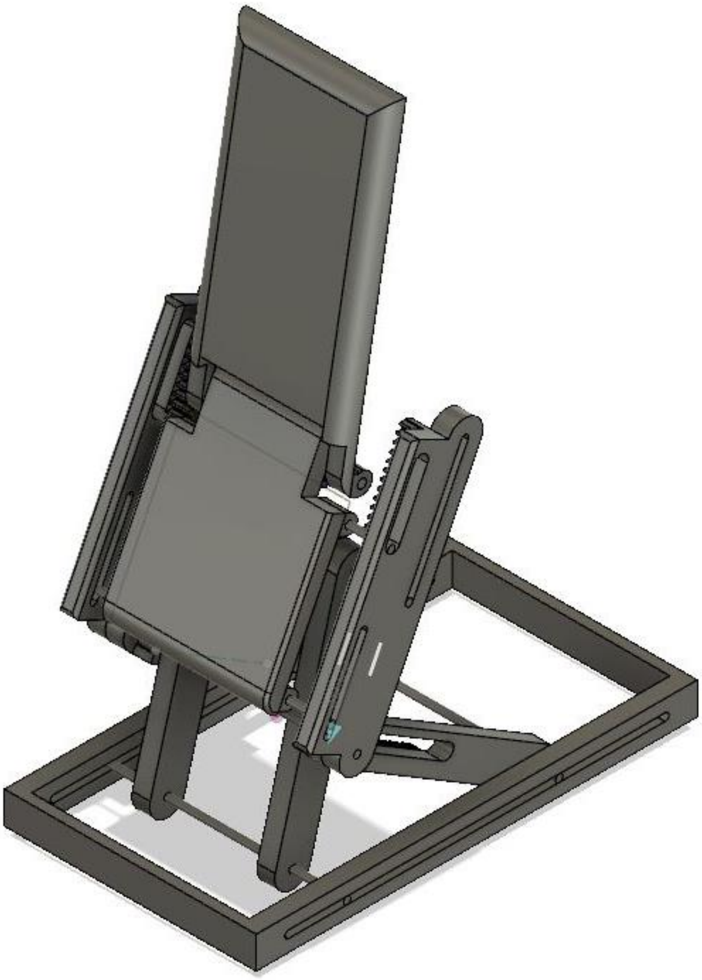


Figure 6 (c) - Standing

Figure 7 (d) - Leaning

4.2 – Chair's dimension according to human proportions

4.2.1 – Human's Proportion

Through designing the chassis of the chair, we thought of the patient's comfort while using it. Therefore, we chose the dimensions of the chair according to the human fit, or what is known as anthropometric measurements.

Anthropometry is the science that estimates the scope of body sizes in a populace. When structuring our item, recall that individuals come in numerous sizes and shapes.

As per Allsteel Inc. Ergonomics Reference Guide, anthropometric measurements for every populace are positioned by size and portrayed as percentiles. Usually practice to plan for the fifth percentile (5th%) female to the 95th percentile (95th%) male. The 5th% female incentive for a specific measurement (for example sitting stature) more often than not speaks to the littlest estimation for plan in a populace. On the other hand, a 95th% male esteem may speak to the biggest measurement for which one is planning. The 5th% to 95th% territory suits roughly 90% of the populace. To plan for a bigger part of the populace, one may utilize the range from the 1st% female to the 99th% male. Figure 1 indicates examinations of percentile guys and females.

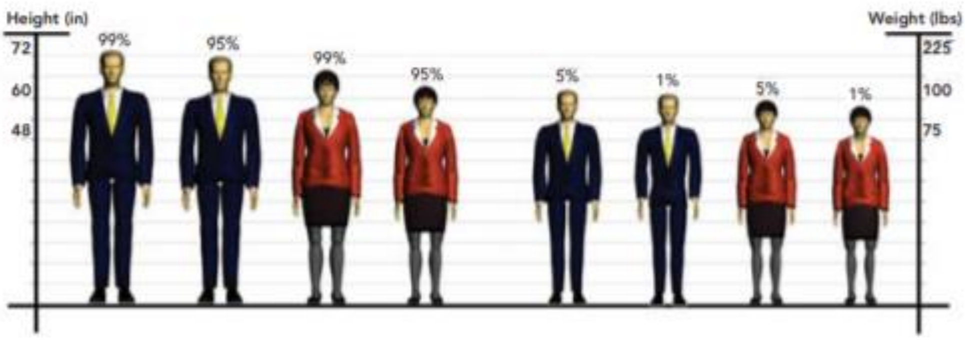


Figure 5- The relative sized of different percentile humans

Data in anthropometric databases may represent static dimensions, such as “lower leg length” or functional dimensions such as “reach.” Figure 2 and Table 1 show common ranges of measurements used in office furniture design.

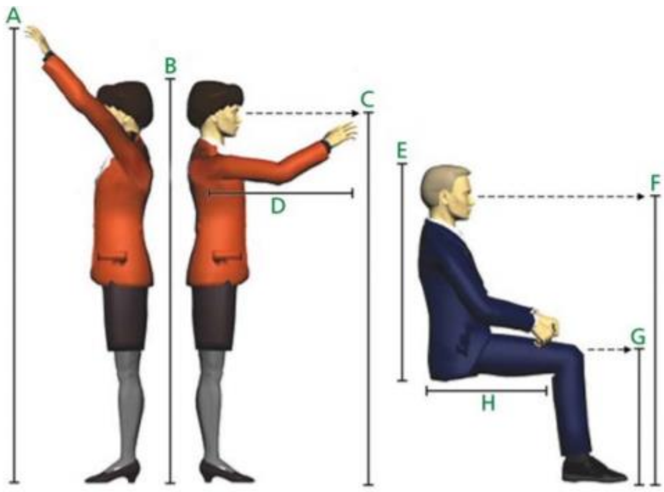


Figure 6 - Posture measurements

Measurement	Letter	Female	Male
Standing Overhead Reach	A	74.9″ – 86.8″	81.2″ – 93.7″
Standing Height	B	60.2″ – 68.4″	64.8″ – 73.5″
Standing Eye Height	C	56.9″ – 65.0″	61.4″ – 69.8″
Standing Forward Reach	D	30.8″ – 36.1″	33.8″ – 39.5″
Sitting Height	E	31.3″ – 35.8″	33.6″ – 38.3″
Sitting Eye Height	F	42.6″ – 48.8″	46.3″ – 52.6″
Sitting Knee Height	G	19.8″ – 23.2″	21.4″ – 25.0″
Seat Depth	H	16.9″ – 20.4″	17.7″ – 21.1″

