Exoskeleton Mount

Final Proposal

Team J – Lerner Exoskeleton II

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May.03.2017

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1.0 BACKGROUND

1.1 Introduction

The human exoskeleton has been used for different purposes, including upper body and lower body assistive activities. This project is aimed at improving currently existing exoskeleton designs to come up with a better human-exoskeleton mounting interface for lower limb rehabilitation. The new design will help in improving the general functionality of the health care industry, especially the sector dealing with neuromuscular disorders. The existing design uses a robotic system that includes motors. They work well in providing the required assistance to individuals with neuromuscular disorder. This project seeks to come up with a new exoskeleton design that can perform better compared to the existing designs.

The team seeks to apply different skills and information in developing the new system. There are various requirements and targets the team seeks to attain, including a better functioning model, providing a design that mounts itself in an effective manner to the users' foot, thighs, as well as to the shank, the part from the knee to the ankle. The team will also make the design adjustable and ease to don off and on. The design will be low profile, insert into normal shoes, have reduced irritations, and be strong while at the same time lightweight. In addition, the team will include electric engineering work in order to make the design function better. Through attaining these targets, the team will have met all the needs that the client had indicated.

1.2 Project Description

The client requires that the team comes up with a design that meets specific requirements. The client's needs a design that is light in weight, has minimal irritation to skin, good grip, adjustable, and easy to use. Based on these requirements, the team will come up with the engineering requirements for purpose of providing design and development details. According to the sponsors, "the goal of this project is to design an adjustable system that mounts the exoskeleton's mechanical components to the lower-extremity. Custom molded orthotic are traditionally used for this purpose; however, they require time-consuming casting and expensive molding fabrication."

This project seeks to come up with an exoskeleton designs that meets the client's standards in order to make it effective and satisfy to the users' needs. The team will work together to brainstorm on the ideas to incorporate in the design in order to make it better. Different aspects of the design will be considered based on the customer needs and the engineering requirements. The project will take 16 weeks to be completed as shown in the tentative schedule in the appendix part of the report.

Patients with lower and upper limb muscles inabilities usually require assistive devices to allow them to perform tasks that require the use of these muscles. The human exoskeletons were designed for purposes of providing assistance during these activities. The exoskeletons help in providing the functions that the weak muscles are not able to perform. In addition, exoskeletons help in exercising these muscles in order for them to recover over time and regain their strength. Figure 1 represents an image of human exoskeleton and how it is mounted to users.

Figure 1. Exoskeleton mounted to custom-molded orthotic [1]

1.3 Original System

Engineers have always been interested in coming up with various designs that are able to provide assistive services to individuals having neuromuscular disorders. As a result of such interest, engineers ventured into the medical fields, among other fields, to come up with machines that are able to assist the medical practitioners in performing their tasks in an effective way [1]. Due to such interests, engineers have developed different kinds of exoskeletons for lower limb, upper limb, or full body assistance. These designs have existed for quite a long time but are consistently changing over time due to significant changes in the worldly activities, including changes in technological knowhow.

1.3.1. Original System Structure

Exoskeletons have existed for several years now and have been used for providing assistance to individuals who have issues with their muscles. They help in supporting people with neuromuscular disorders and assisting them in exercising their muscles. The original designs were built in different sizes, which help in fitting individuals that range in age difference [2]. The systems use materials that are readily available, including strong metals to provide enough support to the users. In addition, there are soft materials used that help in improving the comfort of the system, which allows for effective use. Despite the designs' performance, they still need improvements to make them better.

1.3.2. Original System Operations

The exoskeletons have been operating in different ways, which have been changing over the years with development in technology. The earlier systems were manually used, where the users had to be supported and manually moved for purposes of providing motion. This did not work well, which led to the introduction of control by a third party, where an individual had to help the users to operate the skeleton [4]. To further advance the designs, the systems now include operations that allow the users to control the skeletons by themselves, which has proven to be more effective and user friendly.

1.3.3. Original System Performance

The system designs have been performing their expected tasks as they were meant to. They did this with minimal challenges. The designs were created for purposes of providing assistance in movements for persons with limited muscle strength. However, the systems need constant improvements for purposes of increasing user satisfaction as well as meeting the increasing needs of patients [1].

1.3.4. Original System Deficiencies

Despite the original systems service the purposes that they were built for, these systems have various deficiencies that require being looked into. For example, the materials that were used in constructing the exoskeletons were quite heavy. These materials made it a challenge for the users to comfortably operate the skeletons for long hours. In addition, these systems are not comfortable to put on as they do not have sufficient protectors to the users [5]. The systems are also limited to specific users since they are not adjustable, which is a major reason why many individuals have to look for designs that are custom made to fit their sizes. In addition, the systems are outdated in technology since technology has significantly developed without seeing a change in the systems.

2. REQUIREMENTS

There are various requirements the team seeks to meet by the end of the project. These include the customer requirements, which are those that will be considered while formulating the engineering requirements. The requirements will be include in the final design system to allow for effectiveness in functioning as well as meeting the customer requirements.

2.1. Customer Requirements (CRs)

Customer requirements are the different forms of requests in which the clients and the users have on how to improve a design. Since they are the major users of the device, they tend to experience the ways in which the device operates, its positive sides, and also its negative side. Based on the experience, the clients and users may have views on how the device may be improved, which are translated into customer requirements. The client and users have various views or requirements for the designs, which are showed in the table below.

Customer Requirements	Targets
Improve the original system	To improve the original system to have mounting points that is rigid, both to the thigh and to the shank
Adjustable design	Create a design that is adjustable to fit people that are of various sizes, specifically those ranging from five year of age to seventy-five years
Ease of donning on and off	Making a design that has ease of putting on and removing
Better comfort	Minimizing of the irritation caused by the system
Weight of the device	Ensuring that the design is light in weigh to use effectively
Use advanced technology	Use of electric components for better functioning

Table 1: Customer requirements

Table 1 above indicates the customer requirements are indicated by the client. These requirements are important in the design process. They provide the guidelines in which the team follows when setting designing the device.

2.2. Engineering Requirements (ERs)

When customers come up with various requirements to improve original designs, these designs have to be translated into a manner that they can be specific and detail the changes to be made. These details are defined in specific and measurable aspects, which can then be interpreted using the engineering requirements. From the client's requirements, the engineering requirements may be interpreted as shown in Table 2.

Engineering requirements	Targets
Improve the strength of the device	Yield strength of at least 6Mpa
Adjustability	Adjustable to a length ranging 6cm to 20cm
Fabric use	Use soft fabric (polyester)
Weight limit	Limited weight of 0.75kg/limb
Distance above knee	No dimensions beyond the knee of 5cm

Table 2: Engineering requirements

2.5. Design Links (DLs)

1. Yield strength of at least 40kgs:

The human exoskeleton seeks to ensure that strong enough to support its users. The materials used will be allowed for supporting users of not more than 40kgs. This is because the size and the weight of the materials used, based on the weight that the team wanted the structure to be, can only support a maximum of 40kgs.

2. Adjustable to a length ranging 6' to 20':

One of the customer requirements was that the design should be adjustable. For the design, we decided that the system should be able to be adjusted in its length, where it should be adjusted within distances of 6 cm to 20 cm. this design based on the adjustability will allow for effective adjustments in the system.

3. Use soft fabric:

The use of soft fabric is meant for purposes of ensuring that the system does not cause any form of irritation to the users. The fabric will be used only in areas where the system comes in contact with the users. The fabric can be made of soft clothing, fur-like clothing, or soft sponge.

4. Limited weight of 0.75kg/limb:

The customer requirement was that the design is supposed to be light in weight. From selecting the materials used, we calculated the combined weight of the system will be between 0.5 to 0.75 kg/limb. Based on this, we settled on the weight of the system be limited to 0.75 kg/limb.

5. No dimensions beyond the knee of 5cm:

For the system to be comfortable when putting is on, we agreed that it should not go too high above the knee. The maximum height above the knee should not go beyond 5cm in length, which is a size that is comfortable to provide the required grip on the user.

6. Use advanced technology, the electric system:

The electric system will include the use of electrical components, such as the record box and the motors, to make the design work in a better way. The electric system will allow for transfer of information throughout the system as well as enable coordination of the system as a whole.

2.6. Testing Procedure:

1. Yield strength of at least 40 kgs:

The design is expected to be built to effectively carry weight of not more than 40kg. For this engineering requirement, the design was tested through using individuals of different weight, starting from 20kg, 25kg, 30kg, 35kg, and 40kg. Based on the users' feedback and the analysis done, the design proved to meet the requirements. In addition, the materials used were tested for their strain abilities to ensure that they perform their functions as required.

2. Adjustable to a length ranging 6' to 20':

The adjustability requirement was done through constant adjustment to the size. In relation to the test carried out for the strength, the same individuals were of different heights and weight. Based on this, the system design had to be adjusted as per the users' sizes. The adjustment procedure provided that the design adjusted well and in an effective manner.

3. Use soft fabric:

The softness of the fabric was also based on the responses from the users who tested the system. The feedback was positive. All the users indicated that the fabric used was soft and comfortable for the users. It did not provide any form of irritation to the skin. The engineering requirement was met.

4. Limited weight of 0.75 kg/limb:

The weight of the system was tested once everything was put together. The weight of the design was tested when the design was fully assembles and every bit of it had been put together. The weight tested to be 0.75 kg/limb, which was as per the requirements. The engineering requirement was successfully met.

5. No dimensions beyond the knee of 5cm:

This engineering requirement was measured based on the same users used in the testing procedure. The adjustability of the design was based on the users, where the users measure the comfort of the design above the knee based on the adjustments. The feedback was positive and all users found the design to be comfortable. The engineering requirement was met.

2.7. House of Quality (HoQ)

House of Quality helps us analyze gadgets given various parameters. It investigates the plan to be select by the team to assist in settling on the plan to use. Remembering every one of the prerequisites, which we have investigated above, does this [3]. The requirements include a device that is moveable, light in weight, adaptable, simple to deal with, minimal effort, less settling time and the simplicity of use. This procedure assisted the team in making functional enhancements.

Customer Requirement	**Weight**	**Engineering Requirement**	Yield strength of at least 6Mpa	Adjustable to a length ranging 6cm to 20cm	Use soft fabric (polyester)	Limited weight of 0.75kg/limb	No dimensions beyond the knee of 5cm
Should be adjustable	4			5	4		4
Have good mounting grip	5		4				
Easy to wear and remove	4				5	3	4
Reduce the irritation caused by the fabric	4					3	
Compatibility with shoes and clothing	3			3			
Strong and lightweight	5		5			5	5
Use advanced technology	5			3		3	
Absolute Technical Importance (ATI)			10	10	8	9	7
The Relative Technical Importance (RTI)			9	9	7	9	7
Target(s), with Tolerance(s)			6Mpa	6cm	30	0.75kg/limb	5cm
The Testing Procedure (TP#)			Mpa	cm		Kg/limb	am

The house of quality enabled the team to adjust the exoskeleton design to meet the engineering requirements. Through understanding the weight that each of the requirements hold to the outcome of the design, the team took time to ensure that all the measurement are as expected for purposes of getting the best outcome out of the design process.

