An Upper Limb Paralysis Rehabilitation Activity Monitoring Device For Post-Traumatic Stroke Patients

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***Abstract*-This paper provides a comparative analysis of rehabilitation activity after stroke. Monitoring rehabilitation activity for post-stroke patients has been increasingly common in hospitals and rehabilitation centers worldwide. To develop a home based and low cost device for post-stroke patients activity monitoring is challenging in rehabilitation engineering. Many technological devices have been developed (assistive device, exoskeleton device, and robotic device) to recover daily living activities particularly for stroke patients. These are complex in use for home based training and are also cost ineffective. We identify several functional activities of finger and wrist joint which allow investigating the patterns of finger and wrist functional activity for both normal and upper limb paralyzed subjects. These studies have helped to investigate the activation patterns in different experimental conditions such as 'water bottle take off', 'wrist stretching' and 'grasp force'. Furthermore, comparative studies have been performed in order to provide detailed functional activity for upper limb paralyzed subjects.**

Keywords: Data Glove, Rehabilitation activity, Wireless sensor system

I. INTRODUCTION

Measuring upper limb mobility and coordination in subjects suffering from paralyzed conditions is very difficult because of their obvious immobility. It is important for post-stroke patients to regain the mobility and fitness. Rehabilitation programs help such patients to reduce the complexity of treatment carried out by well-trained people like doctors and physiotherapists. They advised and motivated the patients to do the exercises and undergo control of their movements such that they can regain their normal routine.

Thus rehabilitation process plays a major role in regaining the loss of motor function. Rehabilitation process involves extensive physical exercises that may help to regain the functional disabilities. There are lots of devices such as assistive devices, robotics devices, exoskeleton devices that are used to carry out upper limb paralysis rehabilitation. These systems are extremely costly and complex while also not being suitable for home based rehabilitation training. There are some therapeutic approaches that can be used to regain the loss of activity of daily living (ADL) for paralysis patients for example Constraint induced movement therapy (CIMT), which is a recent advancement in stroke rehabilitation. In this approach patients are advised to constraint their unaffected limb and train the affected limb to do the activity of daily living.

In this proposed system designed with a wireless wearable sensor network, multiple sensors (accelerometer, flex sensor, force sensitive resistor) are used for tracking the range of motion and muscle force of the upper limb extremities. These sensors pick up the signals which are associated with upper limb range of motion. Later this analog signal is converted into digital signal using an 8-channel multiplexing analog to digital converter. Further, this digital data is sent to the microcontroller unit for processing the data which is further sent to the personal computer through wireless Zig Bee protocol. Finally, these signals are analyzed then compared with normal subjects to know the improvement rate of rehabilitation activity. The results can be kept for further analysis.

II. Hardware Components

A. System Setup

Fig. 1 shows the overall system block diagram. It consists of two units: First unit is related to data acquisition and the Second unit consists of the master controller part. Data acquisition part consists of the multiple sensor system (Accelerometer, Flex sensor, Force sensitive resistor sensor) and an analog to digital converter. In the second unit Digital data has been processed by AT89c51 Microcontroller and this processed data is transmitted through the Zig Bee wireless protocol. In the receiver section this data is received by another Zig Bee wireless protocol and then monitored on a personal computer for data analyzing.