Table 2 - Anthropometric measurements

4.2.2 – Chair's Dimensions

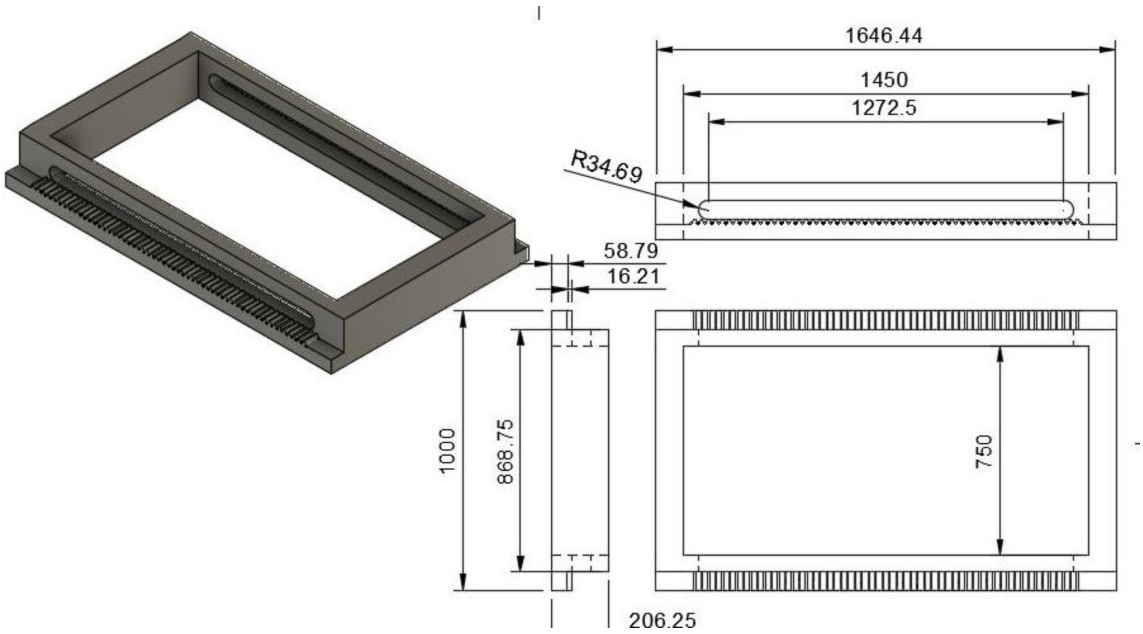


Figure 7 – Base

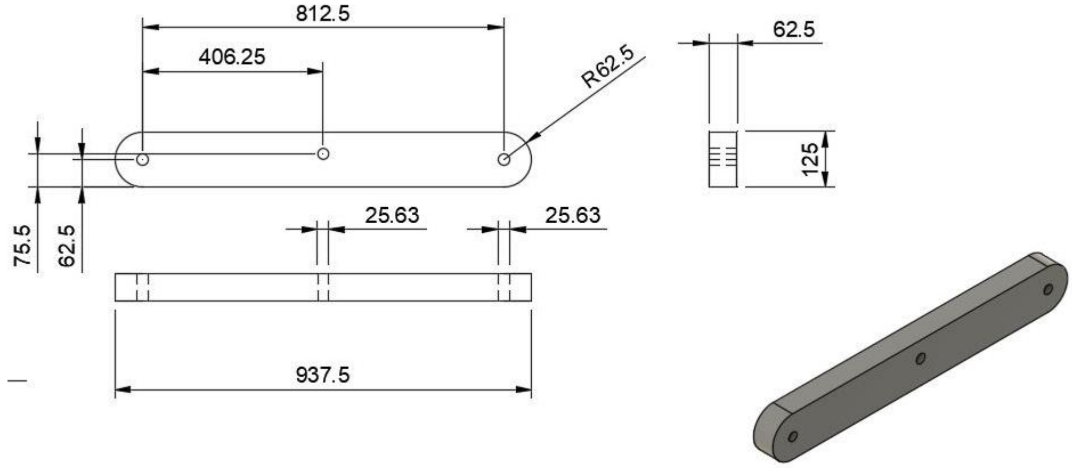


Figure 8 - Beam

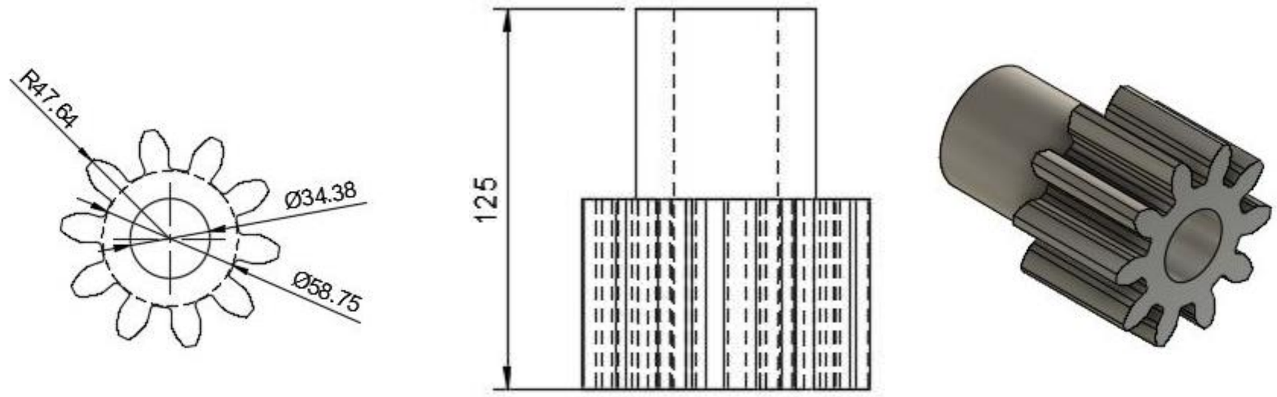


Figure 9 – Gear

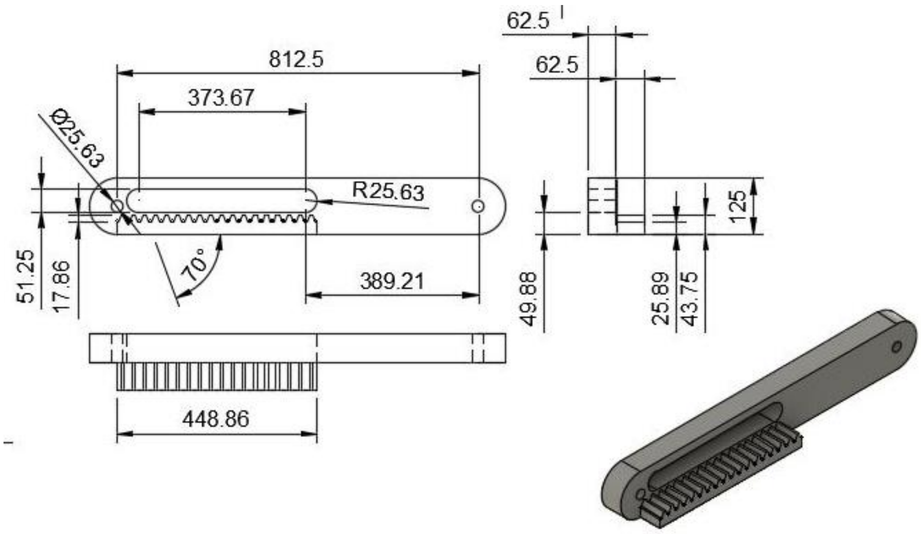


Figure 10 - Racked beam

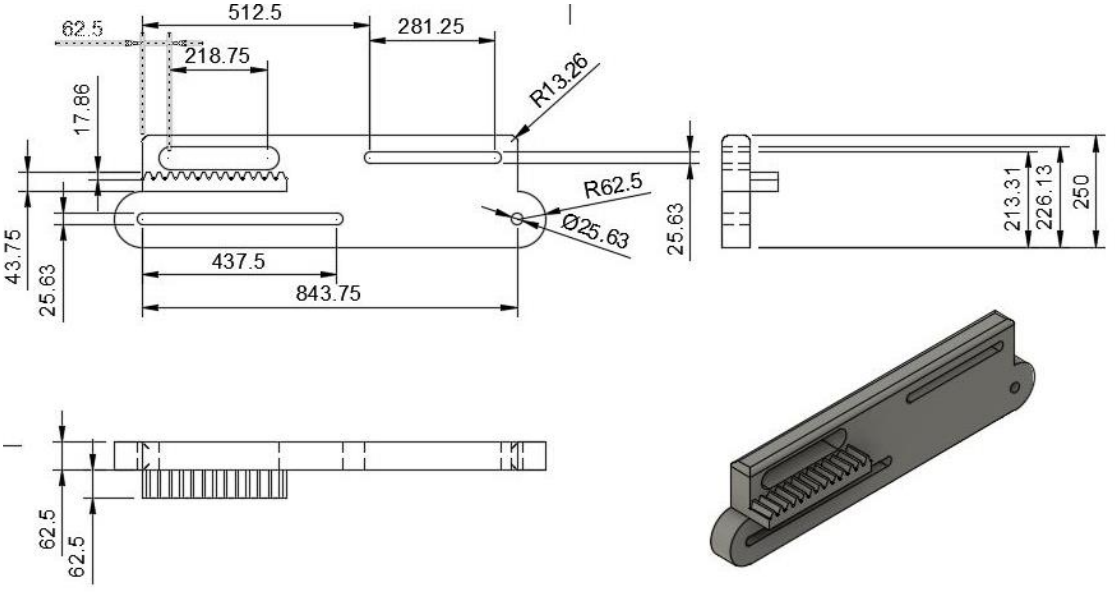


Figure 11 - Seat Frame

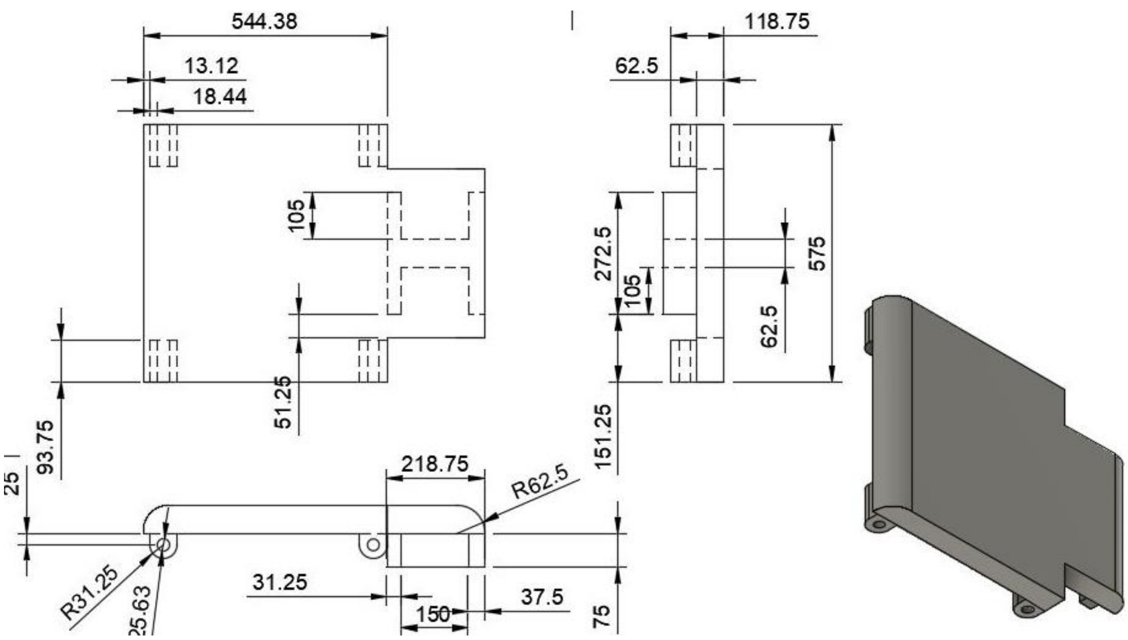


Figure 12 - Seat

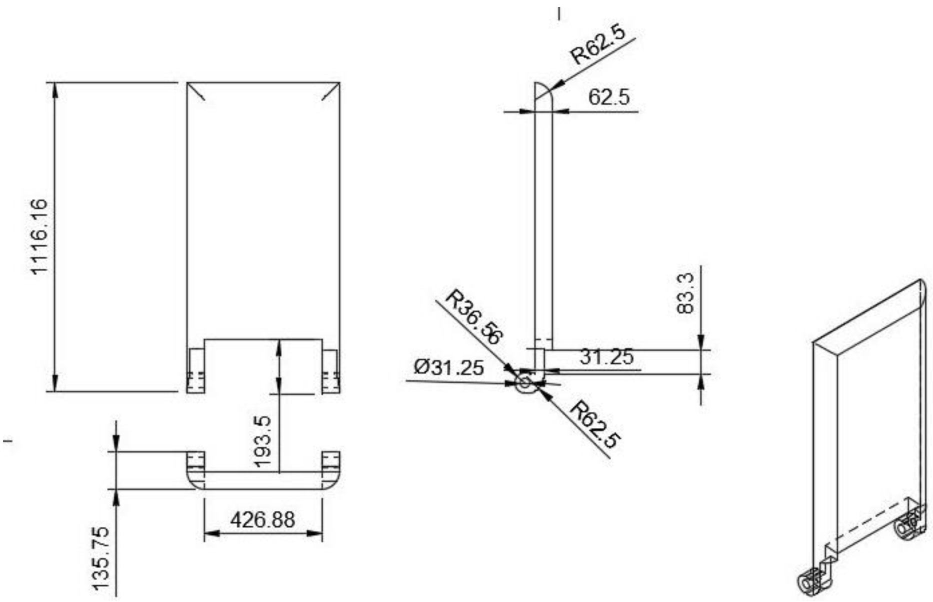


Figure 13 - Back

CHAPTER 5

MECHANICAL DESIGN

5.1 – Stress Analysis

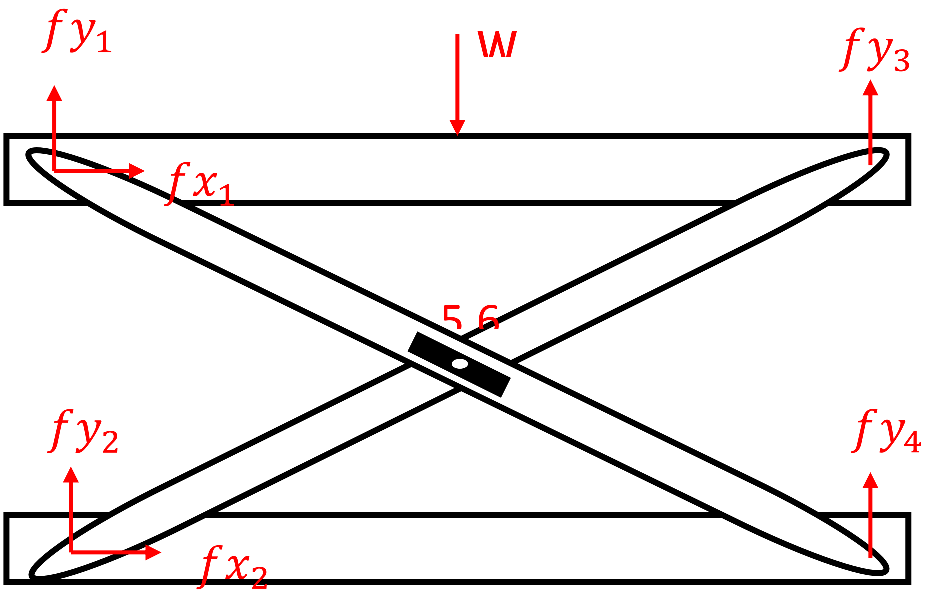


Figure 14 - Free body diagram of scissors mechanism

Consider the whole chair as one rigid body knowing that:

- Points 1, 2, 3 and 4 (points) are rollers (gear)
- 1 and 2 motors are DC braked
- 3 and 4 can move
- W is the weight of the user

Starting from

$$\sum Fx = 0$$

Then, $fx_1 = fx_2$

$$\sum Fy_1 = 0$$

And, $fy_1 + fy_2 + fy_3 + fy_4 - W = 0$

But assuming $fy_1 = fy_2 = fy_3 = fy_4$

Then, $\frac{W}{4} = fy_1 = fy_2 = fy_3 = fy_4$

Now, consider only one of the scissors links,

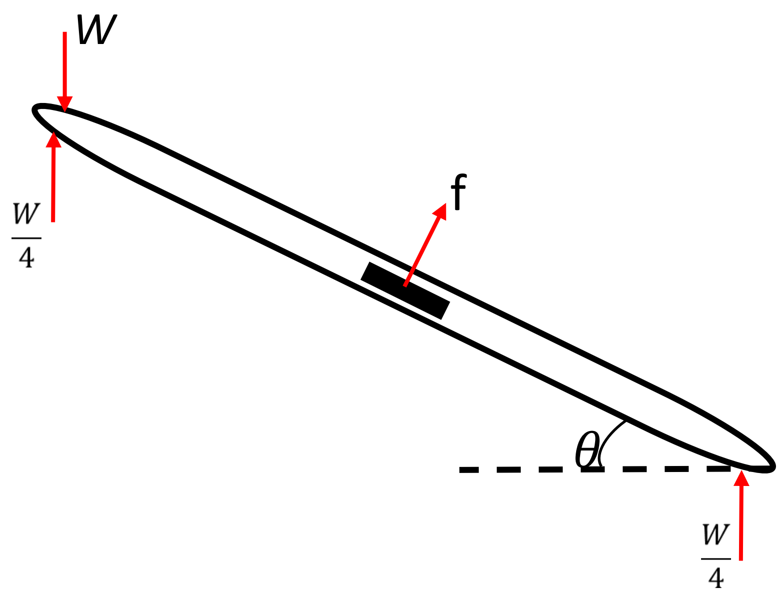


Figure 15 - free body diagram of beam and prismatic joint

