Abstract:
This paper reviews the development of IOT-enabled stroke rehabilitation system using smart wearable gloves (SWG) and robotic hand. The SWG is developed by utilizing the flex sensors, which are used to measure the amount of bending or deflections. Physiotherapy intentions are converted into series of instructions via SWG, which are used to drive the motors connected to the robotic hand. The patient will mimic the robotic hand movements, which is used for rehabilitation purpose. Wi-Fi module is used to transfer the progress. In addition IOT is used to store the patient details and the improvement done by each of the patient.

Keywords: IOT- enabled Stroke rehabilitation system, Smart Wearable Gloves, robotic hand, Wi-Fi, IOT.

1. INTRODUCTION

Stroke which is also known as a cerebrovascular accident or CVA occurs when blood stops flowing to a part of the brain and the part of the body that the blood deprived brain cells control stops working. There are two ways in which stroke generally occurs:
Ischemic strokes usually occur when blood clot or a fatty plaque stops the blood flow to an area of the brain causing death of the associated neurons. Nearly 88% of strokes are Ischemic events.
Hemorrhagic stroke occurs when a cerebral artery ruptures and spills blood over the brain tissue. The spilled blood exerts pressure and causes damage to the delicate brain tissue. Only 12% strokes are Hemorrhagic. Study has shown that recovery of upper limb is slower in stroke survivors when compared to the lower limb. According to the World Health Organization 15 million people suffer stroke worldwide each year. Of these 5 million die and 5 million are permanently disabled. Study has shown Effort towards developing robotic treatments for upper limb has increased due to the increasing stroke related disabilities, which has also helped in cost reduction in health care. We propose a system design in which the robotic hand makes movements according to the instructions given to it by the SWG, worn by the doctor where the SWG utilizes the flex sensors, that is attached to the gloves and the resistance of the sensor element is varied by bending the fingers. Wearing SWG, the patients then mimics the robotic hand. The progress done by the patient is transferred through Wi-Fi module, which is stored in the IOT cloud that provides an effective platform to interconnect all the resources

Figure.1. Robotic hand

The rest of the paper is organized as follows: More about rehabilitation is in section II. The component description is presented in section III. The description of the system is given in section IV. Results obtained in section V. Section VI include advantages and disadvantages. Section VII gives future scope and section VIII conclusion.

II. REHABILITATION

Rehabilitation is a process of restoring health or normal life of a person through training and therapy after illness. The main aim of stroke Rehabilitation is to help the patient to relearn the lost skills by doing exercises or any required remedies. It helps the patient to improve their quality of life and to regain independence. Factors which play a important role in stroke rehabilitation success are:

Extent of injury – when the amount of injury is less, then there will be more chances for recovery.
Attitude of stroke survivor – survivor’s attitude should be positive, which can help the patient to cope with difficult times and for quick recovery.
Support of the Family – stroke survivor’s family are the most important form of support during rehabilitation and the patient seems to recovery quickly.
Time until start of rehabilitation – Immediately after stroke the patient must be provided Rehabilitation therapy. Even simple tasks should begin soon after stroke.

Various approaches for stroke rehabilitation:
Mirror Therapy [1]. This is used to enhance the neuroplasticity in the brain. This therapy tool is developed using kinetic motion sensor. Stroke recovery exercises are performed with non affected hand. Unfortunately the results obtained are not satisfactory. Furthermore it fails to ‘trick’ the brain to think that the affected hand was moved. Sensor Stimulation Therapy [2]. It provides low level stimulation to the arm and hand hence increasing signals delivered to the brain. This system involves sensor box and graphical programming environment, which is used to create its behavior. It is designed as a robotic based
system of sensory device, FES [3]. Functional Electrical Stimulation is a technology in which low energy electrical pulses are used to generate movements. It involves inducing current in specific motor neurons in order to generate muscle contractions. The neurons receive electrical pulses that are delivered to them using electrodes. These electrodes can be placed over the skin, inside a muscle, on the surface of the muscle or wrapped around the nerve. It is also used to treat traumatic brain injuries and various neuromuscular conditions. TENS [4]. Transcutaneous electrical nerve stimulation mainly focuses on acute thermal pain. It sends small electrical pulses into the nerves of the affected region and is said to reduce the pain and numbness for stroke patients. The results are evaluated using oxygen saturation (SpO2), pulse rate (PR) and visual analog scale (VAS). However the drawbacks include chances of increased pain, discomfort and soreness of the muscle.

Robot based hand motor therapy [5]. Robotic devices support and guide hand movements to increase exercise consistency. It has a design of a robotic hand called the Hand Wrist Assisting Robotic Device (HWARD). It assists in holding and releasing movements of the stroke impaired hand.

III. COMPONENT DESCRIPTION

A. Arduino UNO Microcontroller
Arduino Uno Microcontroller is used to integrate the functionalities of all the modules and display the result on personal computer or mobile devices. It is based on ATMEGA 328 microcontroller. It has 14 digital Input/Output pins, 6 Analog Input/Output pins, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It also includes: Flash Memory 32KB of which 0.5 KB used by bootloader, SRAM 2 KB EEPROM 1 KB.