3.0. EXISTING DESIGNS

There are various forms of technologies that have been created for purposes of assisting individuals with different forms of health related issues, including muscular disorders. We have inquired about various gadgets that serve the purpose of assisting individuals with neuromuscular disorders. The team focused on systems that can help the users to be assisted with minimal effort and increased success rate. The team looked into various existing designs in order to understand on the various aspects that it may look into for purpose of improving their performance.

3.1. Design Research

Different designs have been created ever since the first exoskeleton was invented. These designs have been improved over the years, which make them function in a better manner compared to the previous designs. In order to ensure that the team comes up with the best design, one that is better compared to the rest within the markets, the team took time to analyze the downsides of the existing designs [7]. From getting to know the different challenges and downsides facing these designs, the team formulated a formula to design a system that solves all these problems, which is the design that the team is working on.

3.2. System Level

The exoskeleton systems have undergone different forms of changes over the last couple of years. Existing exoskeleton restoration robots have for the most part centered on the position and drive control, and they encounter three phases of advancement in previous decades. The first stage is to play out the robot control by giving position order from the administrator, for instance, the control of Hardyman exoskeleton [7]. This project proposed a mixture and various leveled dynamic, responsive control design for the created exoskeleton restoration robot framework. The existing designs have pros and cons, which the team will learn from in order to make the design better.

3.2.1. Existing Design #1: The ReWalk exoskeleton

This exoskeleton, as shown in figure 2, provides powered knee and hip motion in order to enable people with SCI to be able to stand in an upright position as well as allow them to walk. This is among the few exoskeleton suits that have been cleared by the United States. The system is controlled using an on board computer that includes motion sensors that help in restoring self-initiated walking through sensing of the forward tilt of user's upper body [8]. It then mimics the gait pattern of able-bodied individuals. However, the system has issues with gripping and remaining firm on the user.

The system's solution includes developing better straps that can hold the users better. The straps, unlike the ones used in this design, may be design in a manner that they can be adjusted once they have gone round the user's leg. This may allow the system to hold the user in a firm way.

Figure 2: The ReWalk exoskeleton

3.2.2. Existing Design #2: The Vanderbilt Exoskeleton

The Vanderbilt exoskeleton, as shown in figure 3, is a design that was made by Goldfarb. This exoskeleton is advanced in nature as it assist users in performing the basic motions, including walking, standing, sitting, as well as walking up and down stair cases [9]. The design provides a modular-based design in which users can assemble and then wear it and also disable after use. Each of the thigh segments has been designed to include two different brushless direct current motors used in actuating the knee and hip joints. However, the system is not adjustable and can only be used by users of specific height.

The system's solution may include making the design adjustable, which may involve designing the side bars in a way that they can be adjusted to be longer and shorter. This may allow for the design to be used my people of different heights.

Figure 3: The Vanderbilt Exoskeleton

3.2.3. Existing Design #3: Sarcos Exoskeleton

Figure 4 shows a design that is used for full body assistance. The design is wearable and an energetically autonomous robot. The energetically autonomous aspect of the robot implies that is uses its own power supply that is carried within the system [9]. The system is advanced within the hydraulically actuated concept. It usually employs rotary hydraulic actuators rather than linear hydraulic actuators located on its power joints. This usually takes the design to be powerful as well as effective to its users. However, the design is too heavy and large in size, which is uncomfortable for most users.

The system's solution may involve designing a similar exoskeleton that uses smaller components that can fit in a smaller design. Making the design smaller may make it function better through making it lighter and smaller.

Figure 4: Sarcos Exoskeleton

3.3 Subsystem Level

Studies have demonstrated that dynamic association for administrators in the creation of an engine design brings about more noteworthy engine learning and maintenance than detached development. Guaranteeing the security of the subject is an essential issue. Both programming and equipment ensures the dependability in the proposed framework. For equipment outline, it incorporates selecting secure gadgets, setting crisis to stop catch, and sensible component plan.

3.3.1. Subsystem level #1: Motors

The use of motors in the designs allow for effectiveness in movements within the structure, especially at the joints. Based on the clinical studies results of this exoskeleton, the paralyzed patients have the abilities of standing upright and also walk in an independent manner. The use of motors in the structure helps in improving the quality use. Figure 5 shows a design that has incorporated the use of motors to allow for quality movement by the users [11]. It is among the few exoskeletons to be manufacture that include the use of advanced and up to date technologies that influence its reliability. However, the system may function better if it included a data box.

The system's solution may involve including a data box that can manage the exoskeleton's functioning in general. The data box can help in improving the coordination of the motors, which may help them function better, such as avoiding jamming due to too much turning.

Figure 5: The ReWalk exoskeleton

3.3.2. Subsystem level #2: Controls

Controls are an important aspect of the exoskeleton designs. Controls allow for the devices to be maneuvered as per the users' needs and requirements. The controls are based on various factors, including the technology uses as well as the preferences of the user. The Vanderbilt exoskeleton, as shown in figure 6, has been design in a way that it includes brushless direct current motors used to actuate the knee and hip joints. The controls help in ensuring the coordination within the devise is well organized. It provides repeatable gait with hip and knee joints aptitudes that are same to the ones observed while in non-SCI walking. However, the system's controls consume too much power.

The system's solution may be designing a system that can generate power while in use. Since the controls consume power when in use, a design that can be able to generate power when in use or have a backup power plan may help in solving the issue.

Figure 6: The Vanderbilt Exoskeleton

3.3.3. Subsystem level #3: Structure

The Sarcos exoskeleton, as shown in figure 7, is made for purpose of using force sensing located between the robot as well as wearers for purposes of implementing the systems referred as the "get out of my way" system. The wearer's foot tend to interface with the design through the use of stiff metal plates containing force sensing elements that are able to keep the feet of users to be stiff at all times [11]. The structure of the device is made is a manner that it is able to be worn and removed comfortable as well as fit the users in a comfortable manner. However, the device is quite heavy based on its size and components.

The system's solution may include developing a system that is smaller in size or one that uses smaller components. Also, the device may involve the use of lighter materials in order to make it light and easy to use.

Figure 7: Sarcos Exoskeleton

4.0. DESIGNS CONSIDERE

The team considered different designs while brainstorming. There are a set of designs that the team generated from brainstorming processes. They were based on the various customer and engineering requirements. The designs look into various aspects of the improvements that the customer would like while considering the engineering requirements. The designs are explained in detail below. Some of these designs are included below:

4.1. Design #1: Use of a black box

From the original design, the team analyzed it and found out that it has issues with the general operations, where the functionality was limited. However, the team seeks to improve on this through including a black box into the design. The black box will serve the purpose of storing data and coordinating the user's movements to those of the exoskeleton.

Incorporating the black box will be significant for the team. This will help in improving the general performance of the exoskeleton, where the user will be able to coordinate it with minimal efforts and significant ease. On the other hand, this may be expensive to install and maintain since it may require regular maintenance.

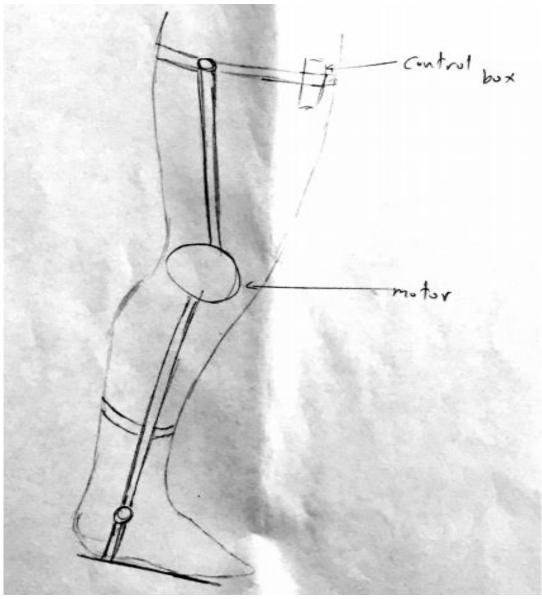


Figure 8: Use of a black box

4.2. Design #2: Use of a motor

The existing design, based on the team's analysis, did not include the use of motors. For the team's design, motors will be included to allow for effective movements, especially at the joints. The motors will be including at the knee joint and the ankle joints.

Using the motors will be advantageous for the design. For example, the design will be able to move effectively at the joints. To make it work better, joining the black box and the motors will allow for quality coordination and ease of use of the design. On the other hand, the motors may also require constant maintenance due to wear and tear.

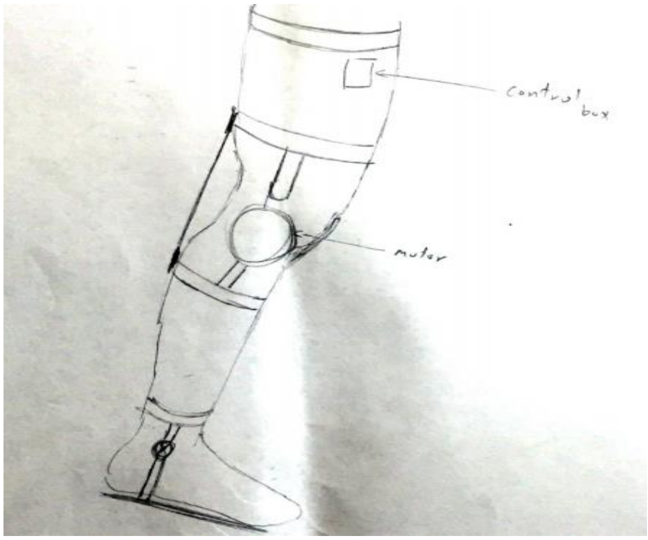


Figure 9: Use of a motor

4.3. Design #3: Adjustable structure

The current design requires users to be of specific ages. The designs are fixed in size, where the users have to request or fit into specific designs that measure to their sizes. This makes it quite a challenge for the users since they have to request for custom made designs and at times grow out of the sizes. However, the team seeks to design an exoskeleton that is adjustable, which can be easily used by people of different ages.

The design will be advantageous since it will be effectively used by individuals of different ages. For example, user of between the ages of 6 and 9 can be able to use a single design, which is just adjusted to suit their preferences or sizes. Despite this, the team may require using additional material in order to have the design operating effectively.

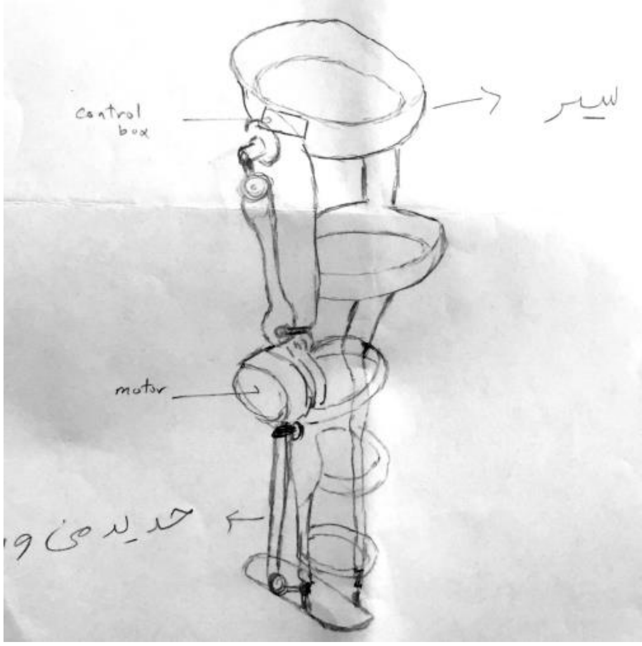


Figure 10: Adjustable structure

4.4. Design # 4: Adjustable straps

Putting on the exoskeleton may at times be tedious. Also, ensuring that the exoskeleton is comfortable when being used is also important. The current design does not effectively consider this. The team considered including straps that can be adjusted in order to allow the users to fit properly. Also, the tightness and looseness of the design can easily be adjusted for effectiveness in using.

