Exoskeleton Mount

Preliminary Proposal

Team J – Lerner Exoskeleton II

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04/07/2017

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1 BACKGROUND

1.1 Introduction

The human exoskeleton has been used for various purposes, including upper body and lower body assistive activities. This project is aimed at improving the currently existing exoskeleton designs in order to come up with a better and more effectively functioning human-exoskeleton mounting interface for assisted gait rehabilitation. The new design will help in improving the general functioning of the health care industry, especially the sector dealing with neuromuscular disorders. The existing design employs a robotic system that allows for effective functioning of motors. The robotic system also allows for abatements that provide the required assistance to individuals with neuromuscular disorder. This project seeks to make improvements to these designs and allow for the new design to be adjustable and mount effectively to lower-extremity.

The team seeks to apply different skills and information in coming up with the new design. 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, make the design adjustable, ease of donning off and on, low profile foot portion, reduce irritations, and make it strong and light weight. Through attaining these targets, the team will have met all the needs that the client had indicated which will be a success.

1.2 Project Description

Patients with lower and upper limp muscles inabilities usually require assistive devices to allow them perform tasks that require the use of these muscles. The human exoskeletons were designed for purposes of providing these assistive activities. The exoskeletons help in providing the functions that the weak muscles are not able to perform. In addition to that, the exoskeletons help in exercising these muscles in order for them to recover over time and regain their strength. Figure 1 below shows how a human exoskeleton looks like and how it functions.

Figure 1. Exoskeleton mounted to custom-molded orthotic

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 walks 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 physical activities, including advancement in technology under this sector.

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 disorder and assisting them in exercising their muscles. The original systems were built in specific sizes and could not be adjusted [2]. The systems use materials that are readily available, including strong metals, such as iron or aluminum, to providing enough support to the users. In addition, there are soft materials that help in improving the comfort of the system thus allowing for effective use. Despite the designs, they still need improvements to make them better.

1.3.2. Original System Operations

The exoskeletons have been operating in different ways. The systems have continuously undergone changes over the years with development in technological knowledge. 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 and resulted to the introduction of control by a third party, where an individual had to help the users to operate the skeleton [3]. To further advance the designs, the systems now include operations that allow the users to control the skeletons by themselves. This advancement 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 in order to increasing user satisfaction as well as meeting the increasing needs of patients [1].

1.3.4. Original System Deficiencies

Despite what the original systems were built for, they have various deficiencies that requires much attention. 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 [1]. The systems are also limited to specific users since they are not adjustable. This 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 since technology has significantly developed with no improvements in the systems.

2. REQUIREMENTS

The client and users have various requirements for the design. The client seeks to improve the original system to have mounting points that are rigid, both to the thigh and to the shank. In addition, the clients want 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 [1]. Other requirements include ease of putting on and removing, minimizing of the irritation caused by the system, and ensuring that the design is light in weigh for effectiveness in its use.

2.1. Customer Requirements (CRs)

The client and users have various requirements for the design. The client seeks:

- ✓ To improve the original system to have mounting points that is rigid, both to the thigh and to the shank
- ✓ 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

- ✓ Making a design that has ease of putting on and removing
- ✓ Minimizing of the irritation caused by the system
- ✓ Ensuring that the design is light in weigh to use effectively

2.2. Engineering Requirements (ERs)

From the client's requirements, the engineering requirements may be interpreted to include:

- Use strong materials
- Adjustability
- Use soft fabric
- Limited weight
- System's size

2.5. House of Quality (HoQ)

We have a goal to make it modest to fulfill client needs. This will be troublesome, yet at the same time, we will adjust our plan to meet the necessity. Our point is to concentrate on what we are outlining and to actualize the thoughts of the better plan to our unique outline to make an ideal item. Through this progression, the group understood that the elements like power, life expectancy, cost, weight, ease of use, all-climate readiness, short setup time, nonhazardous, standard parts utilized and Level of inventiveness are most imperative to be given first significance while outlining the gadget.

HOQ helps us analyze gadgets given various parameters. It investigates the plan to be chosen. This helps us in settling on the choice of selecting the plan. Remembering every one of the prerequisites, which we have investigated above, does this [3]. The requirements list encase that the plan must be moveable, light in weight, adaptable, simple to deal with, minimal effort, less settling time and the simplicity of use. This rundown helped us a considerable measure while planning the gadget. This procedure helped us in making functional enhancements.