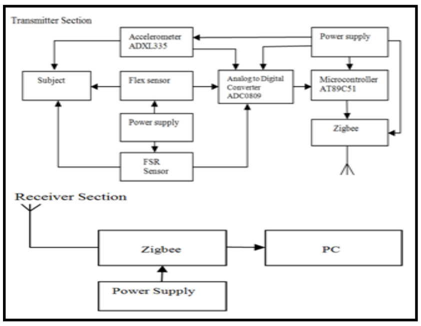

Fig. 1: Overall system block diagram

B. *Flex sensor*

Flex sensor, also called bend sensor, is used to detect the bending action. Inside the flex sensor are carbon resistive elements within a thin flexible substrate. More carbon means less resistance. When the substrate is bent, the sensor produces a resistance output relative to the bend radius. This converts the change in bend to electrical resistance - the more the bend, the more the resistance value. Initially bend sensors being straight, the resistance value is about 10k ohms. When its bend about 90 degree, the resistance increases to 30-40K ohms. Here the flex sensor has been used to detect bending movement of finger and particularly, while making a fist and to monitor object grasp finger movements. Flex sensors are used in gaming gloves, auto controls, fitness products, measuring devices, assistive technology, musical instruments, joysticks, and more. Life cycle of bend sensor is more than 1 million times for a Height of 73.66mm and temperature range between -35°C to +80°C.

C. *Force sensitive resistor (FSR) sensor*

The Force sensitive resistor sensor is used to detect the applied force. This sensor is composed of a thick polymer film. When its active surface is touched, résistance value can be obtained. The FSR varies its resistance depending on how much pressure is applied to the sensing area. Resistance value of FSR is inversely proportional to the applied force on active surface; and hence, the greater the force, the lower the resistance. The sensor has a resistance of greater than 1MΩ when no pressure is applied. The force sensitive resistor sensor has been used for measuring the force response during making of a fist.

D. *Accelerometer*

An Accelerometer is used to detect the static and dynamic motions. Here ADXL335- a thin, small, low power 3- axis motion tracking accelerometer has been used. It measures acceleration indirectly through an applied force. It contains a poly-silicon surface micro machined structure. It has a differential capacitor which consists of two fixed plates attached to the moving mass this setup is used to measure the deflection of structure. The acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Here, this accelerometer has been used to detect the motion of wrist joint flexion and extension.

E. *Analog to Digital Converter*

An Analog to digital converter is a data acquisition component used to convert analog signals into digital data. We have used ADC0809 8-bit analog to digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation conversion technique so that the sensors analog voltage output can be converted into digital data.

F. *Microcontroller*

The AT89C51 microcontroller has been used which is low power consumption, high-performance CMOS 8-bit microcontroller. It has 4K Bytes of In-System Reprogrammable Flash Memory, 128 bytes of RAM, 32 I/O lines, two 16-bit timer/counters, five vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator and clock circuitry. The entire system has been controlled by this master controller.

G. *Zig Bee*

Here, CC2500 Zig Bee module has been preferred which is a Single Chip, Low Cost, Low Power RF Transceiver and has an operating frequency range between 2400 – 2483.5 MHz. It uses FSK modulation technique for data transmission. It gives a 30 meters range with onboard antenna. It can be used on wireless security system or specific remote-control function and others wireless systems. This module supports various modulation formats and has a configurable data rate up to 500 K baud.

H. *Software*

Keil uVision 3 Integrated Development Environment (IDE) is a program platform used to develop program for 8051microcontroller board. The coding language is embedded C. Also MATLAB has been used to obtain the graphical representation of data.

III. EXPERIMENTAL METHOD

A. *Device development*

Fig. 2(a) shows the transmitter section of the device for monitoring upper limb rehabilitation activity. In this proposed device, a 9V battery for power supply has been chosen. This device can be attached on subject hand above wrist joint with the help of soft material bought from an Orthotics & Prosthetics center. This material also gives comfortable feel to subject and the wire disturbances and electrical shocks can be isolated.

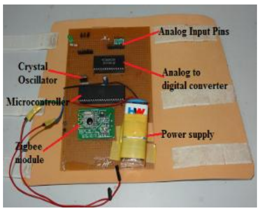

Fig. 2(a): Transmitter section of device

Fig. 2(b) shows the receiver section of the device. The processed data is transmitted by The Zigbee module of transmitter section and received by Zigbee in receiver section depicted in *Fig. 2(b).* This data is converted from the TTL voltage level to RS232 voltage level by MAX232. This data can now be monitored in a PC through RS232 serial port. This proposed device has been designed to be a low cost, light weight and highly secured system that does not restrict the patient's movements.