The design is advantageous since it will allow for the users to be able to fit into the systems in an effective manner, which will allow for ease of use. Also, the design will allow for quality use since the user will be able to adjust the straps to how tight they want it to be. This means that the design does not have any disadvantages to the users.

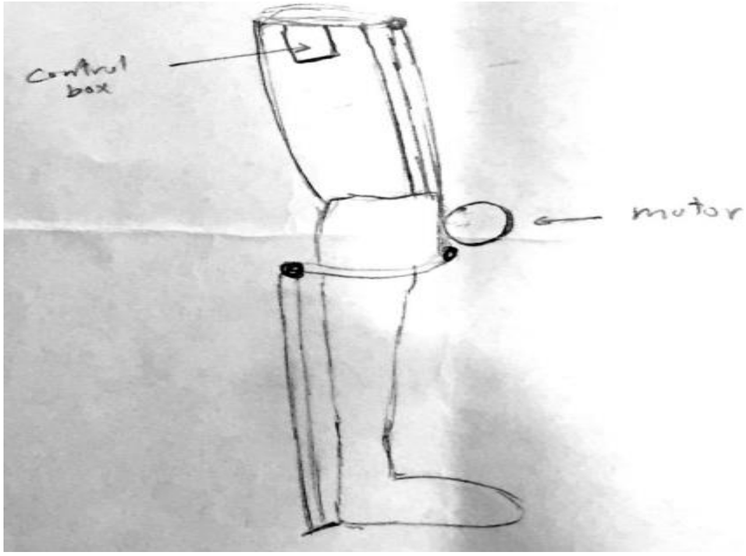


Figure 11: Adjustable straps

4.5. Design #5: Soft fabric

The exoskeleton may at times be quite itchy. The user may be unable to effectively use the existing design due to irritations at the points of contact of the system and the body. Based on this issue in the existing design, the team considered including soft fabric at points where the design comes into contact with the body in order to avoid irritation.

The design allows for quality use of the exoskeleton. It is possible for the users to feel comfortable while using the design. Also, it allows for longer use without feeling irritated while using the design. The team considered using soft fabrics at these points.

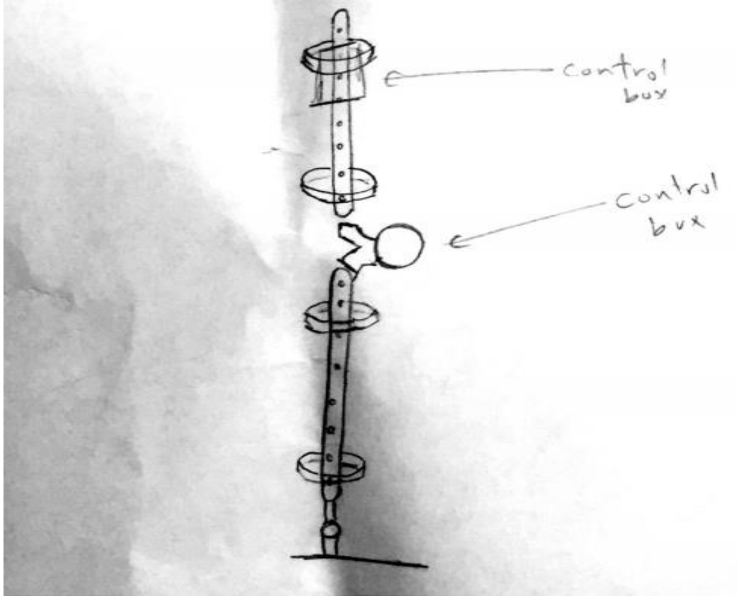


Figure 12: Soft fabric

4.6. Design #6: Iron Structure

The team considered using an iron structure. The rods supporting the structure need to be strong. The team considered using iron rods in order to make the structure strong. This design is advantageous since it makes the structure strong and easily used by users of different weights. However, using iron rod may make the design quite heavy for users, given the fact that they are physically challenged.

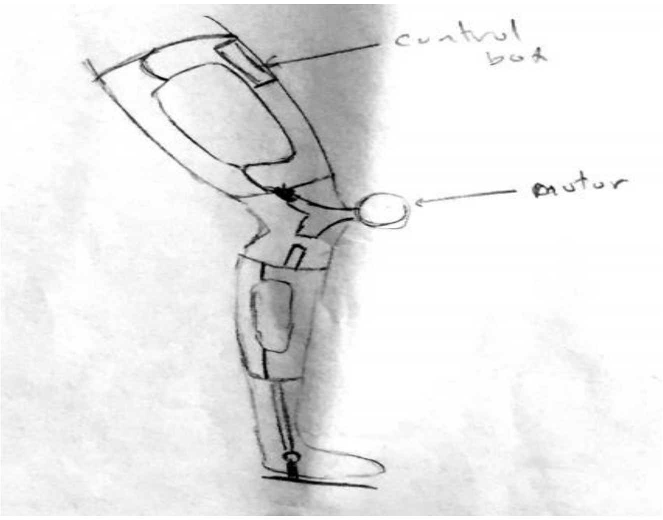


Figure 13: Iron Structure

4.7. Design #7: Aluminum Structure

Further, the team considered using aluminum for the structure. The team considered this since it allows for the use of a strong metal and light at the same time. This will make the design easy and effective to use since it will not be heavy. However, the metal may easily bend, which makes it unsuitable for use in the structure.

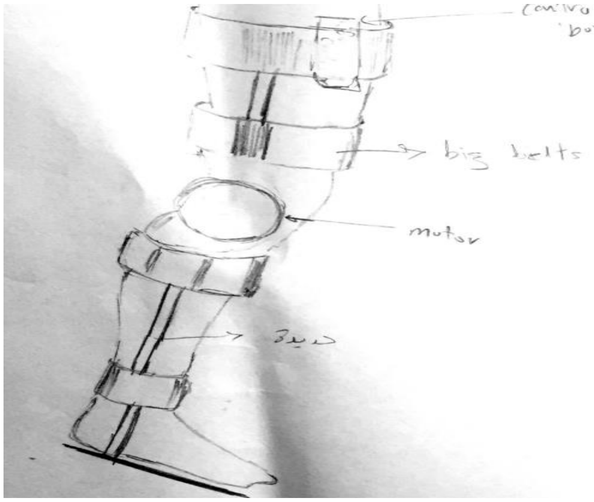


Figure 14: Aluminum Structure

4.8. Design #8: Complete Cover

The use of a complete cover is a design that may allow for quality griping of the user by the design. The complete cover allows for the design to go round the users' legs and cover all the parts. This allows for the design to fit properly and effectively. The design is advantageous since it allows for quality use of the system thus making it comfortable. However, the design may cause significant sweating, which may not be proper for use for long hours.

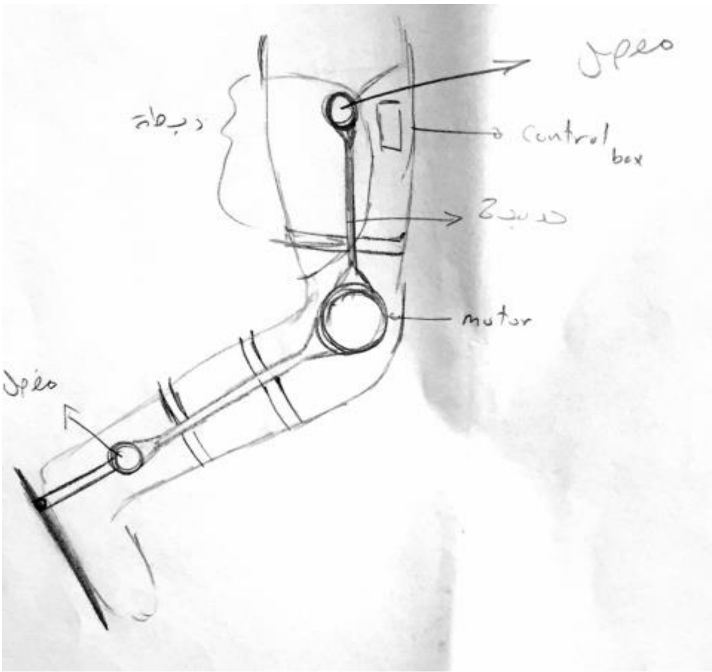


Figure 15: Complete Cover

4.9. Design #9: Partial Cover

On the other hand, the team considered a design that covers the users' legs partially. This design will use straps rather that complete covers. The straps will be located in different places on the leg to allow for effectiveness in griping. The design allows for quality use and reduces irritation as well as the increased warmth when completely covered.

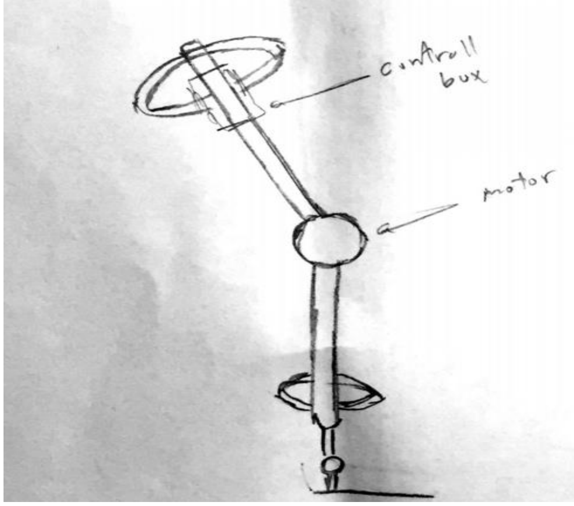


Figure 16: Partial Cover

4.10. Design #10: Advanced design

This design includes the use of advanced systems to make it effective. This includes using these designs into one high quality performance design. The design will include use of a black box, use of motors, use of an adjustable structure, using adjustable straps, and using soft fabric. This will make sure that the design is able to meet most of the users' needs.

The design is advantageous since it is able to ensure that users are comfortable when using the design. The users are able to use the design without being irritated. In addition, the use of the design will be easier due to the existence of motors and black box. Their size can be adjusted, and the tightness of the design can also be adjusted. The design is important since it meets most of the client needs.

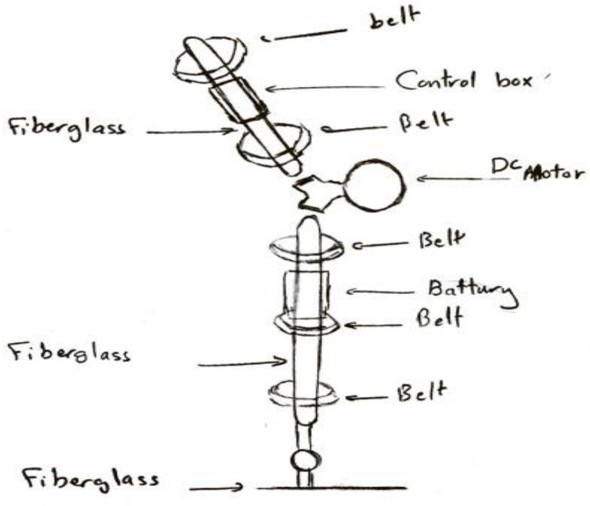


Figure 17: Incorporative design

5.0. DESIGN SELECTED

The team looked into various components before settling on the final design. The design that was selected met all the requirements. Some of these requirements include meeting of the customer needs, meets the needs of the users, and becomes a better design compared to existing ones. Based on these criteria, design 10 had the highest score.

