EXOSKELETON ARM FOR THERAPEUTIC APPLICATIONS AND AUGMENTED STRENGTH

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Abstract - *People who are victims of stroke, accidents and spinal cord injury require a long recovery time and workers are forced to take leave due to injuries triggered by heavy lifting. This project proposes a solution by implementing a 2 degrees of freedom (DOF) lightweight, wearable, powered exoskeleton arm for rehabilitation and augmented strength. The proposed solution is unique where it incorporates lightweight Aluminium frame with 3D printed parts and is operated with the help of electric motors controlled by microcontrollers with pre-set control. The data can be collected and saved into a higher platform depending on the user's decision. Through on board sensing, the skeleton can provide rich data, such as range of motion for use in physical therapy. This data can be used by doctors and patients to accurately track improvement over time. It also provides augmented strength for people suffering from injuries. Thus the proposed exoskeleton is feasible and efficacious.*

Keywords: Flexion, Extension, rehabilitation, pushbutton switch.

1. INTRODUCTION

In recent years, technology has improved healthcare, which means that the life expectancy of patients has increased. Despite this, some patients can live with functional dependencies, which implies a limitation or decrease in their welfare, it is at this point, where the rehabilitation appears. Technology is a branch, which is constantly advancing and developing. It is involved in almost all fields of work, such as military, social, among others. Throughout the last decades, medicine and engineering have worked together in order to develop new systems of rehabilitation, studies of the human body and its limits. In this way, patients could use the new technologies to recover mobility affected or lost due to illness or accidents.

An exoskeleton is a wearable mobile machine that is powered by a system of electric motors, pneumatics, levers, hydraulics, or a combination of technologies that allow for limb movement with increased strength and endurance. Robotics is the application of engineering towards replacing humans from menial tasks, while exoskeletons are the application of robotics and bio mechatronics towards the augmentation of humans in the performance of a variety of tasks. Therefore, in biomedicine the exoskeletons are one of the tools which have been created to improve both the rehabilitation and to dis- cover the new limits of the human body. To explain this in easier words, an exoskeleton is basically a wearable mechanic device and they work in tandem with the user. Exoskeletons are placed on the user's body and act as amplifiers that augment, reinforce or restore human performance. Kinematics of the exoskeleton arm is relied on the human upper limb especially on arm. The human arm has 2 degrees of freedom which consist of flexion/extension of hand, flexion/extension of the elbow.

It is made out of rigid materials such as metal or carbon fibre, or can be made entirely out of soft and elastic parts. They are powered and equipped with sensors and actuators and are mobile or fixed/suspended. Exoskeletons can cover the entire body, just the upper or lower extremities, or even a specific body segment such as the arm, ankle or the hip. The project consists of the design of an exoskeleton especially developed for the fingers and arm rehabilitation with passive motion and augmented strength to help people with limited mobility in their hands.

2. SYSTEM ARCHITECTURE

The following requirements were formulated for a rehabilitation hand exoskeleton that attaches to an arm exoskeleton:

Design Requirements:

1. Low Mass: Mass at the hand must be minimized to reduce required torque of the upper limb exoskeleton.
2. Torque: The torque capabilities of the exoskeleton must be sufficiently large to actuate the hand.
3. Workspace: The workspace of the exoskeleton must contain the workspace of the human hand.

4. Grasp: It must be able to actuate a variety of grasps.

5. Open Palm: It must leave the palm and fingers unoccupied to permit interaction with physical objects.

6. Unisize: It must fit 95% of the general population.

The design of exoskeleton consists of 2 DOF. This proposed robot arm can be used easily with either the user's left or right arm. This robot arm is designed to have low inertia, high stiffness link, and zero backlash transmissions. It supports the patient's arm during rehabilitation which is a repetitive task and takes a period of time. Each joint of this exoskeleton can be rotated from -90 to +90 degrees.

2.1 Degrees of Freedom

The number of independent ways by which the hand can move, without violating any constraint imposed on it, is called number of degrees of freedom. In other words, the number of degrees of freedom can be defined as the minimum number of independent coordinates that can specify the position of the system completely.