Along x-axis, $\sum Fx = 0$

$$fp_x sin\theta + f sin\theta + fp_y cos\theta = 0$$

$$\sum Fy = 0$$

$$-fp_x cos\theta + f cos\theta + fp_y sin\theta = 0$$

Yields a system of 2 equations with 2 unknowns to find the reaction forces of fp_x & fp_y

Along y-axis, $$\sum Fy = 0$$

$$f cos\theta + \frac{W}{4} + \frac{W}{4} - W = 0$$

Assuming θ will be determined to fit a normal sitting state

$$f = \frac{\frac{w}{2}}{cos\theta}$$ Implies the reaction force of the prismatic

5.2 – Fatigue Failure Analysis

$$R_1 = R_2 = \frac{W}{4} = \frac{300 \times 9.81}{4} = 735.35\ N$$

Cut at A

$$\sigma_A = -\frac{My}{I} = -\frac{(735.35 \times 0.5cos70)(\frac{0.125}{2})}{\frac{1}{12} \times 300 \times 1^2} = -0.31\ Pa$$

$$\sigma_{max} = k_f \times \sigma_A = 1.7\ \times -0.31 = -0.527\ Pa$$

From property graphs of aluminum, it is found that $S_{ut} = 758.5\ Pa$

$$S_e = k_a k_b k_c k_d k_e S_{e'} = 190\ Pa$$

Since $\sigma_{max} \ll S_e\ \rightarrow N = infinity$

5.3 – Chair's chassis material selection

After drawing the chair on Fusion 360, we experimented different material for the model to choose the best one with the lightest weight and least safety factor.

The material analysis results were as follows:

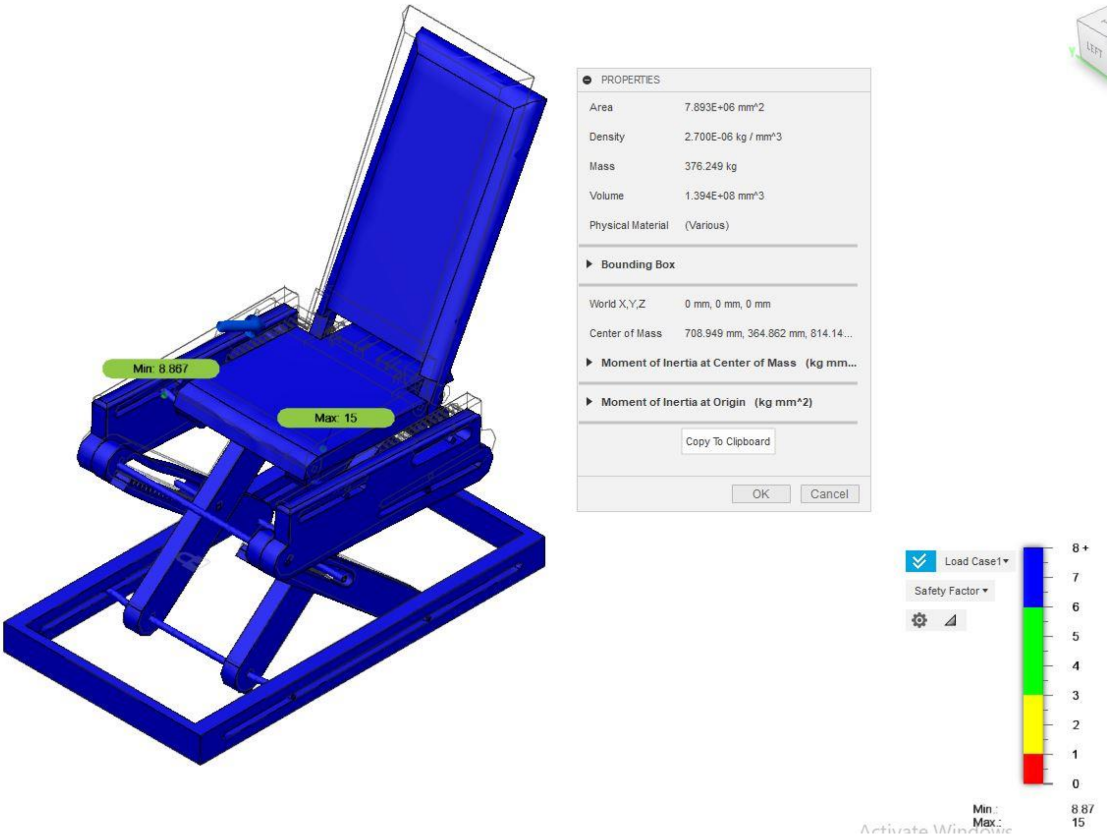


Figure 16 - Safety factors of aluminum chair in sitting position

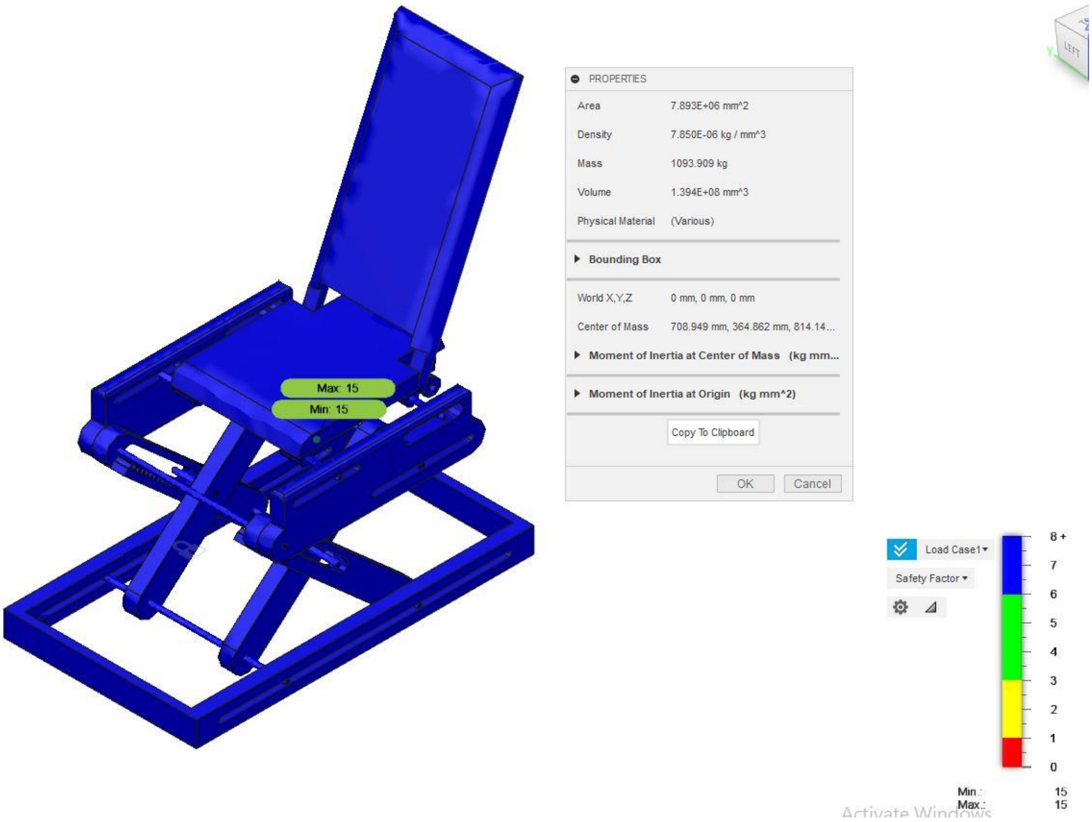


Figure 17 - Safety factors of steel chair in sitting position

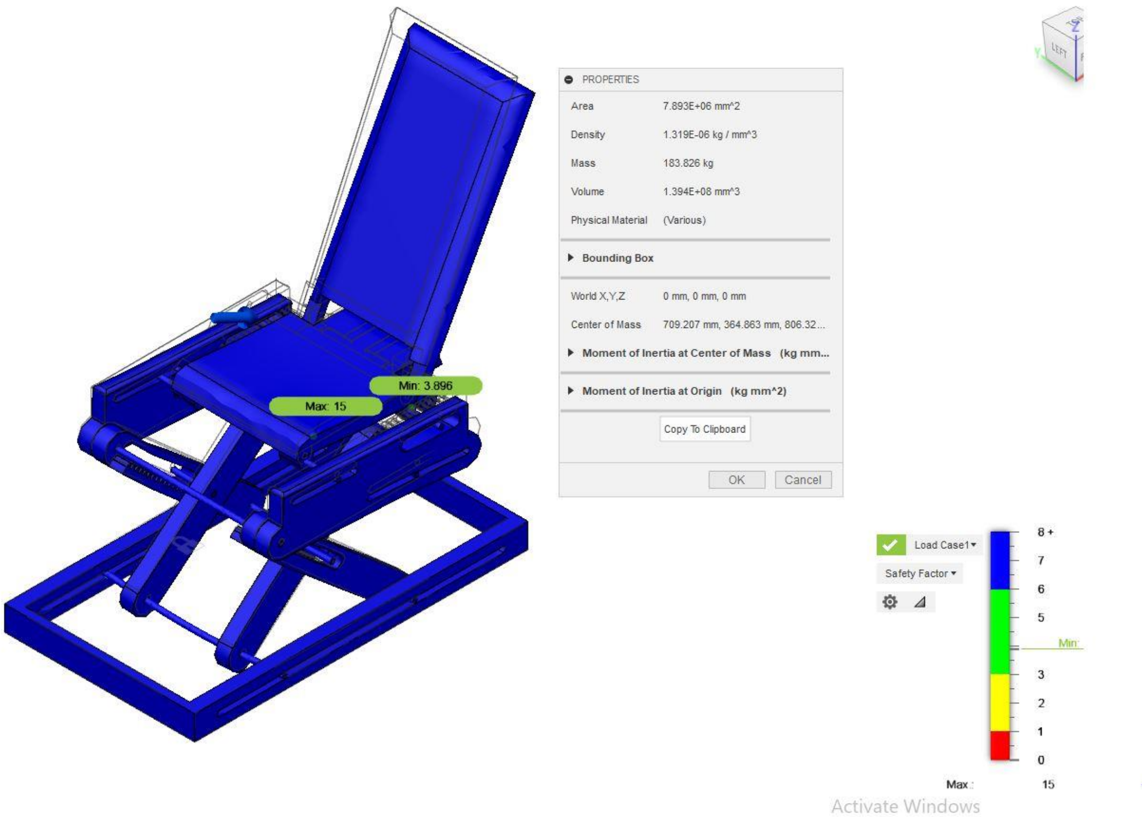


Figure 18 - Safety factors of plastic chair in sitting position

Hence, after studying each material in different position, we chose plastic material for our chair’s chassis since it has the lowest minimum safety factor.

CHAPTER 6

ACTUATORS

6.1 – Degrees of Freedom

The mechanism of the workshop chair is divided into 3 parts, the back part with the seat slider, the scissors mechanism with the base and the wheels.

We calculated the degrees of freedom of our mechanism to know the maximum number of motors that can be used to operate the chair.

Therefore, according to Gruebler's formula applied on a 3D body,

$$DOF = 6(N - 1 - J) + \sum_{i=1}^{J} f_i$$

We had the first part, the back with seat slider having 1 DOF, the scissors mechanism having 3DOF and finally the wheels having 2 DOF for forward and backward motion.

Hence, we can conclude that we will need to use a maximum of 6 motors in total.

6.2 – Wheel's Torque

In order to know what motors should we use for our mechanism, we have first to calculate the torque needed for the wheels.

This is the case where the wheelchair will be in the sitting position, thus, the weight will be distributed uniformly on the chair. And as mentioned before, the patient's mass is assumed to be 120 kg, the maximum mass the mechanism can handle.

The wheelchair will have a total mass of 180 kg that will be considered in the following calculations

Then, we start by

$$m_{total} = 120 + 180 = 300\ kg$$

$$W = m_{total}\ \times g = 2{,}943\ N$$

$$\frac{W}{4} = 735.75\ N$$

Hence, the force in the y-direction will be $f_{fr} =\ \mu_s\ N = 0.8\ \times 735.75 = 588.6\ N$

The equation of torque is given by $T = I.\alpha = F.r.sin\theta$

Since the wheelchair is in sitting position, then angle between the back and the seat will be $\theta = 90°, then\ sin\theta = 1$

$\therefore T = 600\ \times r\ N.m$ where r is the radius of the wheel.

6.3 – Rack and Pinion Torque of Seat

In the following sections, we will use the following equation of the torque

$Torque\ = \frac{Force \times pitch\ distance}{2}$ where the force will be multiplied by the safety factor in order not to stick for a single sitting position of the patient, and the pitch distance of the gear is obtained from the dimensions in figure 9 which is as follows:

$$d = \frac{58.75}{2} + \frac{1}{2}\left(47.64 - \frac{58.75}{2}\right) = 38.4\ mm = 0.0384\ m$$

In this part, we will consider that standing position will be the critical position.

In the y-direction,

$$\sum f_y = 0 \rightarrow F = W = 120 \times 9.81 = 1177.2\ N$$

Using the equation of torque for rack and pinion,

$$T = \frac{F \times d}{2} = \frac{2(1177.2) \times 0.0384}{2} = 45.2\ N.m$$

6.4 – Rack and Pinion Torque of Scissors

The critical point of the scissors mechanism will be when the 2 rods are perpendicular, then the angle with the base is $\theta = 45°$.

The rack and pinion will be holding a total mass of 120kg + 40 kg which is the mass of the patient's body and part of the chair having the critical point.

As shown in the free body diagram below, we have the following summation of forces in the y-direction

$$-W + \frac{W}{4} + \frac{W}{4} + F sin45 = 0$$

Then, $F sin45 = \frac{W}{2} = \frac{(120+40)(9.81)}{2} = 784.8$

$$F = 1110\ N$$

$$\therefore T = \frac{F \times d}{2} = \frac{2(1110) \times 0.0384}{2} = 42.624\ N.m$$

