Lerner Exoskeleton I

Background Report

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DISCLAIMER

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1.0. BACKGROUND

1.1. Introduction

This project aims at making improvements on the current existing exoskeleton design to develop a better functioning Adjustable Human-Exoskeleton Mounting Interface for Assisted Gait Rehabilitation. Further, the health care industry usually utilizes robotic exoskeletons in improving walking biomechanics among people who tend to have neuromuscular disorders. Haptics, Kajimoto, Ando, and Kyung state that the system's powerful motors and their transmissions usually act together in providing assistance to an individual's ankle and their knee joints [1]. This project aims at coming up with a design that is adjustable and allows the exoskeleton's mechanical components to mounted effectively to the lower-extremity.

In addition, the team seeks to operate under a budget of approximately $500 in coming up with the new design as well as ensuring that it is able to function as required. There are different targets that the team seeks to meet by the end of the project. For example, the team is looking forward to ensuring that the design can provide stiff mounting points to user's foot, shank, and at the thigh, to make adjustments to different sizes of users' limbs as well as accommodate people of different ages, make it easy to doff/don, minimize on the skin irritation by the physical interface, low profile foot portion, and make it lightweight. By attaining these specification and client's requirements, the team will have accomplished it mission in improving the exoskeleton design.

1.2. Project Description

Haptics et.al [1] argues that the health care industry usually makes use of a robotic exoskeleton in improving the health conditions of people that have issues relating to neuromuscular disorder. A system with powerful motors and transmissions act in providing guidance to ankle and knee joints [1]. However, attaching this transmission system to the body may at times prove to be quite a challenge. This project aims at improving on the current Adjustable Human-Exoskeleton Mounting Interface to an adjustable design that can be effectively mounted on the lower-extremity. The figure below, figure 1, shows the Adjustable Human-Exoskeleton Mounting Interface.

Figure 1: Adjustable Human-Exoskeleton Mounting Interface

1.3. Original System

There are various systems that have been in existence used for purposes of assisting individuals with neuromuscular disorders. As stated by Walsh and MASSACHUSETTS INST OF TECH CAMBRIDGE MEDIA LAB, the original systems have been faced with significant challenges, including being heavy for the users, not being strong enough, poor quality designs, not meeting demands by users, and inability to be adjusted, among other negative factors [2]. Such issues made people to seek for custom make exoskeletons that would meet their needs, which proved to be quite expensive to many users. However, the team seeks to look into these issues and come up with a better design that is able to provide greater satisfaction to its users as well as meeting the requirements of the client.

1.3.1. Original system structure

The original structures for the robotic exoskeleton are made for purposes of suiting people from different age groups. Walsh and MASSACHUSETTS INST OF TECH CAMBRIDGE MEDIA LAB [2] argue that the robotic exoskeletons are designed in a manner that they are able to fit individuals based on their sizes, where some are created to be small, used by children, while other are designed to be bigger, for use by adults. The materials used in their production are of good quality, where they are strong and durable and serve the expected purposes in an effective manner [2]. The materials are meant to ensure that the users remain comfortable when operating in them, such as ensuring that the skeleton is not heavy and the rate of injury is reduced in case of any accidents. The use of soft materials on points that are in contact with the body allow for increased comfort while operating them [2]. The general concepts of these designs are aimed at ensuring that the users are comfortable and that the designs serve their intended purposes.

1.3.2. Original System Operation

According to Walsh and MASSACHUSETTS INST OF TECH CAMBRIDGE MEDIA LAB [2], the original systems come in different forms, where there were those that are controlled by the users and those that are controlled by another party other than the users. The design is fitted with sensors and operating systems that allow for the users to operate them while they are using them [3]. On the other hand, the designs that are operated by parties other than the users usually require the users to use the skeleton only when there is another person to operate it. According to Ceccarelli and Glazunov, both designed served their purposes in an effective way despite the different forms of challenges that are experienced [3].

1.3.3. Original System Performance

The original designs performed their intended purposes as expected but with minimal challenges. The systems are designed to provide assistive movements and strength for individuals with limited strengths in their muscles [2]. These systems served the purposes in an effective manner, since they have been used over the years to provide the assistance required. However, through development in technology as well as other factors, these systems need to be improved in order to make them function in a more effective manner.

1.3.4. Original system deficiencies

There are different forms of deficiencies that are facing the original systems, which the team is seeking to look into and improve on them. For example, the systems currently use materials and components that make them heavy, which affect the amount of time that one can use them without taking a rest [3]. In addition, the mounting on the foot and thigh is not of the best quality and need to be improved for purposes of better grip. The systems are not adjustable, which is quite a challenge. This means that individuals have to seek designs that are custom made, which is a significant challenge in terms of cost and other factors [2]. In addition, some systems use materials that irritate the users, which make them uncomfortable to use.

2.0. REQUIREMENTS

There are various requirements that are tasked to the team to ensure that it improved on the currently being used designs and make it better and more liable. These requirements are the customer requirements, which may then be interpreted to the engineering requirements

2.1. Customer Requirements (CRs)

Our customer requirements already assigned to the team by the project description. After discussing with the client, the team weighted these requirements from 0 (less important) to 5 (most important) as shown in the table1.