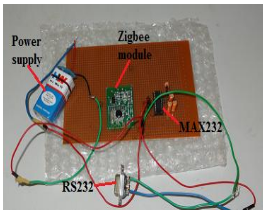

Fig. 2(b): Receiver section of device

B. Sensing system

In the development of an upper limb paralysis rehabilitation activity monitoring device in which a multiple sensor system (force sensitive resistor sensor, Accelerometer, flex sensor) has been proposed for tracking the finger and wrist joint movements. So a cotton working glove in *Fig. 3*has been chosen which is widely available in market for mounting the sensors on it and it was specially modified for placing the sensors. *Fig. 3* shows the placement of the Flex sensors, Accelerometer and FSR sensor. These sensors are connected to the transmitter section's analog input pin through wires for analog signal detection. Then, the analog signal is converted to digital data by the analog to digital converter. This digital data will be sent to the AT89C51 microcontroller.

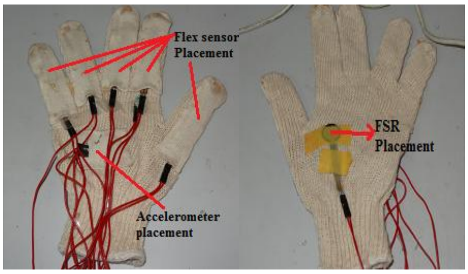

Fig. 3: Modified cotton data glove

C. Data monitoring

Here, the Terminal serial port software has been used for monitoring data. *Fig. 4* shows the terminal software snap shot. Whenever a finger or the wrist is bent, the sensors will detect the movement and the microcontroller will transmit data to the PC in which Terminal will display the data output. The output of analog signal from Accelerometer, flex sensor and FSR sensor are logged to PC by Terminal software where this received data is saved in a .txt format. The .txt files can be further processed into MATLAB to create graphical representation. This graphical representation clearly shows the signal response of movements and further comparative analysis can be done.

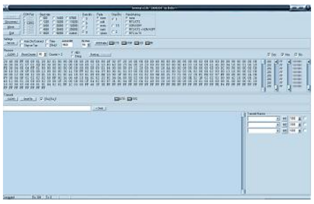

Fig. 4: Snap shot of Terminal software

D. Experimentation

Three distinctive movements have been proposed: Finger fist making, wrist flexion and extension and water bottle take off. Data has been acquired for 5 normal subjects and 2 paralyzed patients shown in *Fig. 5*. Flex sensors are used to detect the fist-making movement activity. FSR is used to detect the applied force signal response while making finger fist. Accelerometer is used to track the motion of water bottle take off and wrist flexion & extension. In order to validate the results, arepeated experimentation has been performed and analysis was be carried out according to characteristics of movements.

Subject	Gender	Age	Data Recorded Hand activity side
A	Male	24	Right
B	Female	52	Left
C	Male	32	Right
D	Male	19	Right
E	Male	46	Left

Summary of Normal subjects details

Subject	Gender	Age	Diagnosis	Age of Affected	Paralyzed side
F	Male	16	Brain Ischemic	5	Right side
G	Male	66	Brain Ischemic	65	Right side

Summary of Paralyzed Patients details

Fig 5: Summary of Subject details

IV DISCUSSION AND CONCLUSIONS

In this paper, a wearable sensor accelerometer, flex sensor and FSR sensor have been used for the development of monitoring the rehabilitation activity. The wireless data transmission has been achieved using Zig Bee protocol. In order to examine the performance of the proposed system, an experiment has been conducted for both subjects (Normal, Patient). Several typical rehabilitation experiments, such as wrist flexion & extension, finger fist making movement, force during fist making and water bottle takes off have been performed. In this project, rehabilitation activity for both normal and paralyzed subjects has been monitored and comparative analysis has been performed. During rehabilitation activity, the data was been recorded in real time. This proposed method allows the monitoring of subjects activity without restraint and rehabilitation can be carried out in home environment instead of specialized laboratory in hospital and also without supervision of physiotherapist.

IV. REFERENCES

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