A Wearable Rehabilitation Activity Monitoring Device for Paralyzed Patients Finger

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Abstract:-The aim of this article is to provide a comparative analysis of rehabilitation activity for paralyzed patient. Monitoring rehabilitation activity for post-stroke patients have increasingly common in hospitals and rehabilitation center worldwide. To develop 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, robotics device) for recover daily living activities particularly for stroke patients. Those are complexity use in home based training and also cost effective. In this article, we identify several functional activities of finger and wrist joint. This allows investigating patterns of finger and wrist functional activity for both normal and upper limb paralyzed subjects. These studies investigated 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.

Key words: Data Glove, Rehabilitation activity, Wireless sensor system, ZIGBEE.

I.INTRODUCTION

Measuring upper limb mobility and coordination in subjects suffering from paralyzed condition it's so much difficult because of their immobility. It is important for post-stroke patients to regain the mobility and fitness. Rehabilitation programs helps to such kind of disease to reduce the complexity of treatment. This treatment carried out by well-trained people like doctor's and physiotherapist. They are advised and motivated the patients to do the rehabilitation exercise. In such a way patients are treated to gain the normal activities [1].

So, rehabilitation process plays a major role to regain the loss of motor function. Rehabilitation process involved the extensive physical exercise's that may regain the functional disabilities. There are lots of devices assistive devices, robotics devices, exoskeleton devices are used to carry out upper limb paralysis rehabilitation activity. Those systems are high cost and huge complex and also not suitable for home based rehabilitation training. There are some therapeutic approaches are also used to regain the loss of activity of daily living (ADL) for paralysis patients. Like, Constraint induced movement therapy (CIMT) is recent advances in stroke rehabilitation. In this approach patients are advised to constraint their unaffected limb and trained affected limb to do the activity of daily living. The most important factor is to know the improvement rates of those rehabilitation processes. So that, a device is developed to achieve such kind of requirements which may leads to motivate patients to complete the rehabilitation process.

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

II.MMETERIALS

A. System Setup

System setup Fig1. Shows the overall system block diagram it consist of two units: First unit related to data acquisition part and Second unit consist of master controller part. Data acquisition part consists of multiple sensor system (Accelerometer, Flex sensor, Force sensitive resistor sensor) and analog to digital converter. In second unit Digital data has been processed by AT89c51 Microcontroller and these processed data were transmitted through ZIGBEE wireless protocol. In receiver section these data has been received by another ZIGBEE wireless protocol then monitored to personal computer for data analyzing.

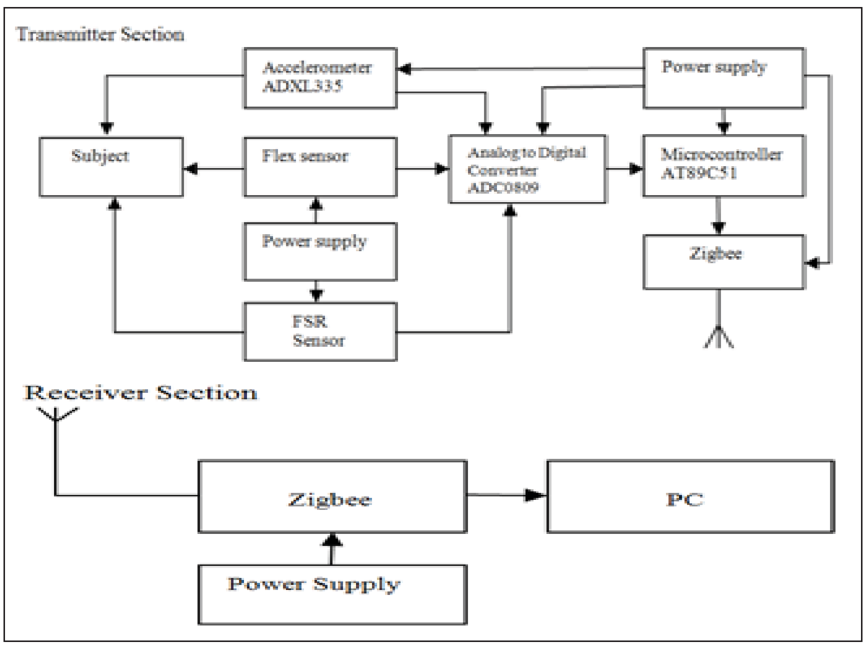


Figure 1: Overall system block diagram

B. Flex sensor

Flex sensor also called as bend sensor which 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. They convert the change in bend to electrical resistance - the more the bend, the more the resistance value. The resistance of sensor depends on the amount of bend. Initially bend sensors being straight the resistance value about 10k ohms. When its bend about 90 degree will give 30-40K ohms resistance. In this project we used flex sensor to detect bending movement of finger. Particularly, fist make and 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. Height 73.66mm and temperature range between -35°C to +80°C.

C. Force Sensitive Resistor Sensor

Force Sensitive Resistor Sensor (FSR) used to detect the applied force which composed of polymer thick film. When its active surface is touched it would give the resistance value. 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, the greater the force, the lower the resistance. The sensor has a resistance of greater than 1MΩ when no pressure is applied then resistance may reduce when the force on active surface increases. In this project we used force sensitive resistor sensor for measuring force response during fist making.

D. Accelerometer

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

E. Analog to Digital Converter

Analog to Digital Converter is a data acquisition component used to convert analog signal into digital data. We 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, sensors analog voltage output converted into digital data.