Table1. Customer Requirements and Weights Scale

Customer Requirements	Weight (5)
Providing rigid mounting points to foot shank and the thigh	5
To allow the design to be adjusted to various sizes of limbs and accommodate individuals of between the ages of five and seventy-five	3
To make the design easy to doff/don	2
To minimize skin irritation by the physical interface	4
To allow the foot portion to be low profile as well as insert into normal shoes	4
Make the design lightweight and at the same time strong	5

2.5. House of Quality

The HoQ usually helps in making analysis of the design based on different considerations. An analysis of the combination of the client's requirements and the engineering requirements will allow for the team to come up with a better and more effective design. The interpretation made by the team will be incorporated within the design to make it function better despite any form of challenges that the team may face. The team seeks to come up with a design that fulfills all the client's needs and requirements. Attaining this may be a challenge but the team is determined to ensure that all the requirements are met. The team seeks to ensure that it sticks to is schedule as well as to actualize the different thoughts of the design in order to come up with the best end product. Based on the analysis of the requirements by the client, the team interpreted that there are elements that are of great concern, including the power of the skeleton, the life expectancy, the weight, cost, ease of use, setup time, all-climate readiness, nonhazardous, level of incentives, and standard parts utilization. The elements may ensure that the design work in an effective manner and meets the needs of the client as well as those of the users. To make the design effective, the team will use the following HoQ table to make its analysis:

Table2. House of Quality

Customer Requirement	**Weight**						
Providing rigid mounting points to foot shank and the thigh	5						
Adjustable	3						
Easy to doff/don	2						
Minimize skin irritation by the physical interface	4						
Allow the foot portion to be low profile and insert into normal shoes	4						
Lightweight and at the same time strong	5						

3.0 EXISTING DESIGN

Research in the powered human exoskeleton devices started in the 1960s, which was almost in parallel with other research groups within the United States and former Yugoslavia [4]. As state by Haruhisa, Ueki, Ito, and Mouri [5], the former, however, was mainly focused on the development of technologies for purposes of augmenting the abilities of individuals who are able-bodied, mostly for military purposes. Haruhisa et.al [5] adds that the latter was focused on developing technology that was assistive in nature for the physically challenged individuals. Ever since them, different designs have been developed over the years, where most of them were meant to improve on the existing designs while others were entirely new designs [4].

3.1. Design Research

There are various designs that have been created over the years to make individuals with lower body disabilities to improve on their effectiveness. The team looked into earlier designs and analyzed them into details. The analysis allowed the team to come up with issues relating to the existing designs. Based on these issues, the team was able to come up with was to improve on the design that it seeks to develop, which will include improving on the issues that are being faced by the current designs. In addition, the team looked into different sources of information, inducing books and articles, to find more information relating to the design and how to make the design work better and in a more effective manner.

3.2. System Level

The existing exoskeletons have for many years centered on position and drive control. They go through three different phases in advancing over the past decade. The first system level was based on a system that was controlled by an administrator, such as the Hardiman exoskeleton [3]. This design grew into improved skeletons that could then be controlled by individual users. The team seeks to use a combination of various systems to make a better and more effective design that is able to meet the needs of the users.

3.2.1. Existing Design #1: Berkeley Exoskeleton

This is considered the most visible DARPA program exoskeletons, which is a Berkeley Lower Extremity Exoskeleton. The exoskeleton is designed to provide effective assistance to individuals with lower body disorders [4]. The design is energetically autonomous and carries its own source of power. Its developers state that it is considered as being an exoskeleton that is load-bearing and energetically autonomous.

3.2.2. Existing Design #2: Sarcos Exoskeleton

Der et.al states that this is a full body exoskeleton that is a wearable energetically autonomous robot. This exoskeleton is energetically autonomous implying that is usually carries its own power supply unit. It has advanced in its hydraulically actuated concept [4]. Instead using linear hydraulic actuators, it employs rotary hydraulic actuators that are located directly on its powered joints, which makes the devise more powerful and effective to its users.

3.2.3. Existing Design #3: MIT exoskeleton

The MIT exoskeleton is a quasi-passice exoskeleton concept that has been developed in Massachusetts Institute of technology Media Laboratory. The design exploits a passive dynamics of the human walking style for purposes of creating a lighter as well as more efficient exoskeleton device [4]. The design does not use actuators for powering the joints. Rather, it relies on controlled release of energy that is stored in springs during the walking gait phase. This system was based on the kinetics and kinematics of the human walking design.

3.3. Subsystem Level

According to Wenger, Chevallereau, Pisla, Bleuler, and Rodic in their research, looking into the system components is important for making the design a success [6]. The system levels are usually made up of smaller components within them. Wenger et.al further explains that an analysis of these components will ensure that the team gets a better understanding of the concepts involved in the design and allow for the ability to come up with a better and more effective design to meet the needs of the clients as well as the needs of users [3]. For example, looking into finer components of the motors may allow for a better and effective understanding of the interactions between various parts of the skeleton, which will then allow for improving the design to allow the system to relate and function even better.

3.3.1. Existing Design #1: Berkeley Exoskeleton

As stated by Mankala, Banala, and Agrawal in their research, the Berkeley Exoskeleton features three DOFs, where one is placed at the hip, the other at the knee, and the last one at the ankle. Mankala et.al [7] adds that out of these, four of them are actuated, including hip flexion/extension, knee flexion/extension/ hip abduction/adduction, and ankle flexion/extension. The hip rotation joints and the ankle inversion/eversion are spring-loaded [2]. On the other hand, the ankle rotation joint had been made to remain free-spinning.

3.3.2. Existing Design #2: Sarcos Exoskeleton

Mankala shows that the Sarcos exoskeleton usually uses force sensing that is between the robot and wearer in order to implements a systems referred to as "get out of the way" system [7]. The foot of the wearer usually interfaces with the system through stiff metal plate that contains force sensing elements, which makes the feet of the wearer to remain stiff and not to bend.

3.3.3. Existing Design #3: MIT exoskeleton

The MIT exoskeleton uses a 3 DOF hip, as explained by Mankala et.al, which usually employs a joint that is loaded with a spring in a flexion/extension direction that is used in storing energy at the time extension is being released during flexion [7]. The design includes a mechanism that allows the user to freely swing their hip towards the direction of the flexion.

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