Robotic Exoskeleton for Neuromuscular Rehabilitation and Exercise (Fourth Generation)

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***Abstract*— With an aging population comes an increased need for advanced rehabilitation. Modern technological advances in the field of robotics are paving the way for high-tech yet cost-efficient biomedical devices. Exoskeletons allow for the rehabilitation of the neuropathways as well as an increased ability in motor function. The fourth-generation design of the robotic exoskeleton for neuromuscular rehabilitation and exercise is the embodiment of this idea. Using the information provided by the three previous generations, as well as the understanding granted from studying other designs and patents, an easy-to-use and sustainable rehabilitation device comes to fruition.** *(Abstract)*

Keywords-component; formatting; style; styling; insert (keywords)

I. INTRODUCTION *(HEADING 1)*

A stroke is defined as a massive blockage of blood flow to the brain, causing immediate death of brain cells. Approximately 800,000 Americans suffer from a stroke each year. This trauma can cause long-term disability and often leads to death. [1]

Following a stroke, survivors often suffer from both physical and mental ailments. While many of these issues can be treated with rest or medicine, physical aftereffects require prolonged rehabilitation. Physical conditions common among stroke survivors include weakness, paralysis, and inattention to one or both sides of the body. [2] The exoskeleton aims to combat these issues on all fronts. The movement of the exoskeleton rebuilds the neuromuscular pathways in the brain and provides stimulation to the affected muscles.

With an increase in the number of stroke patients comes the need for a more efficient method of rehabilitation. This project involves the redesign and enhancement of an exoskeleton used for rehabilitation and exercise. The purpose of this project is to design an external apparatus to assist patients with neuromotor impairments as they progress through their rehabilitation. In order to accomplish this rehabilitation, the device utilizes a master-slave setup. When a user flexes and extends the forearm on their side unaffected by stroke, the motor on the other extremity actuates. This mirroring allows the brain to rebuild neural pathways previously diminished by stroke and regain lost functionality. This device provides aid in the restoration of a patient's mobility and strength, allowing patients to perform movements consistently and predictably, while accurately tracking their progress. The use of robotics creates a system that is efficient, sustainable, and cost-effective.

II. DESIGN

A. Design Overview

Stroke rehabilitation is usually confined to a rehabilitation clinic, and the necessary equipment cannot be transported to a patient’s home. These limitations cause rehabilitation to take a lot of time and are often accompanied by a large out-of-pocket cost. Each year, stroke rehabilitation costs the United States an average of 32 million dollars. [1]

This design aims to provide independence and ease to the user as they progress through their rehabilitation, without adding the extra burden of cost.

B. Components

The key features of the design include the frame, the circuitry, and the control system.

The frame of the exoskeleton includes two arm braces, each configured to fit either the left or right arm of the user. The mechanical components of the frame are manufactured out of aluminum. Aluminum is strong yet lightweight and can be processed at a minimal cost. Each frame is situated on the outside of the arm, with upper arm and forearm supports connected by a joint at the elbow. The frame is a two-bar linkage with adjustable cuffs, a housing unit on the back of the upper arm, and hand supports. The adjustable cuffs allow for the device to be used on patients of varying sizes. The components of the frame can be seen in Fig. 1.

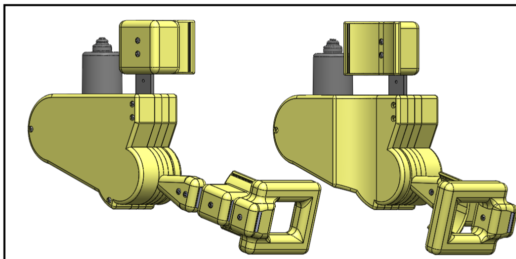

Figure 1. Exoskeleton frame

The housing unit carries the electrical system and the accompanying individual components, including the control system hardware and the motor. The system is programmed

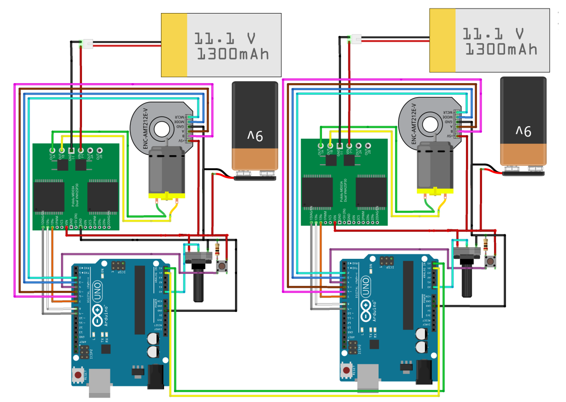

Figure 2. Circuit configuration

using an Arduino Uno microcontroller and the Arduino Integrated Development Environment (IDE). The Arduino ATmega328P boasts high-performance capabilities while remaining compact and inexpensive. Two separate power supplies are used to supply power to either the control system or the motor. The motor driver feeds directions to the motor from the microcontroller, allowing for movement. The circuit schematic is displayed in Fig. 2. Because the exoskeleton is designed to service both sides of the body, two of each component are included in the circuit. Included in each side of the circuit is an Arduino Uno R3 with an ATmega328P microcontroller chip, a 12-bit capacitive modular encoder, a DC gear motor, a Pololu motor driver carrier, and the logic and motor power supplies.

C. *Operation*

The operation of the device relies on user input. The exoskeleton has two settings. The first setting is a master-slave configuration designed for patients with decreased ability in only one side of their body. The fully functioning arm acts as the master while the arm with a decreased ability acts as the slave. The user moves the master arm, triggering a similar movement in the slave arm.

In the second setting, the user can control the speed and direction of the movement using buttons placed near the handgrips. The speed and direction designations are programmed into the Arduino using pulse width modulation (PWM) and the 12-bit encoder.

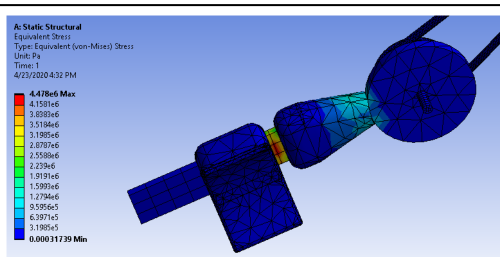

Figure 3. Stress concentration testing results

D. *Artistic Integration*

Deviating from the three previous generations of the exoskeleton, the expertise of an art student was used to ensure a sleek and ergonomic design.

III. Experimentation and Results

The physical exoskeleton was tested to ensure that the design would not break during use. Mesh testing was done using Ansys software, resulting in stress concentration and displacement analyses. The results of these tests are displayed in Fig. 3.

IV. Conclusion

The purpose of this design is to aid in the rehabilitation of stroke patients. Using precise readings of the muscle and brain activity, a more efficient exercise to assist patients with neuromotor impairments is possible. The ability to allow the patient to program their exercises on an ambidextrous system is what makes this project stand out from the rest.

The fourth generation of the robotic exoskeleton for neuromuscular rehabilitation and exercise will improve the lives of patients suffering from the decreased motor ability. The design is optimized to ensure a sustainable and cost-efficient apparatus that puts the needs of the consumer at the forefront.

Acknowledgments

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The design team would also like to thank the students involved in the three previous generations of the exoskeleton.

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