3.0. EXISTING DESIGNS

There are numerous gadgets in the business and market which are intended for assisting individuals. We have inquired about various gadgets on intrigue, particularly which have been intended for disabled patient. We focused on systems that can help the debilitate individuals to do their specialty with no trouble. People with restricted versatility are regularly not able to mingle; prompting to formative difficulties sometime down the road [3]. To discover the requirements of these sorts of outlines, we looked into many articles and went by sites. The site handicapped world additionally gave a total diagram on how the plans must be made to feel the incapacitated individuals to an effective mode. Moreover, the site was also a decent source which helped us a ton to comprehend the prerequisites.

3.1. Design Research

Different designs have been created ever since the first exoskeleton was invented. These designs have been improving on their abilities 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 [3]. From getting to know the different challenges and downsides facing these designs, the team reduced this to a formula in order to design a system that solves all these problems. The team is currently working on this aspect of design.

3.2. System Level

The exoskeleton systems have undergone different forms of changes over the last couple of years. Existing exoskeleton restoration robot contemplates have for the most part centered on the position and drive control, and they go through 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 [4]. This project proposed a mixture of various leveled dynamic and responsive control design for the created exoskeleton restoration robot framework. Amid the creating of control calculation, the neuromuscular exoskeleton model is received, which is useful in building up a natural intuitive interface amongst exoskeleton and administrator.

3.2.1. Existing Design #1: The ReWalk exoskeleton

This exoskeleton 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. This computer includes motion sensors that help in restoring self-initiated walking through sensing of the forward tilt of user’s upper body. It then mimics the gait pattern of able-bodied individuals.

3.2.2. Existing Design #2: The Vanderbilt Exoskeleton

The Vanderbilt exoskeleton is a design that was made by Goldfarb. This exoskeleton is advanced in nature as it assists users in performing the basic motions, including walking, standing, sitting, as well as walking up and down stairs cases. 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.

3.3 Subsystem Level

In this project, the LRR Subsystem is intended to give independent preparing to patients who are occupied with rehashed and serious assignment particular practice to enhance and bring down furthest point engine work. Plus, studies have demonstrated that dynamic association for administrators in the creation of an engine design which brings about more noteworthy engine learning and maintenance than detached development. Wellbeing: The recovery framework is a patient questioned framework [4]. Guaranteeing the security of the subject is an essential issue. The patient ought to guarantee the most astounding need in the execution of the context because the human is inside the control circle. 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. For programming outline, it incorporates the impediment of servomotors' torque and turns point through servomotor drivers, including important security judging explanations, and so forth.

3.3.1. Existing Design #1: The ReWalk exoskeleton

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. It helps in improving the quality of their life. This design has incorporated the use of technology to allow for movement by the users. It is among the few exoskeletons to be manufacture that include the use of advanced and up to date technologies that influence its reliability.

3.3.2. Existing design #2: The Vanderbilt Exoskeleton

The Vanderbilt exoskeleton has been design in a way that it includes brushless direct current motors used to actuate the knee and hip joints. The design has a total weight of 12 kilograms making it among the lightest exoskeletons to be built. The exoskeleton has been used by individuals with T10 motor and sensory injury where it worked in a deserved manner. It provides repeatable gait with hip and knee joints aptitudes that are same to the ones observed while in non-SCI walking.

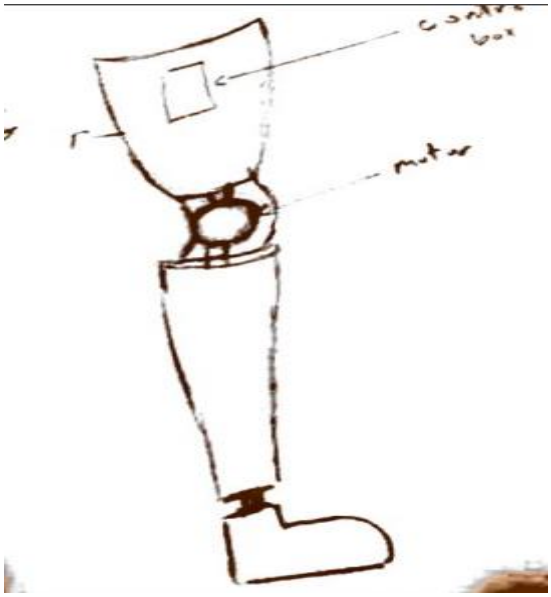
4.0. DESIGNS CONSIDERED

The team considered different designs while brainstorming. 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.