The proposed exoskeleton arm has 2 degrees of freedom which consist of flexion/extension for elbow and fingers. In anatomical terms, Flexion and extension are movements that occur in the sagittal plane. They refer to increasing and decreasing the angle between two body parts:

Flexion refers to a movement that decreases the angle between two body parts. Flexion at the elbow is decreasing the angle between the ulna and the humerus. When the knee flexes, the ankle moves closer to the buttock, and the angle between the femur and tibia gets smaller. Extension refers to a movement that increases the angle between two body parts. Extension at the elbow is increasing the angle between the ulna and the humerus.

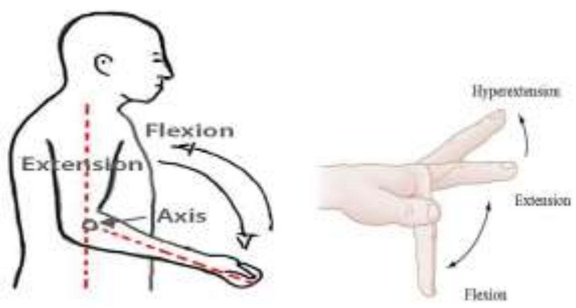

Fig -1: Flexion & Extension of elbow and fingers.

2.2 Block Diagram Representation

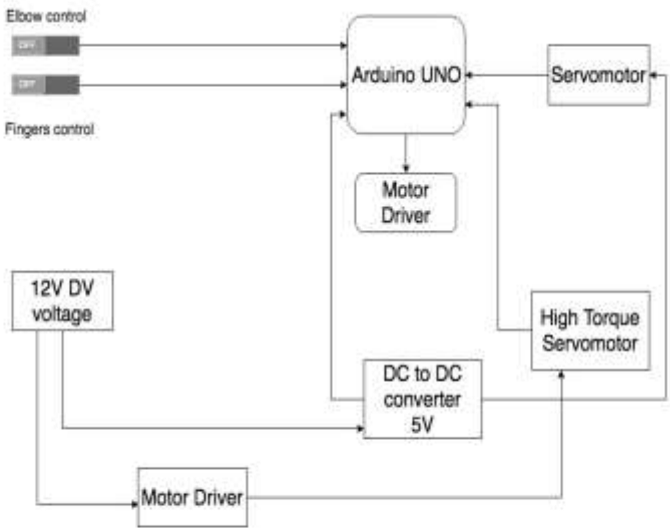

Fig -2: Overall block diagram representation

The controller is the decision maker in the exoskeleton system. Based on the serial input given, it can control any of the motors for the movement of that part. For interfacing the stepper motor to the controller, a motor driver circuit is needed. These drive circuits can be easily interfaced with the motor and their selection depends upon the type of motor being used and their ratings (current, voltage).

Servo motors are great devices that can turn to a specified position. Tower Pro SG90 is a high quality, low-cost servo for all your mechatronic needs. It comes with a 3-pin power and control cable, mounting hardware. There are 5 servomotors which are given to every finger for movement.

For the position control of the elbow, a single motor is used i.e. Ultra Torque Metal Gear 35KGM Coreless Standard Servo Motor. 5V supply to the motor is given by stepping down the input dc voltage from 12 to 5V using a dc to dc converter.

2.3 Control of the actuators

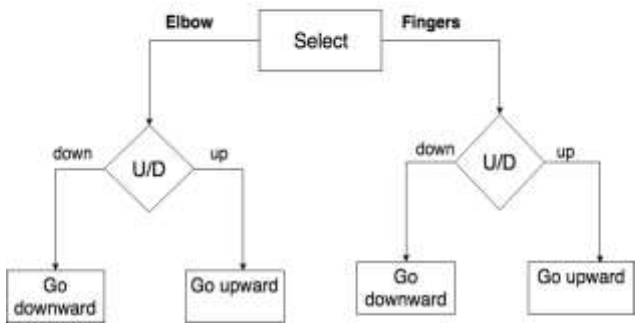

Fig -3: Actuator control flow chart

The two motors for movement i.e. the elbow and finger motors are accurately positioned by the command from the user. The system is switch controlled. Based on the input from the user, each of the motor can rotate clockwise and anti clockwise i.e. from -90 to +90 degrees. Separate switch controls are established for each motor. From the flowchart, if the command to the motor is 'u', the motor moves downward and if the serial input is 'd', the motor moves upward. With using only two buttons the user can pick up and put things down. This exoskeleton arm will provide extra-strength on user's arm which will allow the user to easily pick and put down objects without any hassle. The exoskeleton arm controlling motor and circuit is set-up on backpack which allows the user to carry this entire system with him or her anywhere he wants.