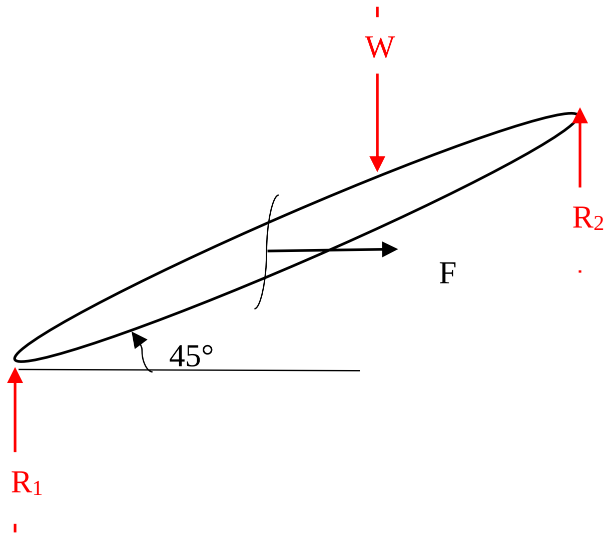


Figure 19 - Free body diagram of scissors mechanism in critical position

6.5 – Rack and Pinion Torque of Base

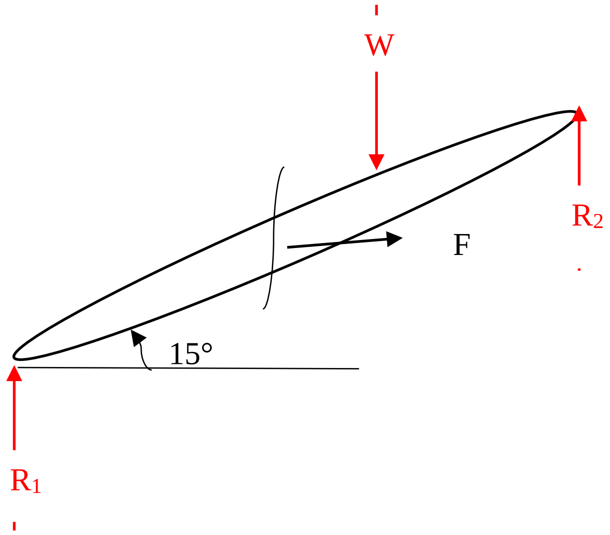


Figure 20 - Free body diagram of base in critical position

$$-W + \frac{W}{4} + \frac{W}{4} + Fsin15 = 0$$

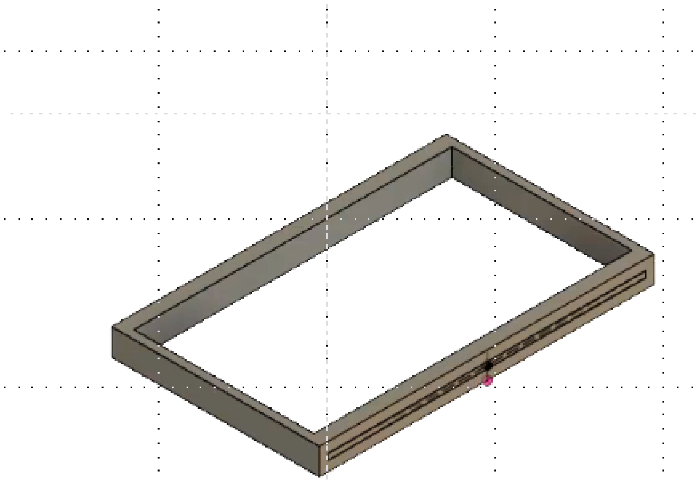
Then, $Fsin15 = \frac{W}{2} = \frac{(120+180)(9.81)}{2} = 1471.5\ N$

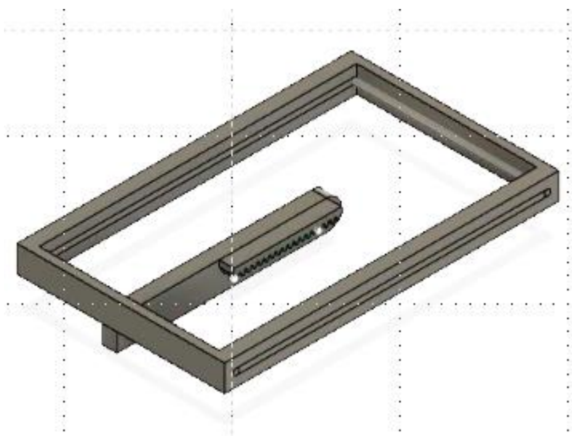
$$F = 5685.44\ N$$

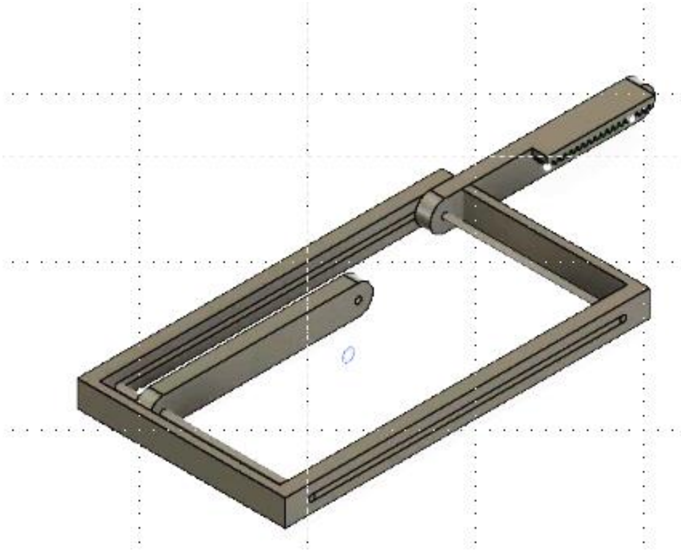
$$\therefore T = \frac{F \times d}{2} = \frac{2(5685.44) \times 0.0384}{2}$$
$$= 218.32\ N.m$$