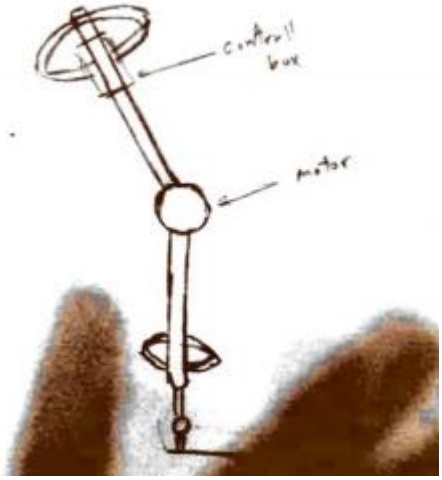
Incorporating the black box will be significant for the team. This will help in improving the general performance of the exoskeleton, where the user will be able to coordinate it with minimal efforts and significant ease. On the other hand, this may be expensive to install and maintain since it may require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



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.

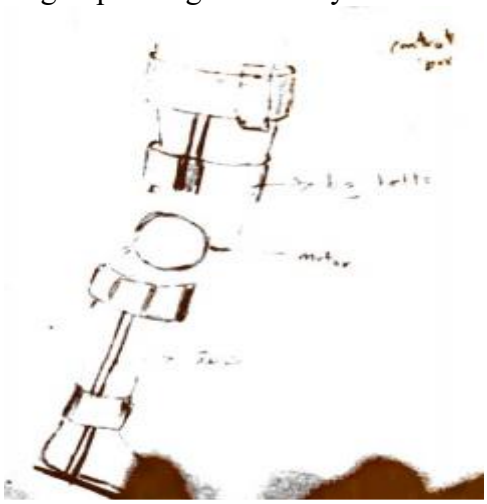
Using the motors will be advantageous for the design. For example, the design will be able to move effectively at the joints. To make it work better, joining the black box and the motors will allow for quality coordination and ease of use of the design. On the other hand, the motors may also require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



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.

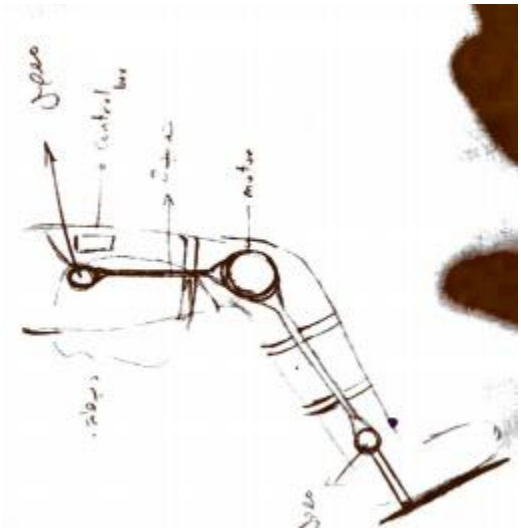
The design will be advantageous since it will be effectively used by individuals of different ages. For example, user of between the ages of 6 and 9 can be able to use a single design, which is just adjusted to suit their preferences or sizes. Despite this, the team may require using additional material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



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.



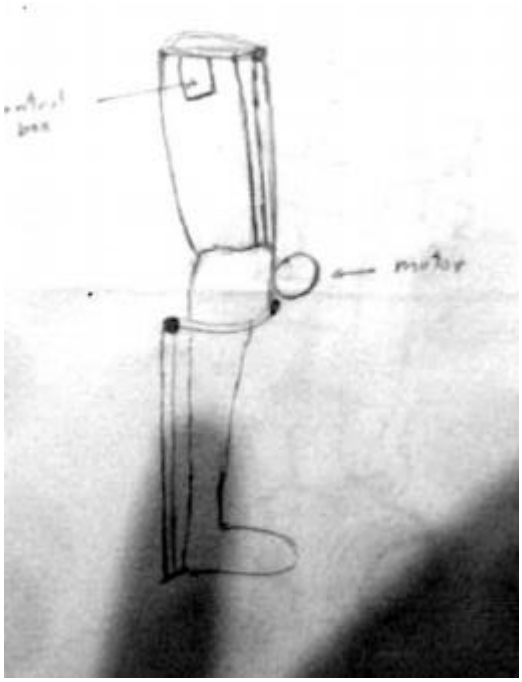
4.5. Design #5: Soft fabric

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.