B. Flex Sensors
Flex Sensors are a type of analog sensors used to detect the amount of bending. The Bending amount is directly proportional to the resistance of the sensor. Polymer ink is printed on one side of the sensor that has conductive particles in it. Flex sensor has two terminals. These terminals are not polarized, hence there is no positive and negative.

C. Wi-Fi Module
Wi-Fi Module can be configured to be connected to the internet or Internet of Things (IOT). Here we use Node MCU ESP8266, which is made by Espressif. NodeMCU is an open source platform. It supports communication protocols such as SPI, I2C, UART etc.


**D. RF Transmitter and Receiver**

Radio communication has a lot of advantage over Infrared Communication as it does not require a direct line of sight between the transmitter and the receiver. This RF Module has two parts i.e. the RF Transmitter and the RF receiver. The transmitter generally takes the data and applies modulation techniques to encode the data and convert it to Analog using DAC (Digital to Analog Converter), which is further amplified to generate a high power signal to be transmitted over the antenna. This antenna transmits the signal in the form of Electromagnetic waves.

At the other side is a receiver device which receives the signal. This signal will be amplified and sent to the ADC (Analog to Digital Converter). Digital signal will be further demodulated and the information is obtained. There are two types of RF module, the one which operates at 434MHz and the other one operates at 433MHz.

**E. Servo Motor**

Servo motor has high torque which makes it best suited for robotics and RC needs.

**IV. DESCRIPTION OF THE SYSTEM**

The primary goal of our system is to provide smart Rehabilitation using smart wearable gloves, robotic hand and Internet of Things (IOT). In order to achieve this we first design two smart wearable gloves (SWG) using flex sensors. One SWG is used by the patient and the other SWG is used by the doctor/physiotherapist. The doctor/physiotherapist wears this SWG and performs the actions, and then the RF transmitter is used to transfer these actions to RF receiver at the patient’s side. The robotic hand which is at the patient’s side does exactly as the doctor’s SWG. Then the patient mimics the robotic hand wearing the patient’s SWG. Progress done by the patient is transferred to the cloud using Wi-Fi module. Cloud storage is used to have the patient’s data and to provide health care professionals, users and caregivers with regular personalized feedback.

The figure shows the proposed block diagram.

![Transmitter unit](image9.png)

**Figure.9. Transmitter unit**

![Receiver unit](image10.png)

**Figure.10. Receiver unit**

**V. RESULTS OBTAINED**

The following are the snapshots of the prototype and operational results: Initially when the doctor/physiotherapist is wearing the SWG and when they do not perform any actions, the robotic hand does the same which is as shown in Fig 11.
Similarly when the doctor/physiotherapist folds his fingers the robotic hand mimics exactly what the signals are sent from the doctor’s SWG which is shown in Fig 12.

The progress done by the patient i.e. when he/she folds or moves his/her finger as indicated in Fig 13, it is displayed on the doctor’s PC or mobile phone using a web page as in Fig 14 and it is also stored on the cloud for future analysis.

V. ADVANTAGES AND DISADVANTAGES

The application of hand rehabilitation is to achieve effective rehabilitation by making serial decisions on the designing of both the smart wearable gloves and smart training robot hand. The advantages of using this system are as follows:

- **Reduced effort for therapists** – Robot assisted rehabilitation reduces physical strain on therapists who can now focus on other aspects of the therapy.
- **Cost effective** – IOT-Enabled rehabilitation system is not only attainable by large rehabilitation centers but also by normal average everyday people.
- **Can be used at home** – This system is usable at ones house everyday without the help of trained personnel.
- **Maintainability** – There exists no repair costs, calibration etc and hence it does not require constant maintenance.
- **Adaptability** – This device is adaptable for use by all or most users.
- **Safety** – Device puts no strain on the body and malfunctions rarely and nothing life threatening.

The disadvantages of this system are:

- **This system classifies only a few hand gestures.**
- **Many servo motors have to be used in order to obtain an advanced rehabilitation system.**

VI. FUTURE SCOPE

An advanced rehabilitation system with gaming elements not only can enhance the user motivation but it can also increase the user engagement. This rehabilitation system can also be extended to train the lower limbs. Further EEG (Electroencephalograph) signals can also be used to control the hand movements.

VII. CONCLUSION

IOT based stroke rehabilitation system consists of smart wearable gloves, a robotic hand and Internet of Things (IOT). The robotic hand gives real time demonstration which helps the user improve their muscle activities and help them in quick recovery. The smart wearable gloves is lightweight and low-cost which is desirable for home rehabilitation, that patients can wear without any professional knowledge. We hope that this system not only shortens the recovery time, but also increases the standard of rehabilitation higher than the one we use today with traditional physiotherapy methods.
VIII. REFERENCES


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