Decision matrix:

Table A1: Decision Matrix

(The score of 1-10 is use, where 1 is the least effective and 10 is the most effective)

Designs:	Meets client's needs	Meets users' needs	Improves the existing designs	Total score
Design#1	4	3	2	9
Design#2	4	2	3	9
Design#3	4	4	5	13
Design#4	4	4	4	12
Design#5	4	3	6	13
Design#6	3	2	5	10
Design#7	3	5	2	10
Design#8	2	3	4	9
Design#9	3	4	5	12
Design#10	9	9	9	27
Design with highest score	**Design #10**			

The team selected design #10, which is a combination of several desings to meet the clients and users‘ requirements. Design #10 had the highest score. The score was based on meeting different needs, which include meeting the client’s needs, meeting the unser’s needs, improving on the existing deisgns. The total score for design #10 was 27, which was higher that all the rest. Based on this high score, the team made the decision to work and develope design #10.

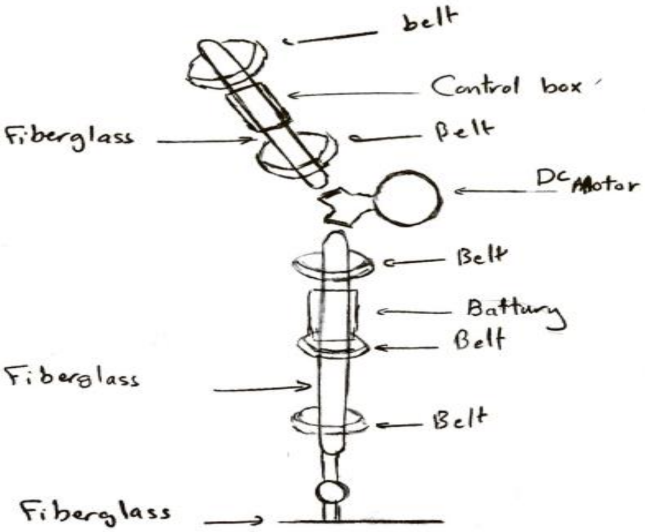


Figure 18: Selected Design

5.1. Rationale for Design Selection

The team decided to work with this design since it meets all of the client’s requirements. The design is also the most effective based on the decision matrix, where it is able to meet most of the users’ needs compared to the existing designs. The design selected is also advantageous in many ways. For example, it is effective in use since it is able to ensure that users are comfortable when using the design. The users are able to use the design without being irritated where the skin gets into contact with the system. The user will also operate the design in an easier manner due to the existence of motors and black box, which will include the electrical design to allow for quality functioning such as coordination of the various parts of the exoskeleton. The design allows for adjusting of the size, and its tightness can also be adjusted to fit the user in an effective manner. The design is important since it meets most of the client needs.

5.2. Design Description

The design will include use of a black box, use of motors, use of an adjustable structure, using adjustable straps, and using soft fabric. The black box will serve the purpose of storing data and coordinating the user’s movements to those of the exoskeleton. The motors will be including at the knee joint and the ankle joints to allow for ease of movement at these points. The adjustability of the design will allow for ease of use, where it can be easily used by people of different ages. The team considered including straps that can be adjusted in order to allow the users to fit properly. Further, the use of soft fabric at points where the design comes into contact with the body, will allow the user to eliminate the feeling of irritation. Combining these designs will allow for a quality end.

5.2.1. Prototype

There are different forms of early designs that have been developed to test the exoskeleton concept. The design shown in the figures below shows a model build for purpose of testing the exoskeleton concept as well as enable a better understanding of the exoskeleton model. The design provides specifications for the general functioning of the exoskeleton system rather than providing a theoretical one. Based on this prototype, the selected design is analyzed and modified to meet the engineering requirements.

Figure 18: Prototype

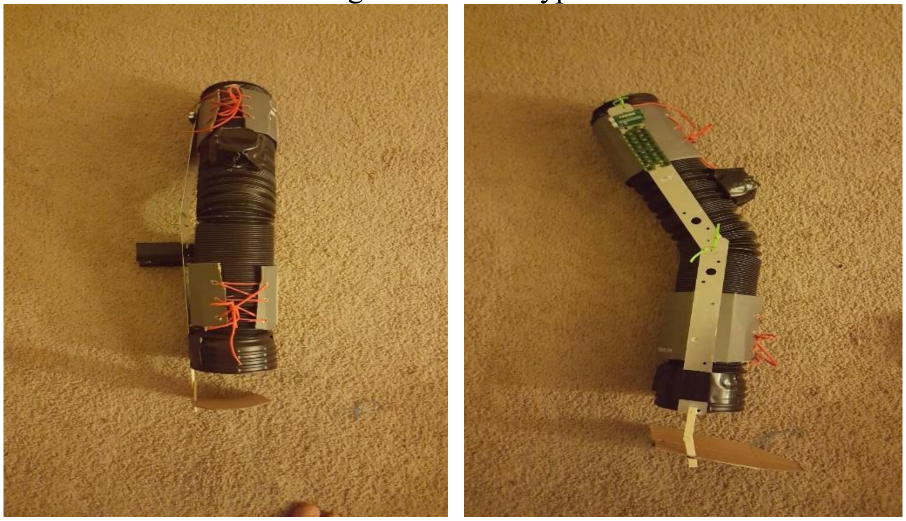


Figure 19 and 20: Prototype

5.2.2. CAD Model

The CAD model shown in the figures below represents a three-dimension figure of the design selected. The figures show the different concepts considered, which include the use of the control box, DC motors, straps, fiber glass, and battery as shown below. The figures show the way in which the final design will looks like in 3D.

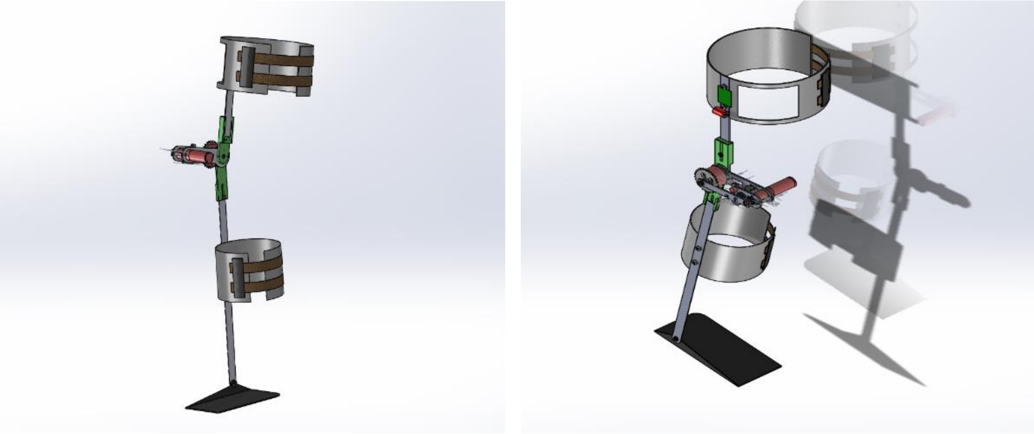


Figure 21 and 22: CAD Models

5.2.1. Control box board

The control box is an important part of the exoskeleton. This board allows the different parts of the exoskeleton to work together in a uniform manner. There are different commands in which the device should interpret when being used. The exoskeleton design has to interpret different kinds of command as provided by the users. The control box helps in interpreting these commands and executing the functions as expected. in addition, the commands may be multiple and the control box is able to execute these commands without failure.

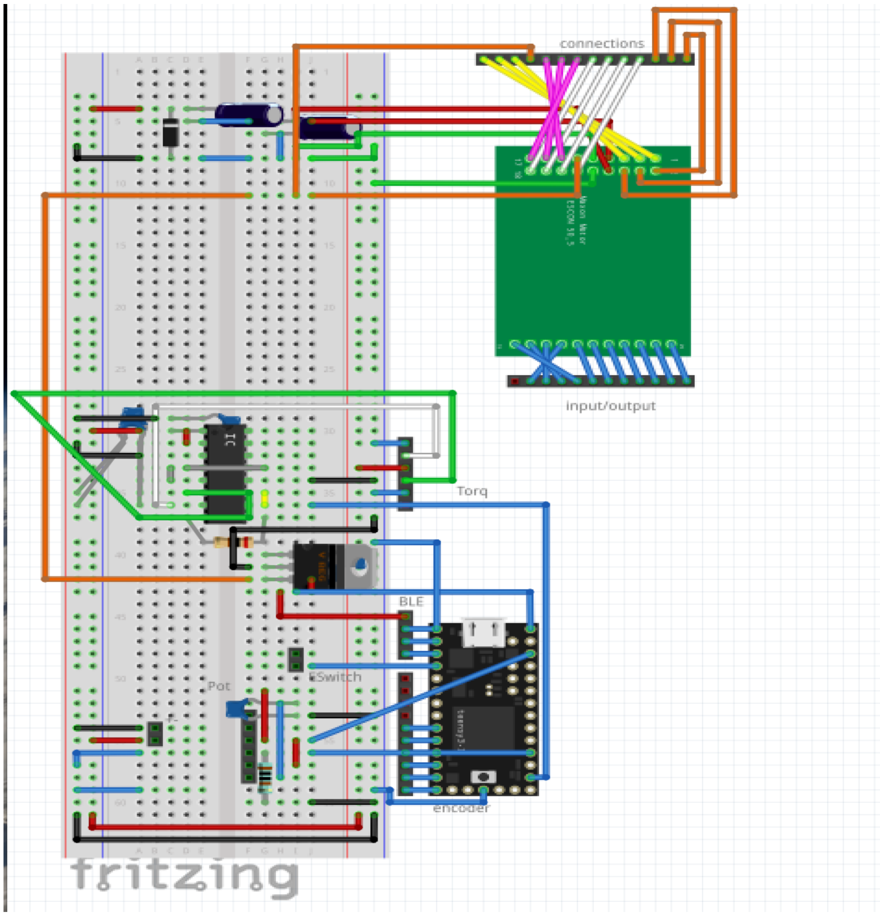


Figure 23: Control box board

5.3. Analytical analysis

Choosing materials for use in prosthetic applications are depended on the user's demands. All the components are have proved to be durable with layers of reinforcing compounds. The compound used and how it is applied with resin determines the durability of the prosthetic. For the majority of geriatric users, fiber glass reinforced with stockinet is adequate. However, if the user's level of activity requires heavy duty device, carbon-fiber glass is recommended. Weight is very important in these components. The end product has to be light enough. The properties of fiber glass and carbon allow for applying several layers of each to achieve high strength at the still low weight.

