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Smart Hand Rehabilitation Glove

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ABSTRACT: In this paper, a model for "Smart Hand Rehabilitation Glove", which is a cost effective and convenient method of exercising was proposed. Traditional Stroke Rehabilitation consists of motor exercises that are needed to be performed by the patient in the supervision of assistants for muscle memory regeneration. However, such Stroke Rehabilitation is inconvenient to the patient and expensive as well. The Glove can be switch controlled for Automatic Replication of Hand Movements, can be in the form of a Replication Glove which copies the movements of the unaffected hand to the affected hand or a brain-controlled glove for exercising.
KEYWORDS- Rehabilitation, paralysis, memory re-allotment, equipment.

I. INTRODUCTION

In 19th century Sir Charles Bell discovered a disease called paralysis. The main cause of paralysis is the damage in nervous system mainly, the spinal cord. There are many reasons for the cause of paralysis. But most common reason is as follows:

1. Due to serious injury.
2. Breaking of muscles.
3. Breaking of neurons of brain, etc.

Many more & Due to this connection between brain and body parts gat lost the connection & no electric pulse (data) transformation from brain to body parts take place & due to this body parts are not able to move.[1]The numbness is initiated either in arms or legs and then spreads quickly[2] . Paralysis is categorized on the basis of infected body parts. "Paraplegia" is a disease in which lower half of body including legs is paralyzed & if hand legs both are infected by this then it is known as "quadriplegia". Depending upon, how much the patient is infected the treatment continues and medicine is also provided, but along with that physical exercise is also mandatory. The major factor influencing recovery is activity dependent plasticity of supraspinal networks[3]. This is called as neuromodulation. The chronic therapeutic electrical stimulation of the central nervous system or special nerves with an implanted stimulating device is known as neuromodulation[4].As the connection between brain & body part is lost and due to the breaking of neurons also, some part gets damaged. So, by continuous exercising some function of body parts active[5]. Due to this slowly and gradually memory re-allotment happens. The memory re-allotment can be explained as E.g. Let's takes the stroke patient A. Because of the stroke his/her brain are not work properly means the 80% of brain is active and 20% of brain is dead so he/she cannot move their specific body part(hand). It doesn't mean that he/she can never move their hand. There is possibility, by which he/she can move their hand by muscle memory [Muscle memory: Muscle memory is a form of procedural memory that involves consolidating a specific motor task into memory through repetition, which has been used synonymously with motor learning.[6]The primitive strategy foorehabilitation is to put the patient in position to be able to practice and improve upon their motor skills.[7]When a movement is repeated over time, a long-term muscle memory is created for that task, eventually allowing it to be performed without conscious effort. This process decreases the need for attention and creates maximum efficiency within the motor and memory systems. Examples of muscle memory are found in many everyday activities that become automatic and improve with practice, such as riding a bicycle, typing on a keyboard, entering a PIN, playing a musical instrument, poker, martial arts or even dancing. The rate at which recovery happens depends on the consistency with which the patient follows the rehabilitation program.[8]

But the main disadvantage is that, as the patient is notable to move, another person is required for the exercise purpose and is i.e. exercising is not an easy task to perform or a person suffering from it. From here, the idea of implementing glove came up. It is automatic and helps to care a person suffering from it. It is mainly used for the hand part an i.e. finger due to which recovery chance gets increased.

II. RESEARCH METHODOLOGY

A Glove which acts as an exercising tool for patients suffering from Paralysis, which can be either switch controlled, controlled by the other non-paralytic hand or controlled by Brain signals generated. The motion would be generated by servo motors.

Here, Arduino is used as a main supporting system and glove is used as a mechanical support on which components can be mounted. Glove's size may vary from person to person depending on the hand size.[9]

2.1Automatic (Switch Controlled)

Figure 1. Block representation of Switch Controlled

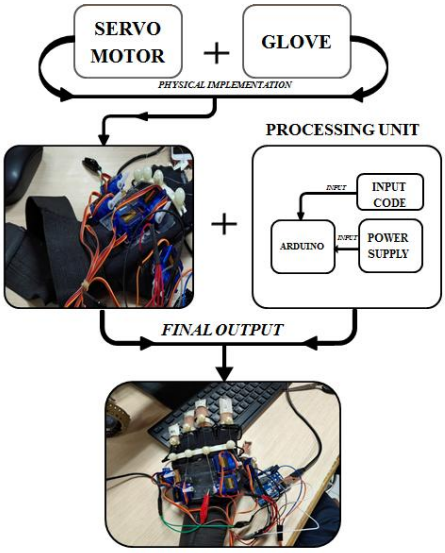

Figure 2. Flow of smart hand rehabilitation glove (propose idea)