3. DESIGN SPECIFICATIONS

3.1 Design of fingers

The software chosen to create the 3D model was AutoCAD Fusion 360. With this program, each part of the exoskeleton palm was created as well as the assembly of them and the movement analysis is done.

Fig – 4: Design of structure to hold servomotor

Flat Aluminium is used for the basic structure of upper arm. The upper arm was designed in coral draw software. The rectangular Al strips are cut as per measurements. This structure is intended for the flexion and extension movements of the elbow which is achieved by an elbow motor.

Specifications:

1. Material: Flat aluminium
2. Measurements: Length-260 mm, Width-24.8 mm, Depth-1.48 mm.

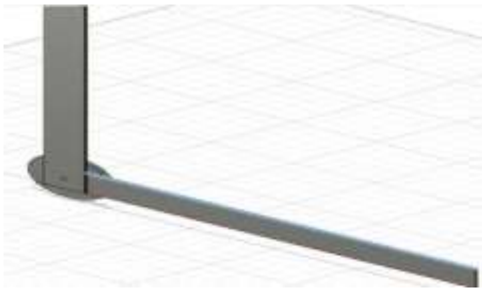

Fig -5: Aluminium frame

3.2 Torque calculation and selection of motor

Weight and torque required(for a body weight of 65 Kg)
Average weight of forearm= 1.75 % of 65 Kg=1.1375 Kg
Weight of Aluminium (1.16g/cm) for forearm of length 26cm =1.16*26 = 30.17g. Weight of laser cut palm in acrylic = 41.1g
Rotor weight = 20g
Total weight = 1.23422 Kg
Total torque required for the lift and for lifting purposes =33.04486Kgcm.
Therefore the selected servo motor for the forearm is Kitsguru KG319 Mg90S Metal gear servo 180 degree.

Designed and 3D printed bearing clamp and shaft for elbow and shoulder also designed the voltage regulator circuit.

Fig - 6: 3D printed bearing clamp and shaft

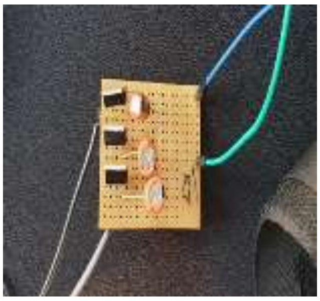

Fig -7: voltage regulator circuit

3.3 Control and power circuits

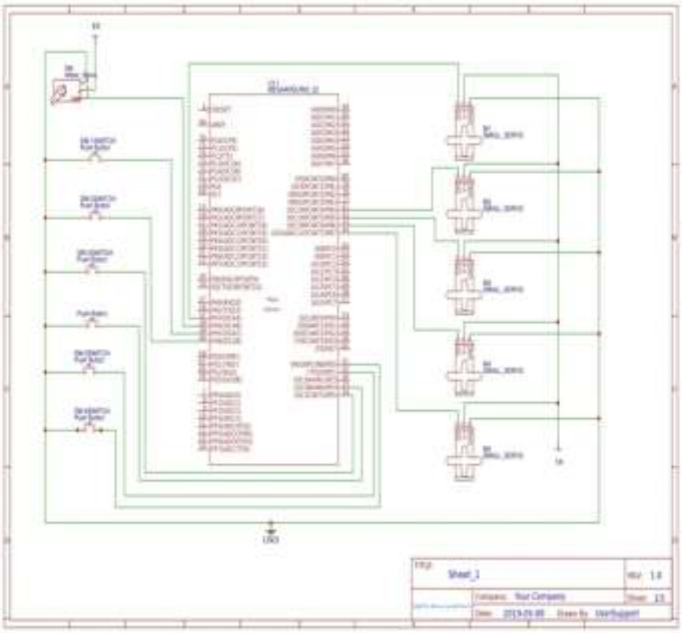

Fig -8: Connection diagram

Pulse Width Modulation, or PWM, is a technique for getting analog results with digital means. Digital control is used to create a square wave, a signal switched between on and off. This on-off pattern can simulate voltages in between full on (5 Volts) and off (0 Volts) by changing the portion of the time the signal spends on versus the time that the signal spends off.