The layer of materials used depends on the activety level of the patient. Vertical strips of carbon tape or a layer of bi-directional carbon cloth are used in heavy duty and super duty applications to achieve increased tension, stiffness and resistance to compression. A layer of fiber glass reinforced with stockinet is used to cover the inner layer and then reinforced with suitable acrylic resin (Cifuentes, et al., 2016).

5.3.1. Properties of Fiber glass and carbon in Orthotics

Fiber glass and carbon are fall in the category of compounds being used for orthopedic applications. Each of the two materials has unique properties and features, and this gives them an advantage over each other. Of the three compounds, fiberglass is the most economical and hence commonly used. It is heavy but can saturate easily with resin. Fiberglass is also found in different forms and properties. The superior qualities that distinguish fiber glass such as durability and flexibility. This is because the fibers provide strength under compression than under tension.

Carbon fiber, on the other hand, is a significant compound to orthopedic incorporations. Although it is very light, carbon is extremely stiff and retains its shape when under stress because it has impressive strength when subjected to tensile and compressive forces. Carbon fiber is very stiff, a property that makes it brittle and as result reduced resistance to effect. When dealing with the two compounds, it is prudent to make sure that the strength characteristics of the compound fiber are shown and developed in the course of the fiber (Pons, 2008). For the maximum resistance degree to fracture of the compound to be achieved, it is important to consider the fiber's position relative to the applied stress. Fiber materials including tape compounds and woven cloth have proved excellent for localized strength. However, they provide one compound property in a single direction. In addition, the fibers in the compound have to be placed at a 90^0 angle to the plane of stress for their effectiveness.

In fiber glass and carbon, the uniform strength is achieved with resistance of equal magnitude to fracture in multiple directions. This is achieved using a quasi-is-trophic compound is used. To achieve this, the compounds are applied in a knit type. This compound fiber is rendered in a 3-dimension plane manner. Because each compound has unique properties, effectiveness in the application for the fabrics is achieved by fusing the constituents to obtain a quasi-is-trophic hybrid compound. It produces a combination with the most desirable characteristics of each fiber in one medium. These characteristics include compressive, torque resistance, tensile, shear, and affect stress from all directions (Lusardi, et. al., 2013). When carbon is blended with fiber glass, it achieves superior high resistance to fracture. The resulting product also possesses a very commendable strength: weight ratio, and with low-cost implications. The product is a hybrid with lightweight characteristics associated with carbon, integrated with cost-effective, durable, as well as, flexible properties of fiberglass.

When reinforced with stockinet, fiber glass is widely used in geriatric amputees. Sometimes the activities may require a high impact prosthesis. In such cases, a blend of carbon-fiberglass knit with stockinet is used. In the instances of the super-duty socket, carbon-Kevlar knit compounds provide the required strength. Carbon-fiber glass finds much application in the average disarticulation prosthesis. The disarticulation prosthesis offers many challenges relative to stress regions and fracture planes. The classical point of fracture forms the distal front and back edges of the socket attachment because of the extra torque moments, tension and compressive stress at this point of the component. Carbon fiber, therefore, meets the demands of this kind of heavy duty application.

The regions of localized stress at the distal points of socket attachment are reinforced using two to three layers of unit-directional carbon tape. This is done while ensuring that the fibers are perpendicular to the stress plane. Care is taken so that the carbon layers do not exceed four. With more than four layers of carbon tape, the prosthesis becomes stiff and unable absorb both torque and impact (Perry, et al., 2010). Because of the properties of fiber glass discussed earlier, it is applied up to two layers, placed between the layers of carbon to make an I-beam effect. This increases strength and resists forces and stresses that are applied by the user.

Maximum Cast Circumference (Centimetres)× Total Cast Length/3 = Total Resins required (grams)

5.3.2. Wight Analysis

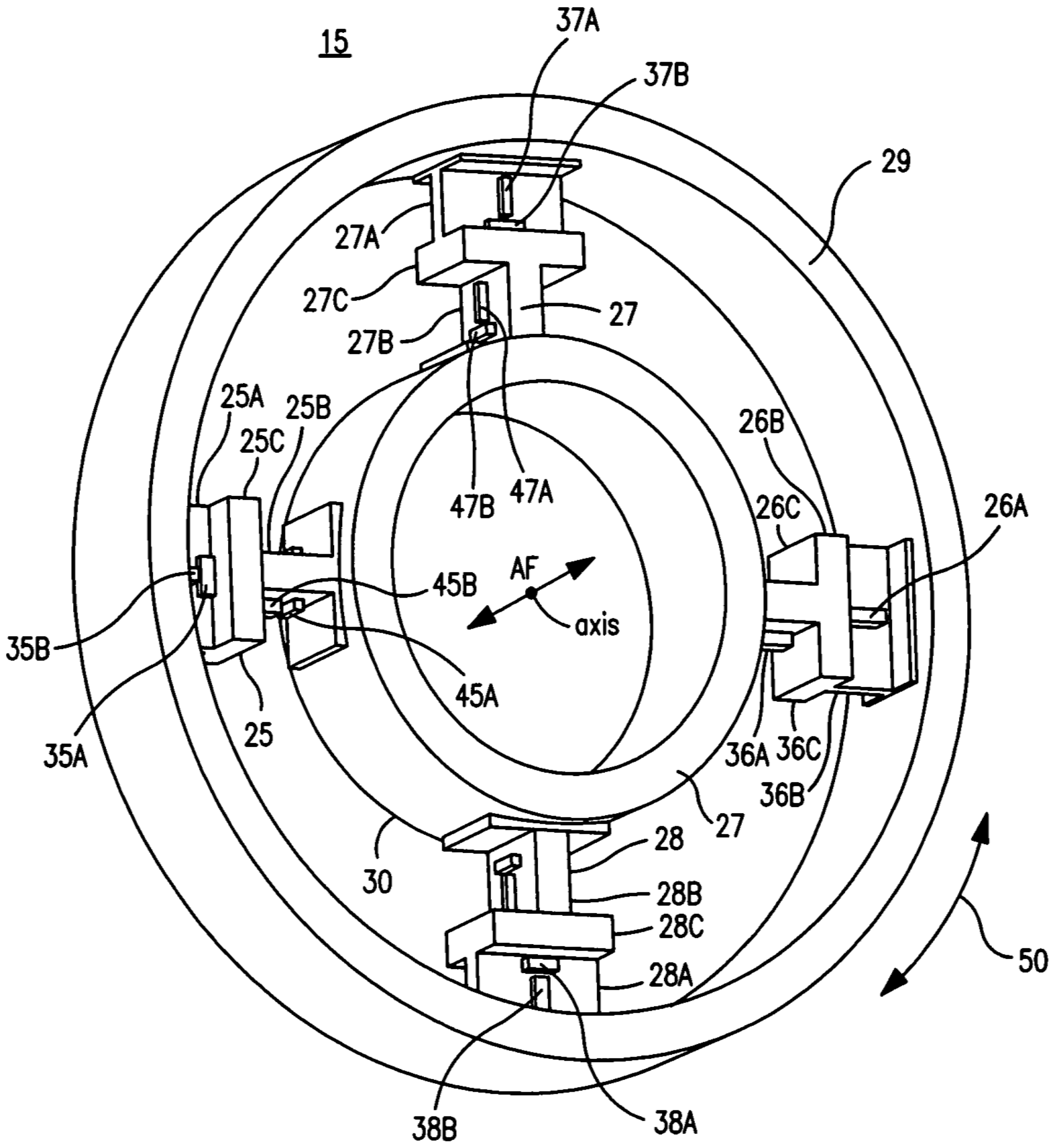
Using this method, the weight of a below-knee socket component is approximately 275g, while the finished prosthesis weighs about 960g. The knee socket described above has a weight of about 300g in average. The above-knee wood shin prosthesis weighs in average 3kgs. This weight depends on the size of foot and knee unit that is included without hydraulic systems.

Where very high levels of stresses are expected, it is advisable to adopt design of structures to develop an I-beam. With the socket layout, fiberglass mixed with carbon woven cloth adds no much weight but increases stiffness up to 40% and strength up to 20%. This achieves ultimate reinforcement at a reduced weight. Care is taken in this design to ensure that stress planes are identified, as well as carbon fibers are at 90^0 to it. (Knudson, 2007). Selection of compounds for the knee socket mentioned above depends on the activity level of the client and requires a total of five layers. Carbon tape is tied up to three inches circling the socket to maintain the shape of the socket and its rigidity. If the socket has to be flexible, layers of compound stockinet are maintained. Other two layers of fiber glass matting are included in the midst of the compound layers to make an I-Beam. This increases the strength, tension, stiffness, and resistance to compression.

Some areas require grinding to ensure the socket or other parts fits properly. Fiber glass layers are applied above the lining of half of an ounce Dacron sleeve. Because of its properties, fiber glass mating provides a light filter that is saturated by an acrylic resin which is easy to grind and buff to achieve a good appearance. The edges can be finished with a sand paper, and an acrylic paste incorporated as a thin coat.

5.3.3. Comparative analysis of orthotic mechanisms

Initially, the Solid Ankle Cushion Heel (SACH) was preferred as the foot of choice because of its light weight, affordability and durability. As long as the heel durometer is soft, the stability of the knee with this kind of knee is generally good. In cases where improved knee stability is required, a single axis foot with soft plantar flexion bumper is preferred. The major disadvantages of this option are the added weight and cost. Multi-axis designs present similar challenges to the single axis but comes with and extra degrees of freedom. This is because of the hind foot inversion/eversion along with traverse rotation. A multi-axis component accommodates uneven ground, absorbs some of the walking torque, protects the user's skin form shear stresses and reduces the wear and tear on the device's mechanisms (Cifuentes, et al., 2016).