4.6. Design #6: Iron Structure

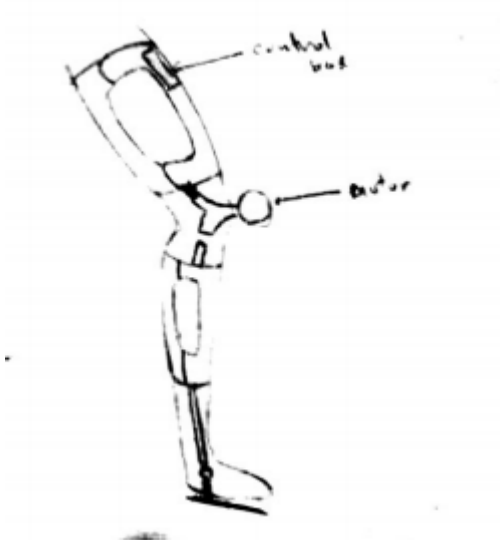
The team considered using an iron structure. The rods supporting the structure need to be strong. The team considered using iron rods in order to make the structure strong. This design is advantageous since it makes the structure strong and easily used by users of different weights. However, using iron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



4.7. Design #7: Aluminum Structure

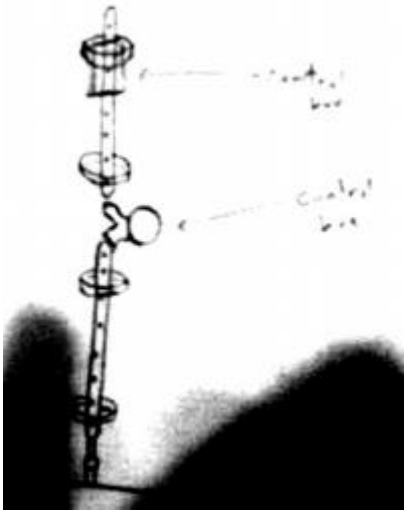
Further, the team considered using aluminum for the structure. The team considered this since it allows for the use of a strong metal and light at the same time. This will make the design easy and effective to use since it will not be heavy. However, the metal may easily bend, which

makes it unsuitable for use in the structure.



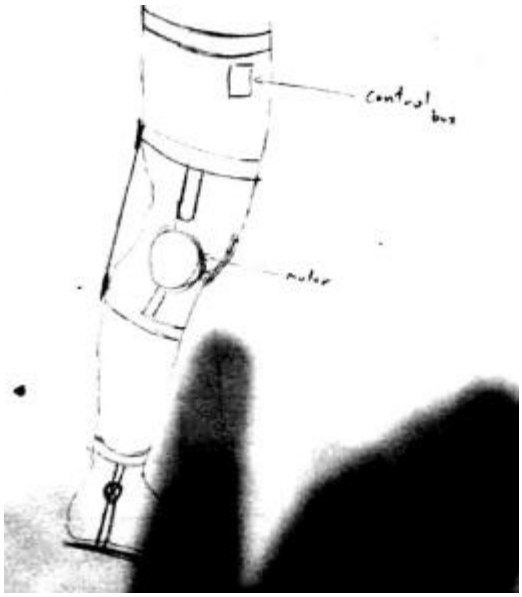
4.8. Design #8: Complete Cover

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.



4.9. Design #9: Partial Cover

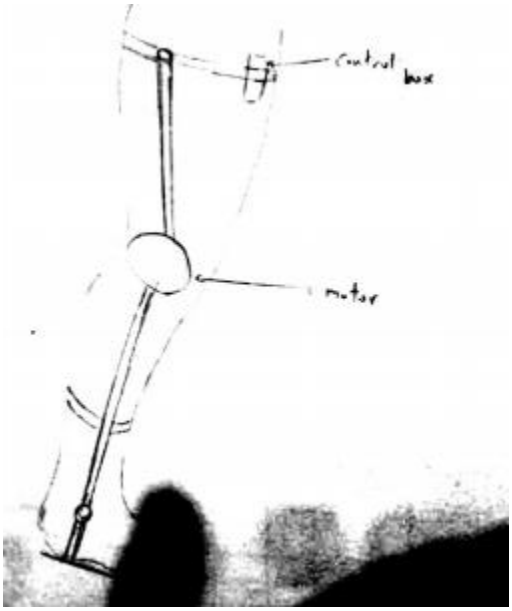
On the other hand, the team considered a design that covers the users' legs partially. This design will use straps rather that complete covers. The straps will be located in different places on the leg to allow for effectiveness in griping. The design allows for quality use and reduces irritation as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



4.10. Design #10: Incorporative design

To make the system effective, the team considered a design that incorporates designs 1, 2, 3, 4, and 5. 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.



5.0. DESIGN SELECTED

The team selected design #10, which is a combination of several desings to meet the clients and unsers‘ requirements.

5.1. Rationale for Design Selection

The team decided to work with this design since it meets most 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. 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.

REFERENCES

[1] M. Hasan, S. Shakeel, F. Malik, A. Khalid, K. Mir, and S. Ahmed. Design and structural evaluation of a lower limb passive exoskeleton. In *Computer, Communications, and Control Technology (I4CT), 2015 International Conference on* (pp. 112-116). IEEE.