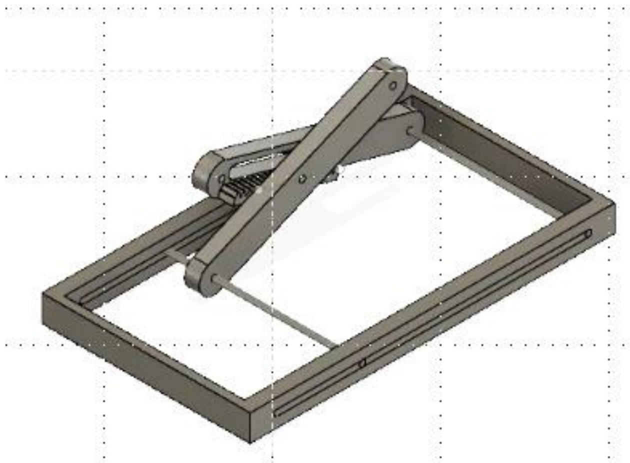
CHAPTER 7

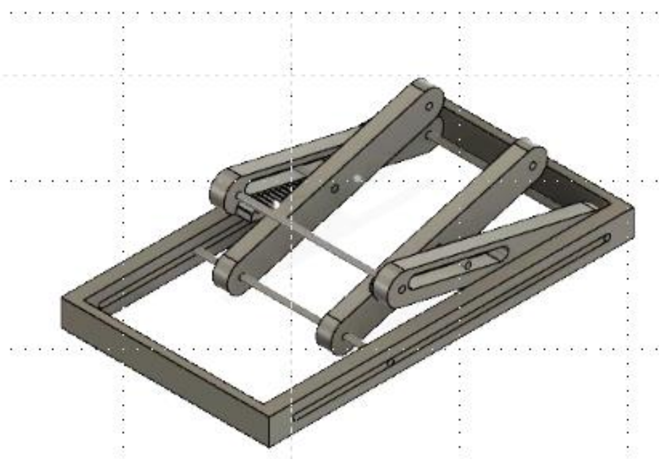
CHAIR'S ASSEMBLY

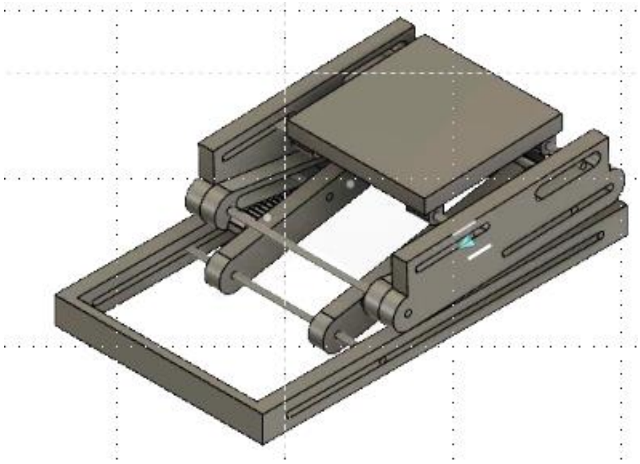


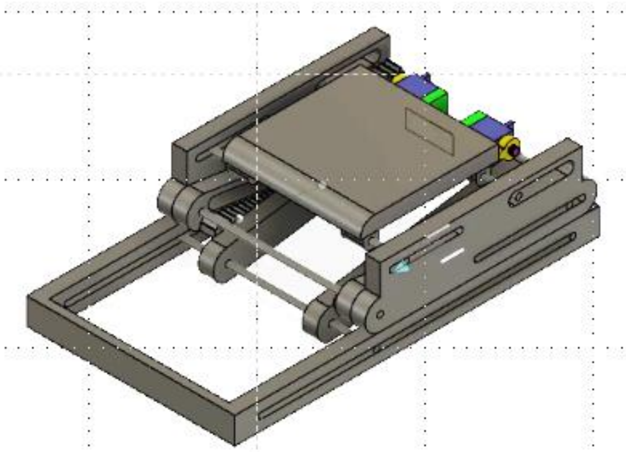


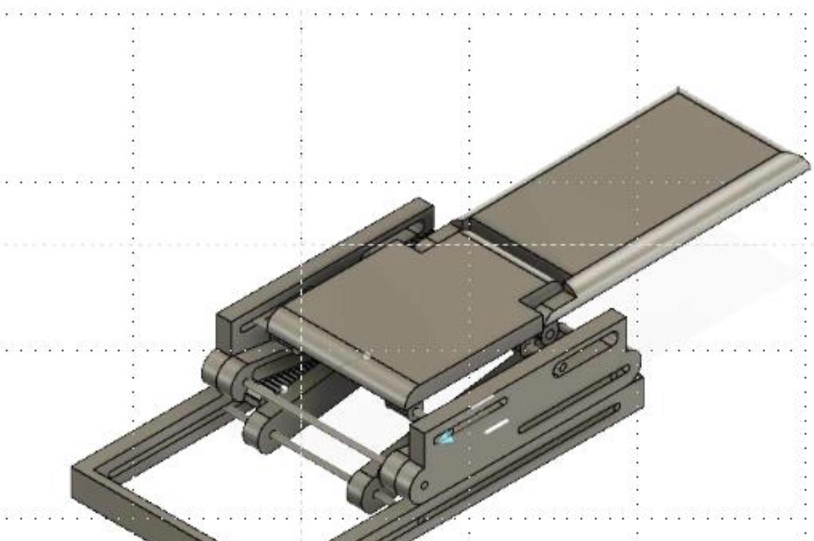


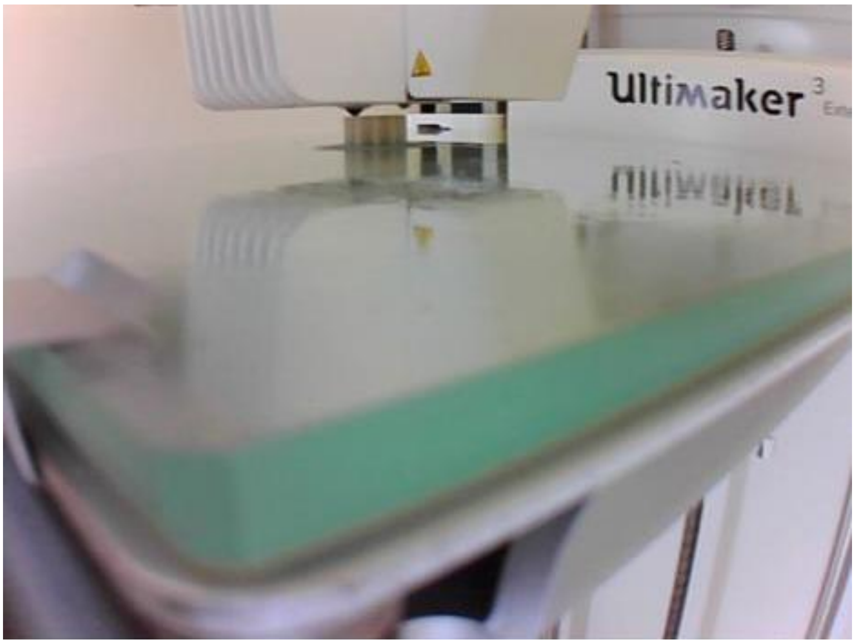











Ultimaker
3

CHAPTER 8

CONTROL

8.1 – Components

In order to construct our prototype, we need materials that thier functionality are described below:

Arduino Mega, Arduino is a microcontroller that will be controlling the entire system. since our project requires lots of inputs and outputs, the Mega model is used. It has 54 digital pins of which 12 are PWM. It operates at 5V and the chipset is ATmega2560.

Keypad, which will be serving as the interface between the user and the controller to extract commands. The keypad used has 16 push buttons. 2 are assigned to control the elevation of the chair. Other 2 are assigned to control the seating position. 2 are assigned for tilting the back seating. 2 are assigned to control the base. 2 for horizontal adjustment.

Geared DC motors, these motors are used to establish the commands sent by the keypads to control movement and adjust position. The number of these geared motors used in the prototype are 4 motors.

Servo motors. These motors are of 9-gram type and are used to adjust the tilting angle of the back seating. The number of servo motors used are 2 motors.

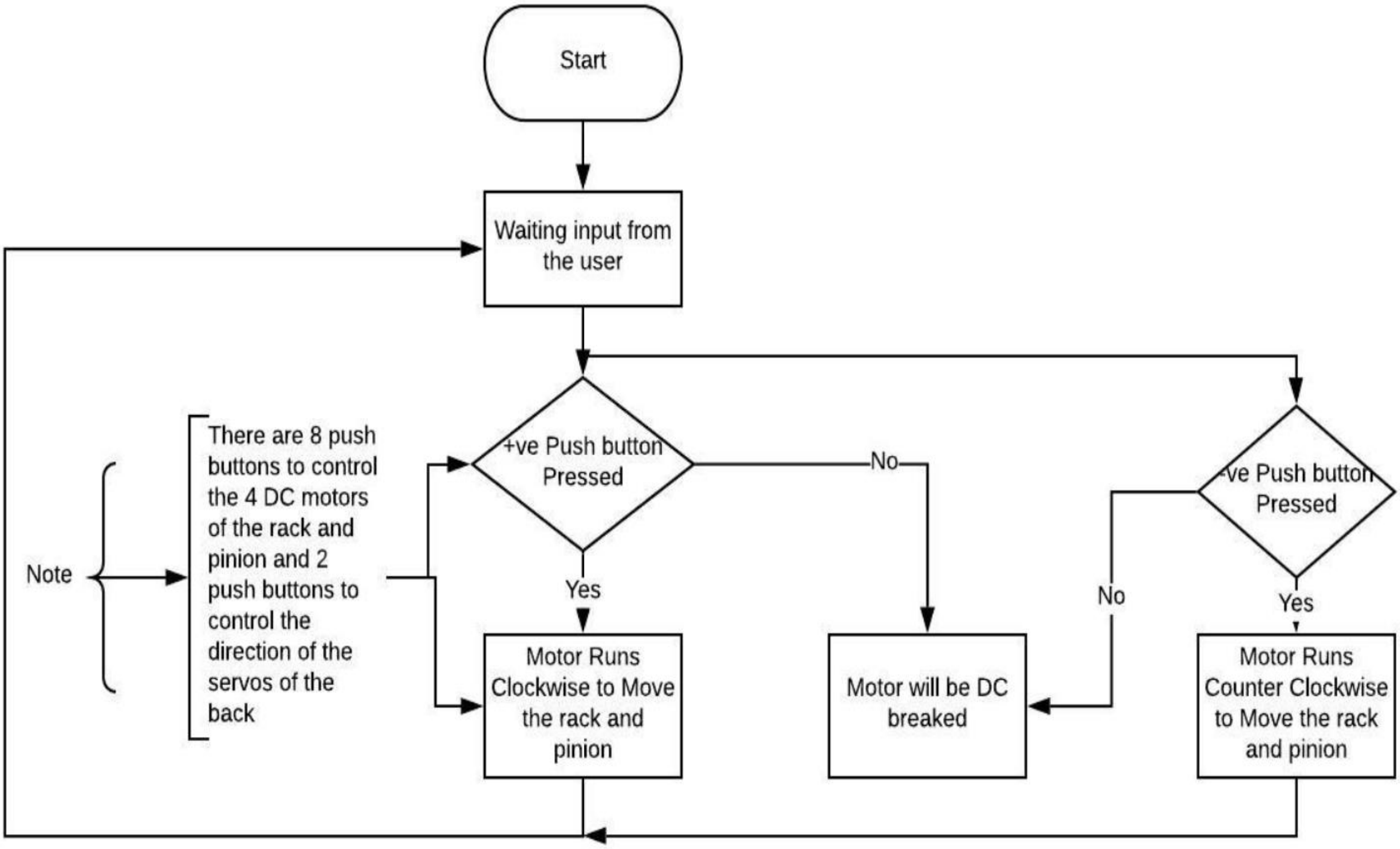
Motor Drivers, these drivers are used to control the DC geared motors and allow them to switch rotating position (Backward and Forward).

Pulleys and timing belts, these are used to synchronize the motion of both sides of the chair using the same motor. 5 of 6.25mm opening and 5 of 4mm opening.

8.2 – Program Flowchart

In the below figure, the programming of the workshop chair is summarized in the flowchart.

The code is found in Appendix E.



CHAPTER 9

SAFETY

When it comes to any engineering design, safety is the top priority. Our workshop chair will take care of the following safety measures to reduce the accidents to minimal while using it.

Center of Gravity

The workshop chair will be used by different body sizes and weights. Thus, we made a design that ensures safety for anybody on the chair even if the load distribution changes through-out position changing which is a main feature of our design.

Bending

Since the chair needs to perform position changing, the actuators in the model have high torque to ensure the ability of moving the mechanism when loaded. And the speed should not be high to not make it comfort when using it and not disturbing. Also, this limits the possibility of losing control of the mechanism when in motion.

Fall Prevention

The workshop chair will be equipped with safety belts that will ensure the user doesn’t fall during motion and when leaning in standing position. The breaks will also be designed to break smoothly to prevent any sudden force that might lead the chair to lose balance and tip. The wheels will also be slippage resistance from water, oil, or any other liquid during work.

Motor Failure

This section is not yet implemented in our system. However, for future progress, in case the motor of the scissor mechanism failed, the system will contain electrical locks that will keep the user in position until assistance from others to mount off the chair.

CHAPTER 10

CONCLUSION AND RECOMMENDATIONS

Building this workshop chair was a very technically rich experience even though we did a small scale prototype. It helped enrich our practical skills that are complementary to the theoretical knowledge in the robotics and mechatronics domain.

The workshop chair is an electric controlled chair for mechanics that are disabled or aging. It has a mechanism that will ensure freedom working on a vehicle by 3 main positions (sleeping, sitting and standing). This chair is controlled by a keypad on the side to move the wheels in all positions, and control position changing. The design was implemented on a small-scale prototype which has shown it is efficient to construct on a larger scale in the future. The safety measures and factors taken prove that the system is feasible and ready for manufacturing and testing on large-scale.

The workshop chair t defines the true meaning of mechatronics, which is to create and invent a new easier reachable applicable way to a task that was very complicated, hazardous and very expansive in means of currency and lives.

Also, we learned that what must be kept in mind and considered first is the need of the end user. So we develop a relation between mechanisms, electronics and the control process through programming and software engineering in order that the most appropriate model of wheelchair that meets people's specific needs can be provided.

The work demonstrated in this report is not final and subject to change. This is a proof of concept project with calculations and design for the real system. The real system might require modification after manufacturing and testing.

After all, engineering is the technique and the skill that enabled us to improve our way of thinking and moving from a scratching theoretical point of view to a designed and assembled prototype. The workshop chair team is dedicated to deliver a high-quality product providing a solution for a better community.