In this version of the glove, the glove is controlled by a switch on the glove. The switch output is relayed to Arduino which then makes the corresponding movements. The output of the glove is generated by a predefined code.[10]

2.2 Replicator (Transfers the motion from one hand to another hand)

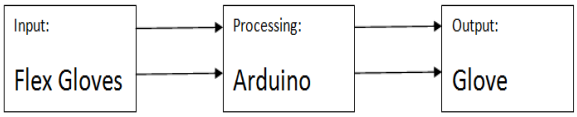

Figure 3. Block representation of Replicator

In this version of glove, flex gloves, on a non-paralytic hand, relay the input. The movements recorded by the flex Gloves, by a healthy hand, are recorded and processed by Arduino, which then makes the corresponding movements in the Glove. The output received is synchronized with the secondary glove that is the flex glove.[11]

2.3 Brain Controlled

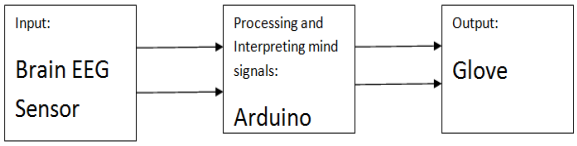

Figure 4. Block representation of Brain Controlled

In this version of glove, inputs are relayed by a Brain EEG (Electroencephalogram) Sensor. The EEG sensor reads the Brain Signals, and sends the measured Voltages to an Arduino. The Arduino processes and interprets the Voltages and makes the corresponding hand movements in the Glove. Whenever the sensor senses an appropriate level of concentration it will start the predefined motion.[12]

Equations

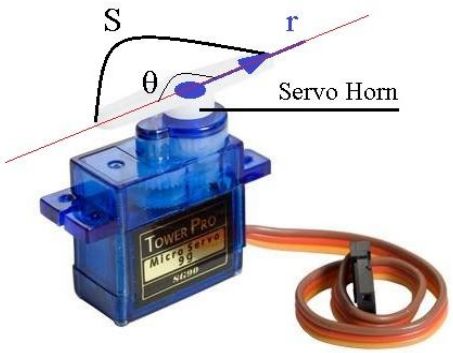

Figure 5. Labeling of Equation parameter

To develop the Smart Glove, the motor should work on DC Power Supply (as it's safe and portable) and should stop at a specific angle by producing a torque large enough to hold the finger at some instant.

$$s=r*\theta \quad (1)$$

S = stretched thread.
r= Distance between The tip of shaft and end point of crossed horn.
θ = Angle of rotation.

III. WORKING MECHANISM

3.1Automatic (Switch Controlled)

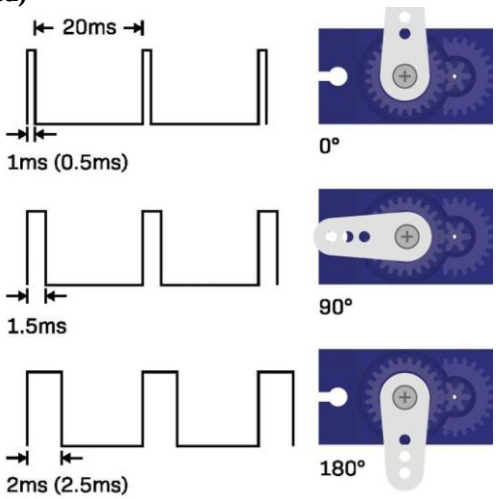

Figure 6. Pulse representation of degree of rotation

In this section, Arduino is used as a processing unit in which the code is already fetched by using computer. In Arduino software(IDE), the programmers writes the program and then compiling and execution process is done later on, that program is fetched in Arduino and code i.e. the program is stored in the memory of Arduino. After that servo motor is connected with digital pins and it's mounted on the glove and that servo motor is used it convert electrical energy into mechanical energy and that energy used to move the patient's finger. The patient's finger and servo horn as connected with the help of thread. When the required amount of potential is supplied to Arduino, then it gets start and sends the electrical pulse to servo motor, depending upon the width of pulses(unit-ms) as shown in fig6, the servo starts the rotational motion in specific degrees and that all rotation and work which are performed by Arduino, depends upon the execution of program.
As mentioned above, the finger and servo motor are interconnected with each other finger starts moving and the process i.e. exercise continue till the voltage supply given to Arduino gets disconnected.

3.1.1Advantage
1. Low cost
2. Environment friendly
3. Programming complexity is low.

3.1.2Disadvantage
1. No feedback path
2. For different exercise the different code is required
3. Electricity is required.

3.2 Replicator (Transfers the motion from one hand to another hand)

In this section, two gloves are used one of which acts as a transmitter and another one as receiver and the Arduino act as a processing unit as a receiver same as the switch control section glove. The only difference between switch control glove and replication model is of transmitter glove.