[2] S. J. Miller. *The Myotron-Aservo-Controlled Exoskeleton for the Measurement of Muscular Kinetics: Final Technical Report*. Buffalo, N.Y: Cornell Aeronautical Laboratory, Cornell University, 2008, pp. 23-114.

[3] S. Moromugi. *Exoskeleton Suit for Human Motion Assistance*, 2003, pp. 45-165.

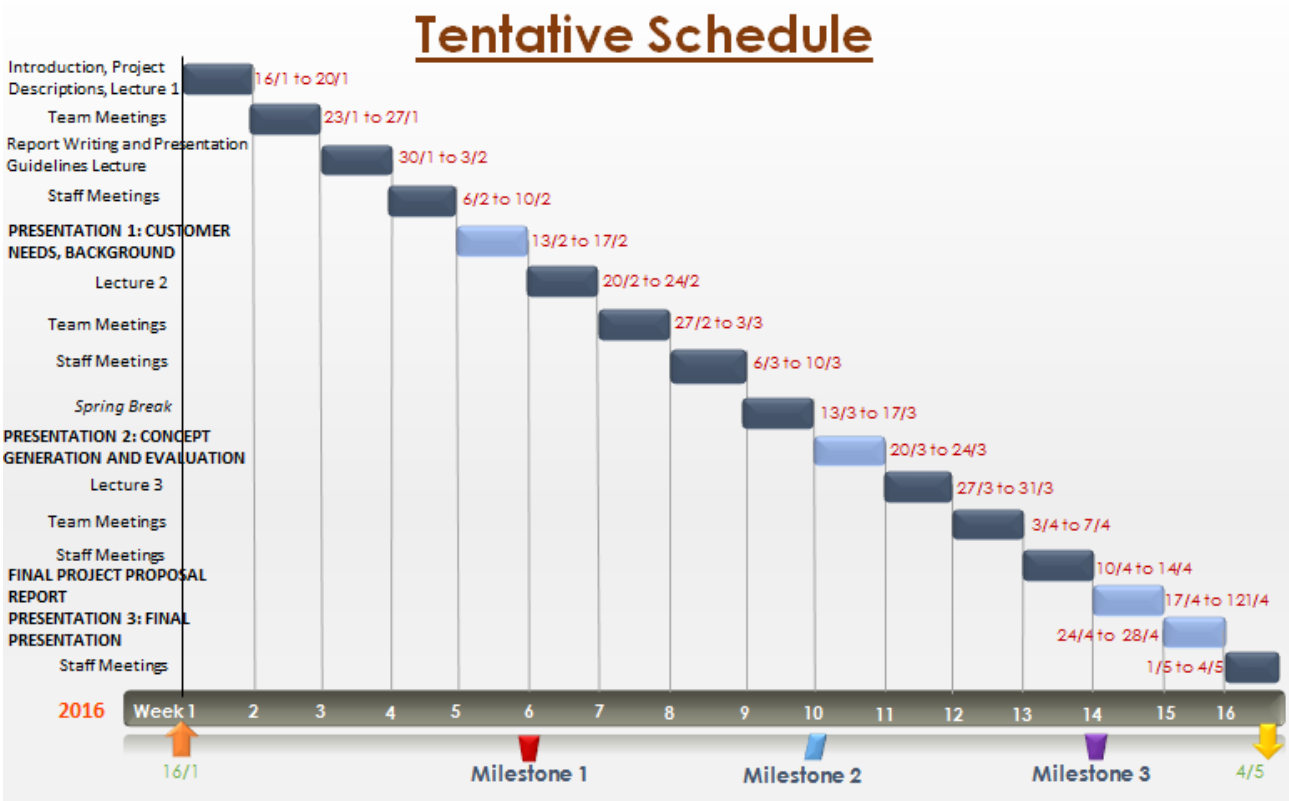
[4] W. Michael. *Lower Extremity Exoskeleton As Lift Assist Device*, 2009, pp. 16-67.

Appendix A

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**			

Schedule



House of quality

The Customer Requirement	**The Weight**	**The Engineering Requirement**	Use by individuals of different ages	Quality and strong materials	Minimizing irritation through using soft fabric	Minimize the weight	Make the system's size reasonable
Rigid mounting points at points on the foot shank as well as the thigh	4		5	4			5
Adjustability	5		5				
Easy to wear and remove	4		5				5
Minimize skin irritation	4				4		
Effective in use	3		5	4	3	4	
Strong and still light weight	5			5			
The Absolute Technical Importance (ATI)							
Relative Technical Importance (RTI)							
The Target(s), with Tolerance(s)							
Testing Procedure (TP#)							