APPENDIX A

ADDRESSING STUDENT OUTCOMES' KPIs

	How was it addressed in the SLP	**Where was it addressed in the SLP**
a. An ability to apply knowledge of mathematics, science, and engineering.		
a.1 An ability to apply knowledge of Mathematics		
a.2 An ability to apply knowledge of Science	Chair's material analysis	Section 5.3
a.3 An ability to apply knowledge of Engineering	Modeling our chair And applying static and dynamic analysis	Chapter 5 Chapter 6
b. An ability to design and conduct experiments, as well as to analyze and interpret data		
b.1 An ability to design experiments	Drawing 3D model of the chair. Sketching free body diagrams to analyze motion of chair.	Chapter 5 Chapter 6 Chapter 7
b.2 An ability to conduct experiments	Coding and optimizing operation..............................	Chapter 8
b.3 An ability to analyze and interpret data	Testing different materials on chair to choose the best Torque analysis to choose the right motors for operation	Section 5.3 Chapter 6
c. An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability		
c.1 Design a system/component of a system or a process to meet specific engineering constraints	Chair's assembly	Chapter 7

c.2 Modify a system/component of a system or a process to adhere to applicable economic, environmental, safety and sustainability constrains	Tuning of program the user will have the whole control of the chair and change its position as he/she wishes	Chapter 8 Appendix E
d. An ability to function on multidisciplinary teams		
d.1 Ability to plan and organize multidisciplinary team tasks collectively	Members were working synchronously, where each had his own task properly mentioned in time table and meeting minutes	Time table Appendix C
d.2 Ability to carry out tasks assigned by a team	Distributed tasks were clear and each member worked on what he is best at	Appendix C
e. An ability to identify, formulate, and solve engineering problems		
e.1 Pinpoint the existence of an engineering problem	Other standing wheelchair mechanisms	Chapter 3
e.2 Ability to model an engineering problem	Static and dynamic modeling of the chair's motion	Chapter 5 Chapter 6
e.3 Ability to justify a solution to an engineering problem	Results of material selection and motors selection	Section 5.3 Section 8.1
f. An understanding of professional and ethical responsibility		
f.1 Differentiate between ethical/unethical behaviors using applicable engineering code of ethics	According to the ASME Code of Ethics - Canon 1, engineers shall hold paramount the safety of public throughout performing his job; for this, the patient will have full control of mechanism and a seat belt will be added	Chapter 9
f.2 Differentiate between professional and unprofessional behaviors		
g. An ability to communicate effectively		
g.1 Ability to write a well-structured formal report/technical document that addresses an assigned task	Submitting several technical reports, progress reports, and meetings' minutes to the advisers and jury	Progress Report SLPI, SLPI Final Report, Progress Report SLPII, SLPII Final Report, and

		Minutes (Appendix C
g.2 Ability to deliver a well-structured formal presentation that addresses an assigned task	Delivering several formal presentations throughout the SLP Project in front of the advisors and the assigned jury.	SLPI Final Presentation, SLPII Progress Presentation, and SLPII Final Presentation
h. The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context		
h.1 Identify global, economic, environmental, and societal impact of implementing engineering solutions	The workshop chair helps create job opportunities for handicapped people	Section 1.2
h.2 Explain global, economic, environmental, and societal impact of implementing engineering solutions	Project overview	Chapter 2
i. A recognition of the need for, and an ability to engage in life-long learning		
i.1 Recognize the need to engage in life-long learning	Attending the workshops and Career guidance seminars organized by the MME department;	Appendix D
i.2 Ability to engage in life-long learning through participation in workshops, seminars, and extracurricular activities	Team members have attended several seminars and participated in extracurricular activities in an act of engagement in life-long learning; Successfully learning Fusion 360 which is not covered in MECA curriculum and implementing them in the project	Chapter 7 Appendix D
j. A knowledge of contemporary issues		
j.1 Ability to identify and discuss contemporary issues	Until our present days, standing mechanisms and self-positioning wheelchairs are under study and development	Section 1.1 Chapter 3
k. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice		

k.1 Identify necessary techniques, skills, tools of modern engineering practice to solve a problem at hand		
k.2 Apply appropriate techniques, skills, tools of modern engineering practice to a problem at hand	The use of new manufacturing technology, 3D printing to print our mechanism’s parts	Chapter 7

APPENDIX B

DYNAMIC STRESS ANALYSIS

$$\sum \vec{F} = m\vec{a}$$

$$F - B\dot{x} = m\ddot{x}$$

$$F = B\dot{x} + m\ddot{x}$$

Using Laplace

$$F = ms^2x + Bsx$$

$$\frac{F}{x} = ms^2 + Bs$$

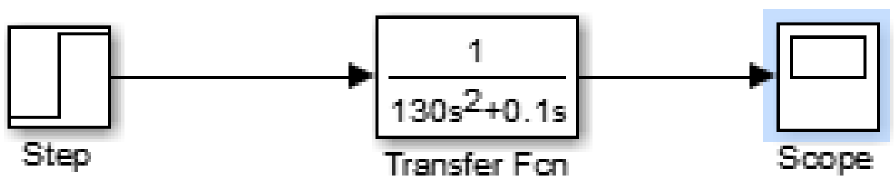
$$\frac{x}{F} = \frac{1}{ms^2 + Bs}$$

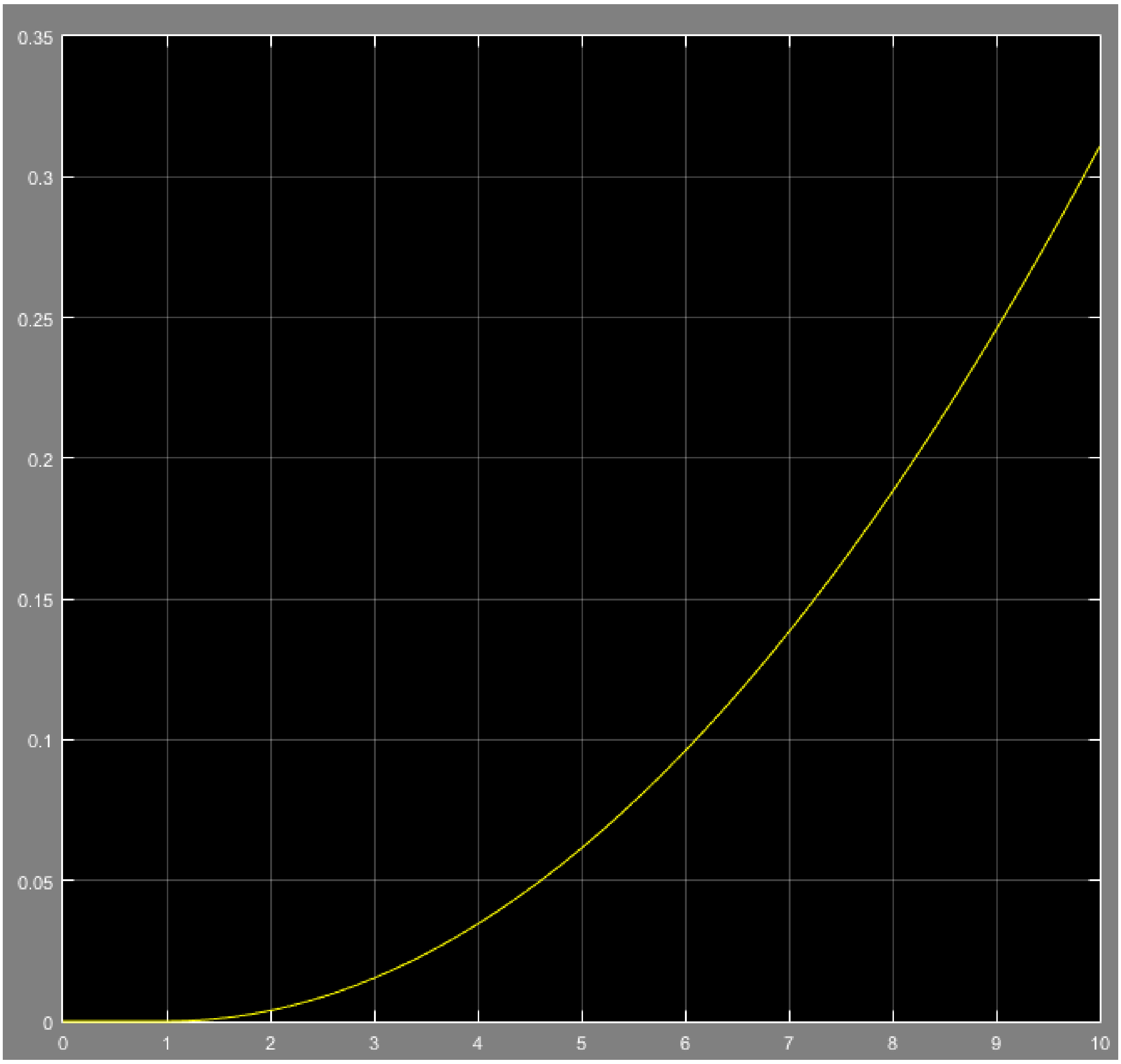
Assuming F is a step function

Then,

$$x = \frac{1}{ms^2 + Bs}$$

In the below figures, we can see the scissors mechanism Simulink block and its output displacement.