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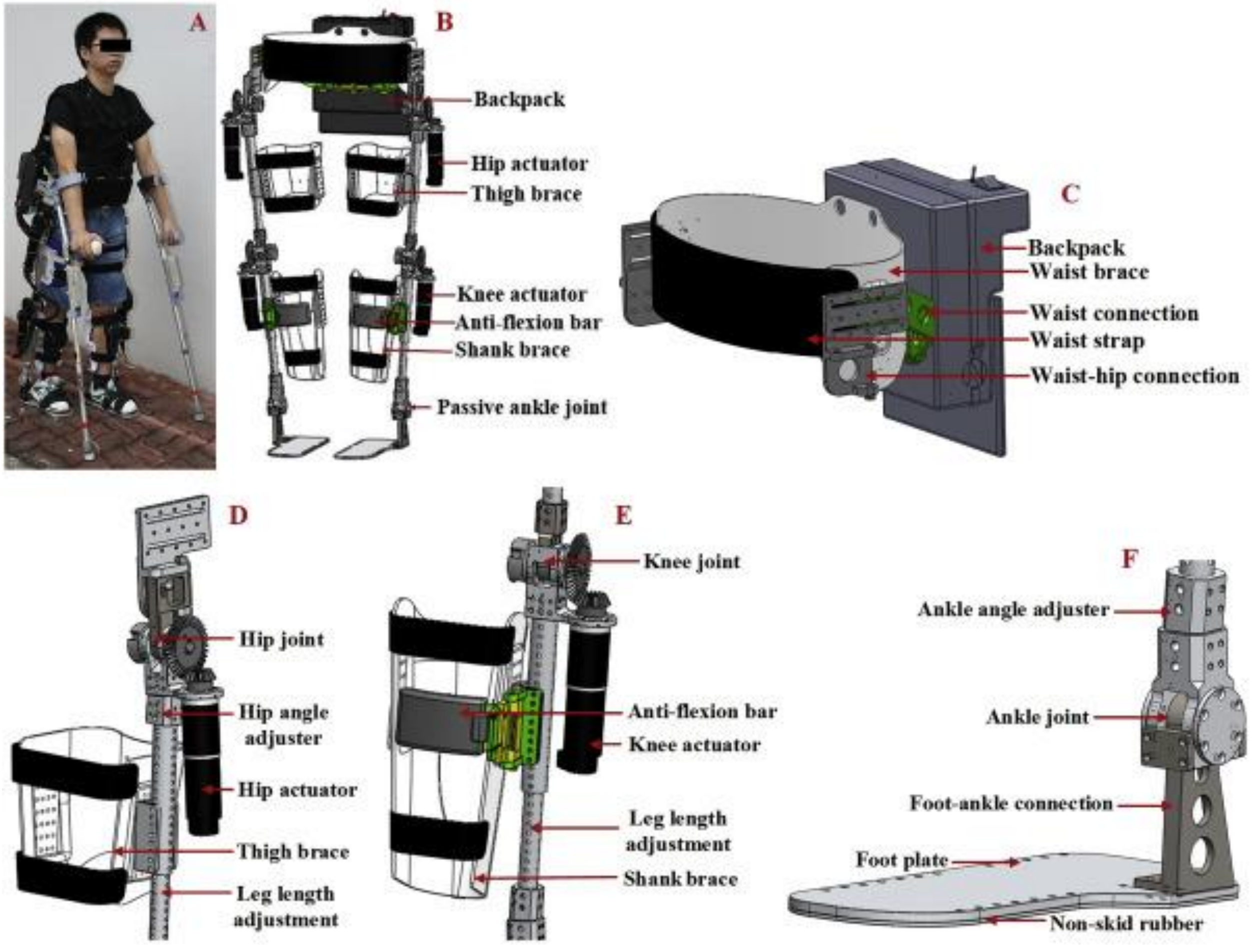
In recent years, more advanced foot prosthetic devices have emerged, and have proved to be successful to the users. There is Soft Ankle Flexible Endoskeleton that could be regarded as Flexible Keel design. Other similar designs include STEN foot and Otto Bock 1D10 which soft, flexible fore foot which providing a smooth rollover of the user. The SAFE design has traverse rotation. Special care is taken during alignment of the soft forefoot to prevent knee buckle from occurring. Nevertheless, if the soft foot is used together with polycentric knee, the opposite happens. The component becomes safer in the phase of late stance.

The polycentric knee mechanism is superior in that it can resist bending moments. This results in powerful stability at heel strike. During the swing phase, it only flexes when the forefoot is planted on the ground while the body rides the device above it. There is a resulting shearing force which interferes with the linkages and allows easy flexion on the knee. The soft, flexible keel delays the shearing moment. This makes the polycentric knee more stable in late stance. Dynamic response feet can also be used to help hip/hemi patient because it provides a subjective active push off.

In all components, it is important to monitor the interaction between the foot and the knee. If the foot mechanism is responsive, the knee unit resistances become more important (Knudson, 2007). Fluid controlled knee mechanisms or those with powerful friction cells are sometimes more preferred. This is because they reduce wastage of the forward momentum due to knee terminal impact. On top of the foot mechanisms, there are numerous ankle components designed for the amputees. They can, therefore, be used together with the feet devices discussed above. This increases the number of degrees of freedom. To reduce the shear forces that are transmitted to the users and the components, torque absorbing units are included in the prostheses. These torque devices are located beneath the knee mechanism. This allows increased durability because it places the mechanism far away from the sagittal stresses generated by the ankle.

Including torque absorbing devices is justified by the fact that the patient lacks three biological joints hence lacks regular rotation of ambulation. The absorbers are combined with almost any type of foot when it is desired. Recently, rotational units have been developed and are fixed above the knee mechanism (Cifuentes, et al., 2016). They allow the user to press a button, which rotates the shank by up to more than 90 degrees to attain sitting comfort. Users can sit cross-legged on the floor and easily enter automobiles and other places.

With the four potentiometers at each joint of an individual, we proceeded to connect the circuit to open the HyperTerminal window perform normal walking and for different readings of the analog signals. The design of these mechanisms is conceived with the help of different disciplines such as medicine, electronics, physics and mechanics. Within the field of electronics, electronic instrumentation and control are recognized as fundamental parts of the system. The instrumentation is responsible for collecting the information useful to be sent to a central processor, which contains the control strategies necessary to make a decision according to the information received. This information should be highly reliable and the principles used should be appropriate for each application. In the electronics of exoskeletons, there are different ways of acquiring the information and different control strategies that are adopted depending on each development, taking into account that the agreed and implemented always have to be in accordance with the developments of the other areas applied to the construction of the exoskeleton. These tests can be performed on people suffering any kind of spinal cord injury in the lower limb, likewise be obtained many tools to design the operation of the exoskeleton according to the requirements of each individual.



(Engineering design, 2015)
The figure above shows the exoskeleton functioning mechanism

5.3.4. Component Design Equations

In this segment, the outline conditions comparing to the CRR-RRR component are exhibited. The motivation to do as such is that it ended up giving the most fitted instruments for the undertaking.

CRR-RRR linkages are considered as two serial chains, CRR and RRR, joined at their end-effectors. The tomahawks are marked as appeared in, beginning at the settled C joint and going around up to the last settled R joint. For each joint i, let si=si+∈soi be the joint hub, with revolution θi, and slide (for the C joint just) di. We express the forward kinematics conditions of the CRR and RRR chains utilizing double quaternions

Q^CRR(Δθ^1,Δθ2,Δθ3)=∏3i=1(cosΔθ^i2+sinΔθ^i2Si)Q^RRR(Δθ6,Δθ5,Δθ4)=∏i∈{6,5,4}(cosΔ^θi2+sinΔ^θi2Si) (1)

Where Δθ^i=δθi+∈δdi is the double edge, and all di = 0 with the exception of d1 comparing to the round and hollow joint. The forward kinematics so communicated speak to the arrangement of relative relocations of the fasten as for a reference design.

So as to make the plan conditions, we limit the separation between the relocations caught in Section II.B. We perform dimensional blend, that is, the objective is to discover the area and measurements of the component that performs roughly the undertaking.

The outline conditions are made by likening the forward kinematics of the system to each of the discrete positions got from the movement catch. In the event that we indicate each limited uprooting of the thumb as Pˆi, we can make the relative removals as for the principal position of the thumb, Pˆ1i=Pˆi(Pˆ1)−1, to yield plan conditions

QˆCRR(Δθˆi1,Δθi2,Δθi3)=Pˆ1i,QˆRRR(Δθi6,Δθi5,Δθi4)=Pˆ1i,i=2,… ,m .
(2)

In these conditions, the factors we are occupied with are what we call the basic factors, which are the Plucker directions of the joint tomahawks si=si+∈soi at the reference setup. Furthermore, the advancement procedure yields the edges of the chains with a specific end goal to achieve the thumb relocations.

To finish the arrangement of conditions in we force estimate imperatives on the system so it can be joined to the lower arm and with sensible measurements. Specifically, for the six-interface CRR-RRR system, we include the limitations of separation between both settled tomahawks and furthermore between the settled tomahawks and the thumb,

S1·S6=cosα+∈asinαS1·P1=cosβ+∈bsinβ (3)

where P1 is the screw hub of the primary thumb position, and we settle the separation between the tomahawks along the regular ordinary, a, to an incentive in the vicinity of 50mm and 150mm, and the separation between the thumb connection and the coupler tomahawks, b, to comparable qualities.

5.3.5. Calculations

For the trial subjects, both the firmness and helping power were kept consistent (n = 1, Kt = 50N, Kd = 30Ns/m, Dt = 1m). What changed was the width of the virtual dividers, i.e. the level of requirement on the trail. The requirement was maximal for the principal square of preparing trials as the passage dividers were tightest (Dn = 0.002m). The pathway was less compelled (more prominent suitable deviation of the trail from the recommended way) for squares 2 and 3 (Dn = 0.005m). The imperative of the controller was additionally decreased amid the fourth square of trials (Dn = 0.007m).

5.4. Biometric Tests

Biomechanical tests propose that it might be conceivable to assemble a leg exoskeleton to diminish the metabolic cost of strolling while at the same time conveying a heap. A semidetached, leg exoskeleton is exhibited that is intended to help the human in conveying a 75 lb payload. The exoskeleton structure runs parallel to the legs, exchanging payload strengths to the ground. While trying to make the exoskeleton more proficient, detached hip and lower leg springs are utilized to store and discharge vitality all through the step cycle. To decrease strong knee exertion, a variable damper is executed at the knee to bolster body weight all through early position. In this proposal, I guess that a semi-inactive leg exoskeleton of this outline will enhance metabolic strolling economy for conveying a 75lb knapsack contrasted and a leg exoskeleton with no versatile vitality stockpiling or variable-damping capacity. I additionally envision that the semi-detached leg exoskeleton will enhance strolling economy for conveying a 75lb knapsack contrasted and unassisted stacked strolling. To test these speculations, the rate of oxygen utilization is measured on one human test member strolling on a level surface at a self-chose speed. Pilot test information demonstrates that the semi-inactive exoskeleton builds the metabolic cost of conveying a 75lb rucksack by 39% contrasted with conveying 75 lbs without an exoskeleton. At the point when straightforward stick joints supplant the variable-damper knees, the metabolic cost on unassisted load conveying declines to 34%, recommending that the preferences of the damper knees did not make up for their additional mass. At the point when the springs are expelled from the previously mentioned stick knee exoskeleton, the metabolic cost on unassisted load conveying expanded to 83%. These outcomes show that the execution of springs is valuable in exoskeleton outline.

5.4.1. Knee Joint

The Dual State Knee Mechanism (DKSM) is the device that controls and manages knee motion in the exoskeleton system. Theoretically, this would allow for FNS stimulation to be turned off during stance, conserving energy and delaying the onset of fatigue. The intent behind the design and operation of the mechanism is to support the user's knee joint during the stance phases of gait while allowing free motion during the swing phases. This device is shown in detail in fig: 2.

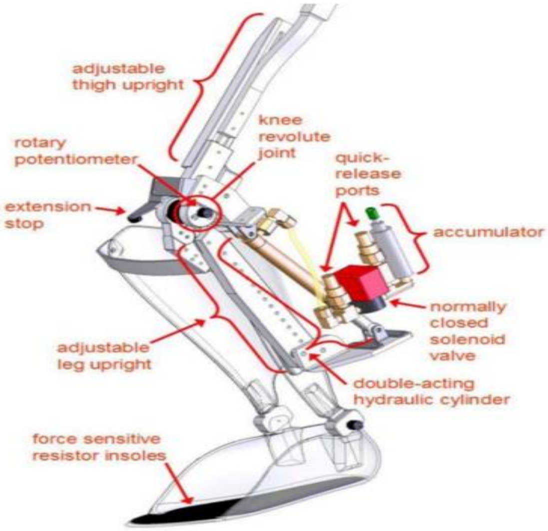


Fig 24: Component view of the Dual State Knee Mechanism (DKSM).