The pushbutton is a component that connects two points in a circuit when you press it. When the pushbutton is open (unpressed) there is no connection between the two legs of the pushbutton, so the pin is connected to 5 volts (through the pull- up resistor) and we read a HIGH. When the button is closed (pressed), it makes a connection between its two legs, connecting the pin to ground, so that we read a LOW.

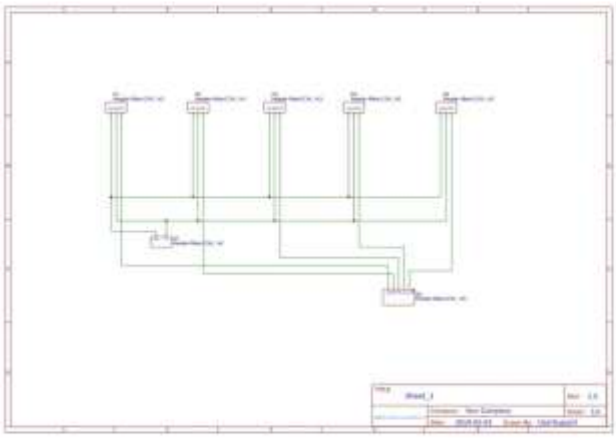

Fig -9: Connection diagram of servomotors

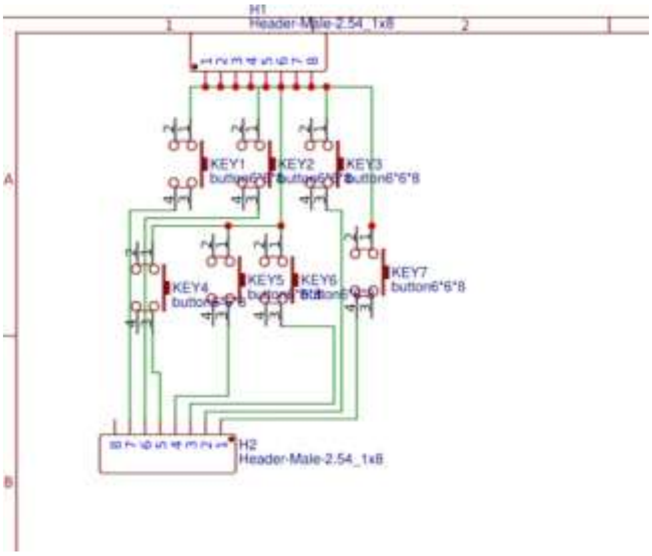

Fig -10: Connection diagram of switches

4. FINAL PROTOTYPE

The two DOFs for the fingers and elbow is successfully achieved in this prototype.

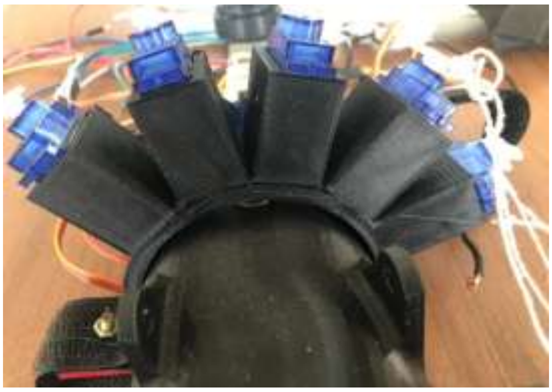

Fig -11: Mounting of servomotor

Fig -12: Final prototype of hand exoskeleton

5. CONCLUSION

The 2-DOF robotic exoskeleton arm was designed and built which can be utilized for rehabilitation and training purposes. The arm can rotate cover the range of -90 to +90 degrees for each joint. Hence, it covers the range of human joint's motion. The prototype has a compact, strong and lightweight design, it allows for the possibility of handling it with safety and simplicity. The hand exoskeleton focused on hand motor rehabilitation for patients with neuromusculoskeletal motor disabilities. The system includes independent movements for flexion and extension for the elbow and fingers. For comfort reasons, abduction-adduction movement is included but not actuated. Compared to many existing robots, this exoskeleton is compact, light-weight and has an adequate torque for patient rehabilitation routines. It has the capacity to be adapted to different finger sizes and to accommodate different palm sizes, including the particular motion of knuckles.

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