0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
1
2
3
4
5
6
7
8
9
10

APPENDIX C

COSTS AND EXPENSES

Item	Real Scale	Price	Small Scale	Price
Scissor motors x2	13KN/50cm Linear actuator	$ 400	1300N/5cm Linear actuator	$ 100
Seat+ lower fixture motors x3	1200N/40cm Linear actuator	$ 150	120N/4cm Linear actuator	$ 120
Inner scissor pin motors x2	1500N/50cm Linear actuator	$ 160	150N/5cm Linear actuator	$ 90
Movement(wheels) X2	High torque dc motors	$ 200	DC Motors	$ 60
Back adjustment motors	TBA	TBA	TBA	TBA
Chassis material	Aluminum links and sheets	$ 100-200	Filaments for the 3d printer	$ 20-40
Labor for chassis work(CNC machining for large scale or 3d printing for small scale)		$ 200-400	3D Printed	$ 0.00
Control and electrical work	Arduino Mega +relays(2 per motor) +transistors	$ 100	Arduino Mega +motor drivers(1 per 2 motors)	$ 70-80
TOTAL		**$ 1330-1630**		**$ 470-500**

APPENDIX D

MEETING MINUTES

The Workshop Chair
Meeting Minutes

Meeting Purpose:	*Keeping up with the SLP progress work*
Meeting Date:	*Wednesday, January 30, 2019*
Meeting Time:	*1:00 pm*
Meeting Location:	*Meeting room – RHU MME department*
Meeting Facilitator:	*Dr. Hassan Hariri*
Attendees:	*Abdallah Kaissi, Khaled Zaatari, Mohamad Saydeh, Rawan Ghalayini*
Minutes Issued By:	*Rawan Ghalayini*

Next Steps:
CAD drawings of the system
Stress analysis for the big scale system
Updating the SLP report and powerpoint presentation

Discussion:

- *Calculated the DOF for the part of the system where the person will be sitting (with the changing of the sitting positions) and it was found 4*
- *Specified each part of the system how many motors it requires:*
  - *Back system: 1 motor*
  - *Scissors + base: 3 motors*
    (total of 4 motors which means that our DOF calculation is correct)
  - *Wheels (for forward and backward movement): 2 motors*
    Hence we will need 6 motors in total
- *Discussed the requirements and constraints for large scale chair design*
- *For the small scale chair, we agreed on 3D printing the parts for its low cost, precision and flexibility.*
- *For the report, we received the following feedback*
  - *Add time plan of the work progress during the semester*
  - *Move the cost table to appendix*
  - *Include the meeting minutes*
  - *Write about the outcome and things been learned while working on the project*

The Workshop Chair
Meeting Minutes

Meeting Purpose:	*Keeping up with the SLP progress work*
Meeting Date:	*Monday, February 11, 2019*
Meeting Time:	*1:00 pm*
Meeting Location:	*Meeting room – RHU MME department*
Meeting Facilitator:	*Dr. Hassan Hariri*
Attendees:	*Abdallah Kaissi, Khaled Zaatari, Mohamad Saydeh, Rawan Ghalayini*
Minutes Issued By:	*Rawan Ghalayini*

Next Steps:
Finalizing drawings of the system
Signing up in Lira
Updating the SLP report and powerpoint presentation

Discussion:

- The parts are being drawn on Fusion 360 instead of SolidWorks because it is more flexible with 3D printer.
- The problem in SolidWorks that we have it as a cracked version on our laptops so we don't have the libraries and we don't have time to sit in the university lab.
- We need to research about the mechanisms we are using
- We need to specifying the load in order to choose the motors' power then doing static and dynamic analysis

APPENDIX E

CAREER GUIDANCE SEMINARS

The department of Mechanical and Mechatronics Engineering at Rafik Hariri University had organized, in collaboration with the American Society of Mechanical Engineers Student Branch (ASME) at RHU a series of seminars focused on introducing students in general, and graduating students in particular, to the career life of an engineer, responsibilities to hold in an industry, and obstacles he/she might face in the work place, in an act to prepare the students to their career after graduation as engineers. Moreover, each seminar had an RHU alumna as a guest speaker, who shared with the attendees his/her experience in the workplace, and gave several advices based on his/her experience. Our team had attended several seminars of the series in an act to form a preliminary idea about the life as an engineer.

APPENDIX F

CODE

```
#include<Servo.h>
Servo Servoback1;
Servo Servoback2;
int elevationpos = 22;
int elevationneg = 23; // elevation pins 12v of the base opposite motion
int tiltingpos = 24;
int tiltingneg = 25; // 1 base motor grounded, middle 6v motor and 12v motor will move in opposite
direction
int seatpos = 26;
int seatneg = 27; // all motors are grounded 6v top motor will move
int horizontaladjpos = 28;
int horizontaladjneg = 29; // all motors are grounded and bottom motors will move in same direction
int motorlow1pole1 = 2; // positive pole of 12v motor 1 base
int motorlow1pole2 = 3; // negative pole of 12v motor 1 base
int motorlow2pole1 = 4; // positive pole of 12v motor 2 base
int motorlow2pole2 = 5; //negative pole of 12v motor 2 base
int motormidpole1 = 6; // positive pole of 6v mid motor
int motormidpole2 = 7; // negative pole of 6v mid motor
int motorseatpole1 = 8; // positive pole 6v seat motor
int motorseatpole2 = 9; // negative pole 6v seat motor
int x1;// elevation +
int x2;// elevation -
int x3;// tiliting +
int x4;// tilting -
int x5;// seat +
int x6; // seat -
int x7; // horizontal +
int x8; // horizontal -

void setup() {
  // put your setup code here, to run once:

  pinMode(elevationneg, INPUT_PULLUP);
  pinMode(tiltingpos, INPUT_PULLUP);
  pinMode(tiltingneg, INPUT_PULLUP);
  pinMode(seatpos, INPUT_PULLUP);
  pinMode(seatneg, INPUT_PULLUP);
  pinMode(horizontaladjpos, INPUT_PULLUP);
  pinMode(horizontaladjneg, INPUT_PULLUP);
  pinMode(motorlow1pole1, OUTPUT);
  pinMode(motorlow1pole2, OUTPUT);
  pinMode(motorlow2pole1, OUTPUT);
  pinMode(motorlow2pole2, OUTPUT);
  pinMode(motormidpole1, OUTPUT);
  pinMode(motormidpole2, OUTPUT);
  pinMode(motorseatpole1, OUTPUT);
  pinMode(motorseatpole2, OUTPUT);
  Servoback1.attach(12);
  Servoback2.attach(11);
```

```
  Serial.begin(9600);



  Servoback1.write(0);
  Servoback2.write(180);
}

void loop() {

  // iniitialize parameters
  x1 = digitalRead(elevationpos);
  x2 = digitalRead(elevationneg);
  x3 = digitalRead(tiltingpos);
  x4 = digitalRead(tiltingneg);
  x5 = digitalRead(seatpos);
  x6 = digitalRead(seatneg);
  x7 = digitalRead(horizontaladjpos);
  x8 = digitalRead( horizontaladjneg);
  Serial.println(x1);
  delay(100);
  Serial.println(x2);
  delay(100);

  // case 1
  if (x1)
  {

    Motor(255,0,0,0,0,0,0,0);
    Serial.println(x1);
//    analogWrite(motorlow1pole1, 200);
//    analogWrite(motorlow1pole2, 0); // motor 1 bot will move in direction left
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 180); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
    while (x1)
      x1 = digitalRead(elevationpos);

    Motor(0,0,0,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0); // turn of motor1 bot
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0);// turn of motor2 bot
//    analogWrite(motorlow2pole2, 0); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
  }
  // case 1 negative
  else if (x2)
  {
```

```
    Motor(0,200,0,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 200); // motor 1 bot will move in direction left
//    analogWrite(motorlow2pole1, 180);
//    analogWrite(motorlow2pole2, 0); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
    while (x2)
      x2 = digitalRead(elevationneg);

    Motor(0,0,0,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0);
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0);
//    analogWrite(motorlow2pole2, 0); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
  }
  // case 2 positive
  else if (x3)
  {
    Motor(0,0,160,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0); // motor 1 bot will move in direction left
//    analogWrite(motorlow2pole1, 160);
//    analogWrite(motorlow2pole2, 0); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 100); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
    while (x3)
      x3 = digitalRead(tiltingpos);

    Motor(0,0,0,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0);
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0);
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
  }
  //case 2 negative
  else if (x4)
  {
    Motor(0,0,0,160,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0); // motor 1 bot will not move
//    analogWrite(motorlow2pole1, 0);
```

```
//    analogWrite(motorlow2pole2, 160); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 100);
//    analogWrite(motormidpole2, 0); // mid motor is will move to the left
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
    while (x4)
      x4 = digitalRead(tiltingneg);

    Motor(0,0,0,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0);
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0);
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
  }
  // case 3 positive

  else if (x5)
  {
    Motor(0,0,0,0,0,0,100,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0); // motor 1 bot will move in direction left
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 100);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
    while (x5)
      x5 = digitalRead(seatpos);

    Motor(0,0,0,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0);
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0);
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
  }
  // case 3 negative
  else if (x6)
  {
    Motor(0,0,0,0,0,0,0,100);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0); // motor 1 bot will move in direction left
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0); // motor 2 bot will move in direction right
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
```

```
//    analogWrite(motorseatpole2, 100); // seat motor is dc breaked
    while (x6)
      x6 = digitalRead(seatneg);

    Motor(0,0,0,0,0,0,0,0);
//    analogWrite(motorlow1pole1, 0);
//    analogWrite(motorlow1pole2, 0);
//    analogWrite(motorlow2pole1, 0);
//    analogWrite(motorlow2pole2, 0);
//    analogWrite(motormidpole1, 0);
//    analogWrite(motormidpole2, 0); // mid motor is dc breaked
//    analogWrite(motorseatpole1, 0);
//    analogWrite(motorseatpole2, 0); // seat motor is dc breaked
  }
  //case 4 positive
  if(x7)
  {
    Motor(0,0,180,0,0,0,0,0);
     while (x7)

      x7 = digitalRead(horizontaladjpos);

    Motor(0,0,0,0,0,0,0,0);
}
// case 4 negative
  if(x8)
  {
    Motor(0,0,0,180,0,0,0,0);
     while (x8)

      x8 = digitalRead(horizontaladjneg);

    Motor(0,0,0,0,0,0,0,0);
}
else if(digitalRead(53)==HIGH)// push button for servo control+
  {

    myservo1.write(myservo1.read()+1);
    myservo2.write(myservo2.read()-1);// tell servo to go to position in variable 'pos'
    delay(5);
    Serial.println(count);

  }
  //Serial.println("a");
  else if(digitalRead(52))// push button for servo -
  {

    myservo1.write(myservo1.read()-1);
    myservo2.write(myservo2.read()+1);// tell servo to go to position in variable 'pos'
    delay(5);
  }
*/
}

void Motor(int a, int b, int c, int d, int e, int f, int g, int h) {
```

```
  analogWrite(motorlow1pole1, a);
  analogWrite(motorlow1pole2, b); // motor 1 bot will move in direction left if a = 0, b= number to the
left
  analogWrite(motorlow2pole1, c);
  analogWrite(motorlow2pole2, d); // motor 2 bot will move in direction right
  analogWrite(motormidpole1, e);
  analogWrite(motormidpole2, f); // mid motor is dc breaked
  analogWrite(motorseatpole1, g);
  analogWrite(motorseatpole2, h); // seat motor is dc breaked
}
```

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