Mechanically, the device is a 4-bar linkage, with a hydraulic cylinder serving as one of the links. The actual knee joint is a simple revolute joint with a fixed instant center. The geometry is optimized to maximize holding torque at small flexion angles (such as when the user is standing straight up during stance). The graph of moment arm vs. flexion moment can be seen in fig: 3.

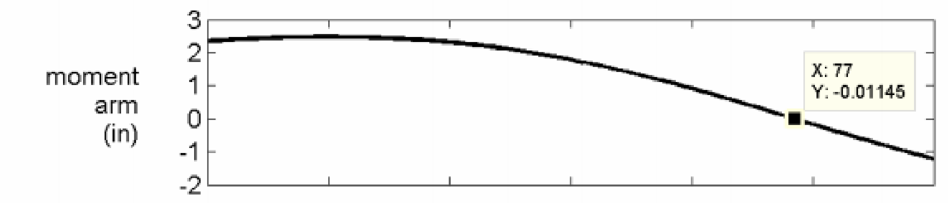


Fig 25: Moment Arm profile for DKSM

The graph shows the disadvantage of a 4-link setup as compared to a rack and pinion setup as found in the hip joint – there exists a point of zero moment arm, and thus zero holding torque. That singularity is unavoidable, no matter how the geometry is adjusted. The best than can be done is placing the singularity at the most inconvenient place possible – an angle not typically seen in normal gait patterns. In this case it is placed at 72 degrees of knee flexion, far beyond the typical range of motion found in gait. The hydraulic circuit for the DKSM is relatively simple, consisting of a single hydraulic cylinder, a single hydraulic solenoid valve, and a single hydraulic accumulator.

Since the objective is to lessen the metabolic cost of load conveying and increment the perseverance of the exoskeleton wearer, the cost capacity to be limited is the normal leftover power that the human would need to use. It has been demonstrated that the metabolic cost identified with negative work is 0.3-0.5 times that of positive work

5.4.2. Exoskeleton design

The exoskeleton was intended to track the human leg movement. Three degrees of opportunity were actualized at the hip, one at the knee, and one at the lower leg. The exoskeleton interfaces to the human through shoulder straps, an abdomen belt, thigh sleeves, and a shoe connection.

5.4.3. Calculation and equation

The Harman informational index did exclude hip edge information but rather gave the most extreme and least hip plots for strolling with a 47 kg rucksack. The hip edge from an ordinary strolling informational collection [Bogert (2003)] was scaled to fit the extreme and least point imperatives determined by the Harman informational collection. The edge information for the knee and lower leg for both the Bogert and Harman informational collections are sensibly comparative. In this manner, scaling the Bogert hip informational collection is a sensible first-arrange estimation to that of the real hip plot for a member conveying a 46kg rucksack. The aggregate mass of the exoskeleton is 15.5 kg, and it conveys a payload of 35kg (76lb). The exoskeleton is fit for carrying a bigger payload, yet 75 lb was picked as a delegated load that a fighter or administration individual may convey. Roughly, 6.5 kg of the exoskeleton mass is situated around the hips, which would build the powerful rucksack load to 40.5kg. A suspicion is made that the biomechanics of a 40.5kg viable payload and a 9 kg net exoskeleton mass can be approximated by Harman's biomechanics information of conveying a 46 kg rucksack

5.4.4. Calculation Equation and Symbol

Using conventional admittance method, we kept CF to be 1.724.For showing efficiency of our proposed variable, this report demonstrates regular admittance controller first to evaluate performance.

Arm movement Experiments with joint space force fields using an exoskeleton robot show an exoskeleton arm with seven GDL, which eliminates disturbances due to Inertia and gravity using an experimental 3D platform. They measure the position and torque at each joint, at a sampling rate of 960Hz, and calculate velocity and acceleration. They implement circuits of adaptation and filtering of the signal, to eliminate the noises generated by the derivation of the same. To measure the force, end effectors use sensors on the joints and Motorola PPC 603 drivers that support real time to the control system. The rehabilitation of the upper limbs is also a topic of great interest and importance; so several working groups in the world have developed different

proposals that seek to help in the subject.
Variables

We exhibit the idea and plan of a particular, reconfigurable lower appendage exoskeleton that can be adjusted. Variable physical stiffness property is exploited for the first time in the context of legged robot control, to the authors. The acquainted particular plan permits with make bring down appendage exoskeletons with up to four degrees of opportunity for each leg: snatching/adduction of the hip and flexion/expansion of the hip, knee, and lower leg. Every inactive joint can be stretched out by a module as far as usefulness, e.g. by activation or spring adjustment. The algorithm scheme utilized as a part of H2. The balanced reference direction θ adj is given by (1) and (2), where s is the Laplace administrator.

$\theta adj=\theta ref-\theta int$ (1)
$\theta int=GintTiJs2+Bs$ (2)

Θ ref is a vector containing the recorded points in light of typical stride from a sound subject, and θ int is the edge identified with the collaboration torque T i amongst exoskeleton and subject's appendage. This edge is evaluated utilizing the estimation of idleness J and damping B of the exoskeleton outline alone, and it increments or abatements relatively to the connection torque between the subject and exoskeleton. Accordingly, θ int as given by (2) increments and it is subtracted from θ ref, providing for the position controller an amended edge. The most extreme esteem that the adjusted direction can go astray from the recorded direction can be balanced utilizing G int, which is a standardized pick up an incentive in the vicinity of 0 and 1, where 0 permits no deviation from the reference direction. With the UI, physical specialists can change this raises value impromptu for every circumstance in light of the patient's incapacity.

5.4.6. Analysis forces applied to the system

The exoskeleton experiences different forms of forces exerted on it, which may vary depending on the users. The more weight that the user had, the more force is exerted on the device. Based on this, the design should ensure that it considers such factors. This implies that it should be able to withstand the forces exerted on it. It is supposed to be effective in use at all-time despite a number of forces that is exerted on it. Some factors to consider in order achieving this is the general structure of the system and the materials used in the construction process.

The quasi-stiffness of the knee in the flexion ($K_f = 5.276 + 0.178\overline{V}$, $R^2 = 98.7\%$, p = {0.059,0.007}) and extension ($K_e = 27.230 - 0.064\overline{V}$, $R^2 = 98.7\%$, p = {0.000,0.007}) Modes, and in the weight acceptance stage ($K_K = 16.250 + 0.057\overline{V}$)

5.6. Architecture for control of the exoskeleton

The design of the exoskeleton was based on the requirements observed. this section gives a short description of the components to be used, the type of control for the actuator and steps to develop the physical design of the exoskeleton.

5.6.1. Device and testing of gear

It is necessary to know with any degree of accuracy how evolve joint angles along the way, to efficiently control the actuator of the exoskeleton, in this case the servomotor. It is therefore an adaptable device was the lower limb, in order to create tests and obtain parameters regarding the human gait. Thus observe and analyze graphs using gait patterns and different angles to evolve. This device consists of an electronic part and a series of four belts that were developed to be adapted to the member bottom.

5.6.2. Development of belts for measuring angles member lower

In order to obtain actual movement data of the lower limb, he developed a series of belts capable of obtaining with high accuracy the angular position of one end to another. That is, you can measure the relationship between the position of the foot, lower leg, hip and leg when walking. These belts were made of two wooden rods bound together by a precision potentiometer 10k calculated for resolutions up to 256 readings per revolution value. It should be clarified that this device is presented as a tool for the design of the exoskeleton in the condition of a spinal cord injury, however it requires a more efficient design, because it has a lot of noise in the analog signals, due to the cable length between the belt and the circuit.

As previously mentioned, it does not require great precision these tests, because the same results will not be obtained test after test, or step by step. A servomotor is an electric motor, which has the capability of being controlled in both speed and position. The servos are frequently used in radio control systems and robotics , but its use is not limited to these. A servomotor can be modified for a DC motor that while longer has the capability of servo control, retains the strength, speed, and low inertia, which characterizes these devices It consists of an engine, a gearbox and a control circuit. A servo therefore has reduced power consumption. The current required depends on the size of the servo. Normally the manufacturer indicates that the current is consumed. The current depends primarily torque, and can exceed one ampere if the servo is locked, but is not very high if the servo is free moving all the time. Servomotors make use of the width modulation of pulses (PWM) to control the direction or position of the DC motors. The majority works in the frequency of fifty hertz, and the PWM signals have a period of twenty milliseconds.

5.6.3. Material prototype

The material to be used for the realization of the prototype will be the ABS, covering the needs of resistance that need strength and impact as well as being very easy to work material. The prototype will be made into a 3D printing using a printer of this kind, as the material used is the Acrylonitrile Butadiene Styrene (ABS) already mentioned, which is thermoplastic hard, heat-resistant and impact.

5.6.4. Numerical optimization

The general improvement of new designs of the equipment to assess new exoskeleton ideas has been significantly difficult. It would be important to have the abilities of test different ideas in order to understand as well as select the best ideas. This may require adaptability in the equipment as well as its control. In addition, the general progressive designs of the exoskeletons should consider various factors, which are based on the demands of the users. This makes it possible for summing up the different forms of learning acquired with exoskeletons as well as utilizes it within new exoskeleton plans. In light of the stage estimation, cyclic signs can be evaluated.

The team decided to use the evaluated signs to enhance or to lessen undesired dynamical impacts. The human exertion amid strolling and the change of human metabolic cost because of support with an exoskeleton is measured with respiratory investigation. This measure gives no understanding in how changes in metabolic vitality rise. To get this understanding, extra estimations are required. Some of these estimations are motor and kinematic measures got from step examination. This investigation can, for instance be utilized to perceive how much mechanical power the human and the exoskeleton assimilate and create.

Pressure Positions of roughly 1-3cm were observed to be required at the lower leg and hip to accomplish a full scope of movement and changed marginally relying upon the subject's life structures. Likewise, beginning analyses demonstrated that force amplitudes of 4-6cm were important to make 300N in the multiarticular stack way and 150N in the hip augmentation stack way. The team found that switching between the peak of the pull and the Tension Position of the opposite leg requires travel of Δposition = (Pull Amplitude) + 2(Tension Position) which is 8-12cm for both load paths.

The base step period for subjects strolling at 1.79m/s (4.0 mph) was measured to be 0.9 seconds. One contributing element to this was the engine requires some investment (30ms) to switch course amid which time there is little actuator movement. Having the actuator turn around bearing before allows the multiarticular stack way to have up to roughly 20% of the stride cycle (180ms) for each move between the legs. The ostensible hip force profile reaches out for 30% of the stride cycle, which gives the actuator 20% of the step cycle to switch legs.