The working of transmitter is like: - for every finger, One separate flex sensor is used. The working principle of flex sensor is bending strip i.e. Change in the resistance happen whenever the strip gets twisted. As the non-paralyzed hand moves, flex also bends, because of that change of resistance happens which is measured by Arduino as flex is connected to the analog pin of Arduino. Depending upon how much change of resistance has occurred, the Arduino send the pulses that rotate the servo motors and that move the paralyzed hand finger. The transmitter glove has wear on non-paralyzed hand and receiver glove on paralyzed hand.

3.2.1Advantage
1. Feedback path get generated
2. High efficiency then switch controlled glove
3. One time programming is require for every exercise as exercise depends on transmitter end.

3.2.2Disadvantage
1. High cost thenSwitch Controlled
2. Bulky
3. High voltage supply required.

3.3 Brain Controlled

In this proposed idea, Electroencephalogram (EEG) is used for the brain mapping purpose to detect the small electrical signal, which is produced by the billions of active neuron present in brain. EEG is work as the billions of neuron of brain produced small electrical signal that can be detected by EEG machine and it amplify that small signal and record them in a pattern of wave on graph paper or on a computer screen. The user has to think aloud in order to make it effective.[13] . By thinking aloud the thought process can be captured and make effective utilization of the same.[14]

Later on that graph is converted into numbers by using Arduino with programming. It easier to work on the number as compared to graph. For different work the neuron generate different electrical signal, when the patient is going to perform exercise as different electrical signal gets generated and that will be detected by EEG then it produce numeric equivalent value and that value is used by Arduino and it perform several operation (depending upon program) like motion of servo which mounted on gloves and the finger starts moving.

3.3.1Advantage
1. Feedback path
2. Controlled by brain
3. One time programming
4. Depends upon brain (not like replicator).

3.2.2Disadvantage
1. High cost
2. Bulky
3. More power consumption
4. Complex programming
5. More power consumption
6. Maximum concentration required while performing exercise.

IV. RESULTS AND DISCUSSION

4.1 Observed tables

TABLE I. : Condition to use the motors

Sr. No.	Motor	Used in Project	Reason
1	AC Servo Motor	Not Used	It's dangerous, as AC is lethal and can harm the patient.
2	DC Servo Motor	Used	It is safe, as voltages are in the range of 0-5V, and is portable too, in form of a battery.
3	Brushless DC Servo Motor	Not Used	It is quite expensive.
4	Positional DC Servo Motor	Used	It is cheap and requires DC power supply. It allows easy determination of angle using $s=r\theta$.
5	Continuous Rotation	Not Used	It performs Continuous Rotation, which makes it difficult to stop at a specific angle.
6	Linear Rotation	Not Used	It's rotor is "unrolled", thus instead of producing a torque, it produces a linear force, along it's length.

Table Idisplayed, The types of motor and which motor are better to use in this models and reason also mentions in fourth column, second column the types of motor are available in the market.

TABLE II. Specification of used motors

Size	32x11.5x24mm (Include Tabs) 23.5x11.5x24mm (Not Include Tabs)
Weight	8.5gm (Not including a cable and Connector) 9.3gm (Including a cable and a Connector)
Speed	0.12 sec/60 degrees(4.8V) 0.10sec/60 degrees(6.0V)
Torque	1.5N-cm(4.8 V) 2.0 N-cm (6.0 V)
Voltage	4.8 – 6.0 V
Connector Type	JR type (Yellow: Signal, Red: VCC, Brown: GND)

Table II shows the specification of used motor and in fourth row the torque of motor is given and that much torque is enough to move the fingers of patient as the patient is not going to counter the motion of servo. Weight of finger is only one thing that much of opposition force is present in opposite of servo's applied motion.

4.2 Result

Paralysis is most often caused by damage in the nervous system. So, in order to recover the body actions, various physical exercises need to be performed. Our project is a small idea to overcome this loss to a certain extent and completely in some cases. The idea was to create an electronic device that will help in the recovery of the memory of muscles of the affected arm. The Smart Glove was developed by placing the Positional DC Servo Motors at the position of joints in the gloves. The motion of Servo Motors was controlled by a C program fed to an Arduino UNO board, running on 9 V batteries. This helps in faster recovery of the muscle memory and thus aids in rehabilitation of the affected limb.

V. CONCLUSION

A Smart Glove, to help in rehabilitation of patients experiencing paralysis due to stroke, was developed using Servo Motors and Arduino. The Smart Rehabilitation Glove aims to reduce the functional limitations and disabilities of a stroke victim, while also helping in recovery of the muscle memory of the affected limb. The Glove, as a tool is efficient in recreating the Hand Movement and performs Motor Skill exercises that help improve muscle strength and coordination.

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