5.7. Technologies that lead to reduced fall rates increase

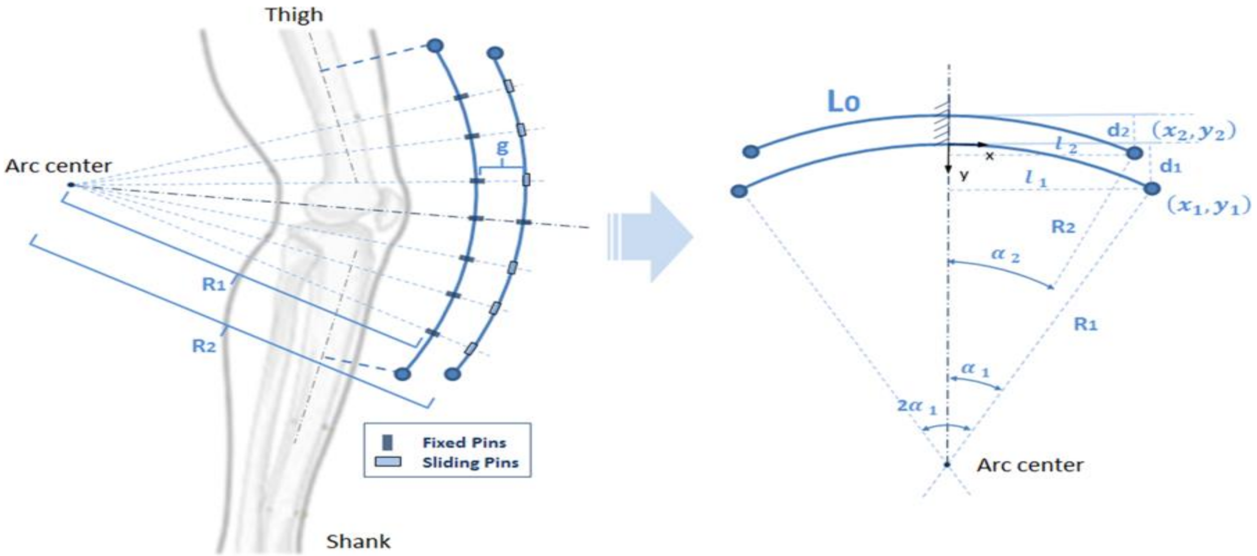
One of the major drawbacks in the use of the robot interaction devices has been their control [3]. This is because many of the devices are difficult to operate and have tedious controls. This makes their popularity low. This project aims at improving the quality of life for the elderly and disabled people. Currently, there are different devices similar to the one which is proposed in the project. Most of the devices are in experimental phase [4]. However, some are in the projection phase. Undertaking this proposal will make it possible to grasp a better understanding of the most efficient features. Moreover, it will make it possible to unravel the problems that are common in most of these robotic devices. That is, at present, there are no definite and commercialized devices or exoskeletons. This rings true for case of the exoskeleton of the lower limbs.

Figure 26: A stroke patient attending his first training session

For the development of this project, the fact that there are no definitive devices plays in our favor. This is because there is the option of design will be completely beta. In other words, the device will be the first of its kind. As such, it will be better than nothing. But there are different reasons that can lead to some type of disability in the upper limb. These causes include injuries in the marrow area of the limb (either for genetic reasons or hereditary reason), or any trauma and accident that the person may have suffered. Other cause of the injuries may be attributed to activities that lead to loss of the motor and sensory faculties of the upper extremities. Therefore, focusing on the rehabilitation of the patient is required at present. Most of the therapies are performed manually and involve routine movements in which physical effort is required by the physiotherapist.

In this sense, many developments focus on the implementation of robotic devices that can be controlled in the most natural way possible [1]. These devices should not encompass any long periods of training. For more effectiveness, the devices make use of algorithms that effectively detect the intention of the user and the use of new channels to direct the physical interface of the robot. This way, the interface, mechanical structures and controls must be based on a human model involving the person's cognitive, physical and sensory characteristics, as well as a human motor model. Therefore, progress in rehabilitation, neuroscience and prosthetics depends on acquiring a detailed understanding of how the Central Nervous System (CNS) represents motor tasks. It also involves understanding how these representations depend on the constraints imposed by the external world.

The scientific progress of such robotic limbs depends on inferring control strategies used by people with neuro-motor problems that generate disabilities. These topics are addressed in the field of human motor control. It is a field of research that intersects between neuroscience and other disciplines such as biomechanics. In many rehabilitation treatments, there are varieties of machines that enhance the improvement of the patients under treatment. They include Electro stimulator machines that alter the gravity so that patients can move their legs with less effort.



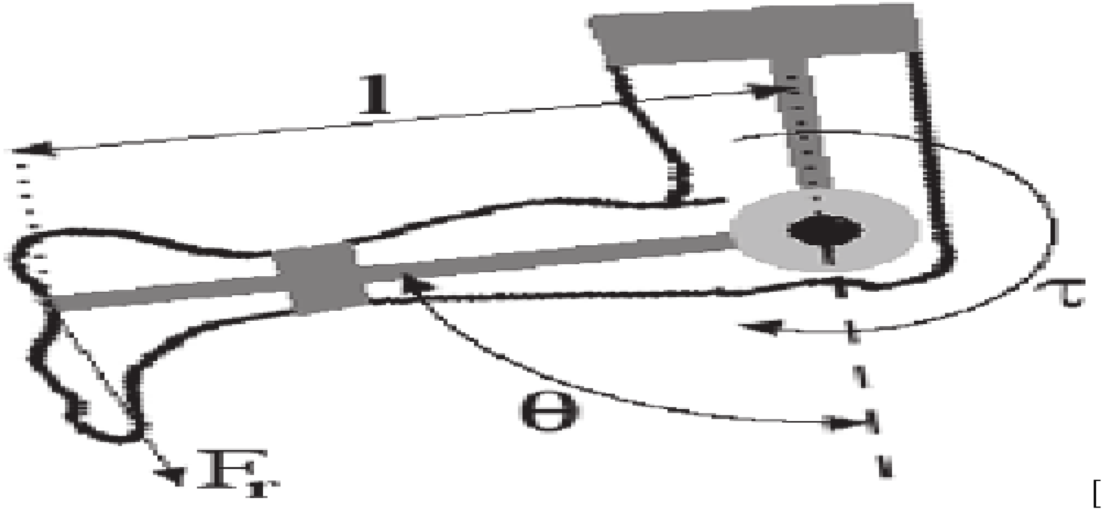
[4]

At this juncture, one has to review the role of engineering in the design, tuning and development of the robotic machines as the means of solving daily problems. One can infer that engineering involves designing apparatus that solve problems. In this particular case, there will be focus on the design of a device that is usable for exercising the movements of the upper extremities. In specific, this will be the design of a robotic exoskeleton for the rehabilitation of the upper limb. It is something novel in the real world but has been explored in science fiction many times. Owing to advances in engineering, it is now a reality and is already being tested for strengthening the lower extremities. Once it is out of the beta phase, it will be marketed for the treatment of mobility in these patients. This device allows patients with various legs problems (such as people who are in a wheelchair) to practice daily walking. In this case, there are propositions of making the patient walk in the future.

The purpose of this project is to create a self-powered exoskeleton for the improvement of human strength and endurance that is ergonomic, very maneuverable, mechanically robust, lightweight and durable. The first experimental prototype of the exoskeleton consisted of two power legs, a power unit, as well as a backpack for supporting loads. The device is rigidly connected to the user in the foot and in order to avoid abrasion and lighter on the body. By using the exoskeleton, the user can carry large loads, over considerable distances, without reducing their agility, which significantly increased their physical efficiency. The system is designed in such a way that, if the device loses power (for example, by depletion of the fuel), the legs of the exoskeleton can be removed and converted into a standard backpack.

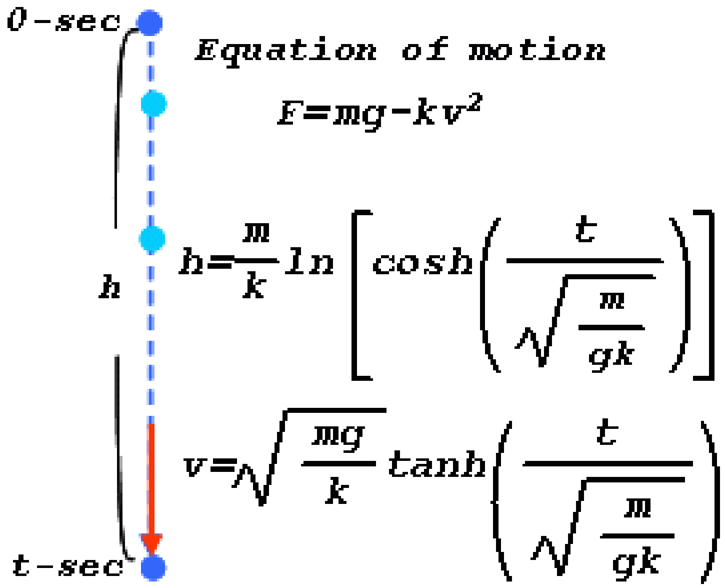
A human movement (for example, getting up from a chair) can be recognized as an aggregate of several elementary movements. The constant adaptation of rehabilitation techniques to the patient's response that is achieved through the use of an automatic motor rehabilitation device will not only avoid wasting time on ineffective therapies, but will also enable systematic treatment with better results. In the current project, a solution will be developed at the level of design and development of an exoskeleton for the rehabilitation of the upper limbs.

Studies show the human body behaves when it is under an external load [2]. Many technical aids which rectify functional disability compensation are based on the application of loads. The study will be important for the future development of technical aids which reduce disabilities. Overall, this project will attempt to elaborate on a mechanical device that adapts externally to the upper limbs. The device will be adapted to the human arms to perform the exercises with greater comfort. The design and control of the extremities of exoskeletons is different from the design and control of conventional robots, since the interface with humans is similar. A human being transfers commands to the force extenders through the contact between the extenders eliminating the need for a joystick, pushbutton or keyboard. In this unique configuration, the human body is in physical contact with the extender, exchanges both power and information signals with the extender. Due to this unique interface, the human becomes an integral part of the robot.



[3]

Equation:



[3]

Equation ==➔ F = m a

F= force, m = mass, a= acceleration

A= gravity (9.81 m/s^2)

Table.

Age (years)	Average mass (Kg)	falling Velocity (m/s)	force (N)
5-7	20.6	2.9	201.8
7-9	25.6	3.9	250.9
9-12	32	4.9	313.6

[4]

6. Conclusion

The past decade had been characterized by development of technology and increased invention and innovations. The human exoskeleton has also faced significant changes in design. The human exoskeleton has been used for different purposes, including upper body and lower body assistive activities. This project aimed at improving currently existing exoskeleton designs to come up with a better human-exoskeleton mounting interface for assisted gait rehabilitation. The selected design will help in improving the functionality of the health care industry, especially the sector dealing with neuromuscular disorders. The selected design includes use of a black box, use of motors, use of an adjustable structure, using adjustable straps, and using soft fabric. The team applied different skills and information in developing the new system. The ability to work together as a team allowed for quality in operations, which was a major factor for success for the team. The selected design will go a long way in improving physiotherapy for individuals with lower limb neuromuscular disorder.

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Appendix A: Decision matrix

Table A1: Decision Matrix
(The score of 1-10 is use, where 1 is the least effective and 10 is the most effective)

Designs:	Meets client's needs	Meets users' needs	Improves the existing designs	Total score
Design#1	4	3	2	9
Design#2	4	2	3	9
Design#3	4	4	5	13
Design#4	4	4	4	12
Design#5	4	3	6	13
Design#6	3	2	5	10
Design#7	3	5	2	10
Design#8	2	3	4	9
Design#9	3	4	5	12
Design#10	9	9	9	27
Design with highest score	**Design #10**			

Appendix B: Schedule