F. Microcontroller

We used AT89C51 microcontroller 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. ZIGBEE

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

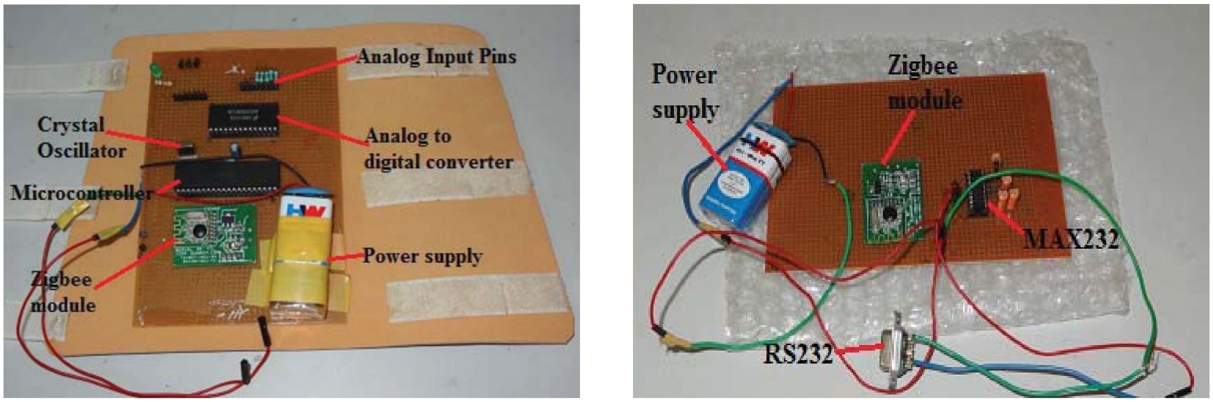
H. Software

Keil uVision 3 Integrated Development Environment (IDE) is a program platform used to develop program for 8051microcontroller board. Coding language is embedded c. terminal is a serial port software used for monitoring data. We used Matlab for plot the graphical representation of data.

III.EXPERIMENTAL METHODS

A. Device Development

Figure 2(a) shows the transmitter section of the device for monitoring upper limb rehabilitation activity. In this proposed device we used 9v battery for power supply. This device attached on subject hand above wrist joint with the help soft material bought from orthotics & prosthetics centre. This material also gives comfortable feel to subject and isolated electrical shock, wire disturbances. Figure 2(b) shows the receiver section of the device. Processed data are transmitted by ZIGBEE module of transmitter section and received by ZIGBEE in receiver section depicted in Figure 2(b). These data are converted TTL voltage level to RS232 voltage level by MAX232. Followed by, these data are monitored in PC through RS232 serial port. This proposed device has been designed with low cost; light weight and high security without restrict the patient's movements.

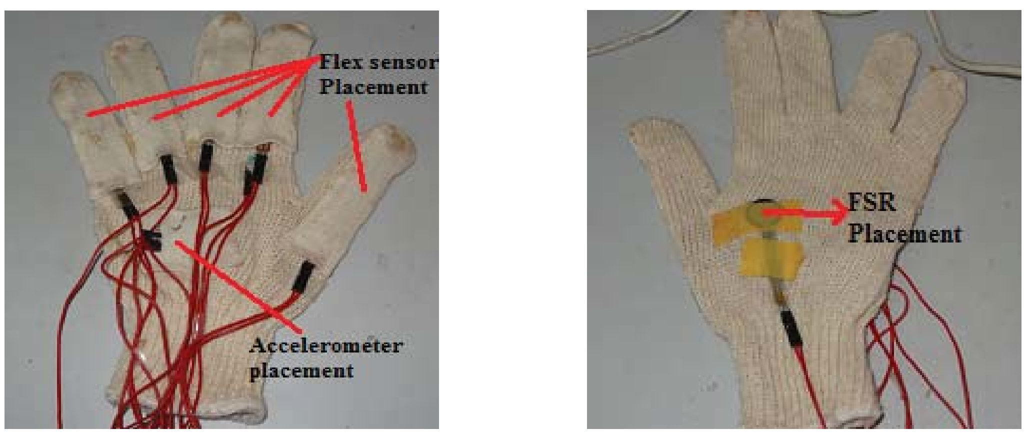


(a) (b)

Figure 2(a). Transmitter section of device (b).Receiver section of device.

B. Sensing System

We have developed an upper limb paralysis rehabilitation activity monitoring device in which we proposed multiple sensor system (force sensitive resistor sensor, Accelerometer, flex sensor) for track the finger and wrist joint movements. So, we bought cotton working glove (depicted in figure 3) available in market for mounting sensor on it and it specially modified for placing sensor. Figure 3 shows Flex sensors, Accelerometer and FSR sensor position. These sensors are connected to the transmitter section analog input pin through wires for analog signal detection. Then, the analog signal converted by analog to digital converter. This digital data will be sent to the AT89C51 microcontroller.



(a) (b)

Figure 3.(a) Cotton Glove with Flex and Accelerometer sensors fixed. (b). Glove with FSR Sensor

C. Data Monitoring

We have used terminal serial port software for monitoring data. Figure 4 shows the terminal software snap shot. Digital data have been received in the form of any digital format (decimal or hexadecimal). Whenever finger and wrist is bend, the sensors will detect the movement and microcontroller will transmit data to 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 these received data saved as 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.

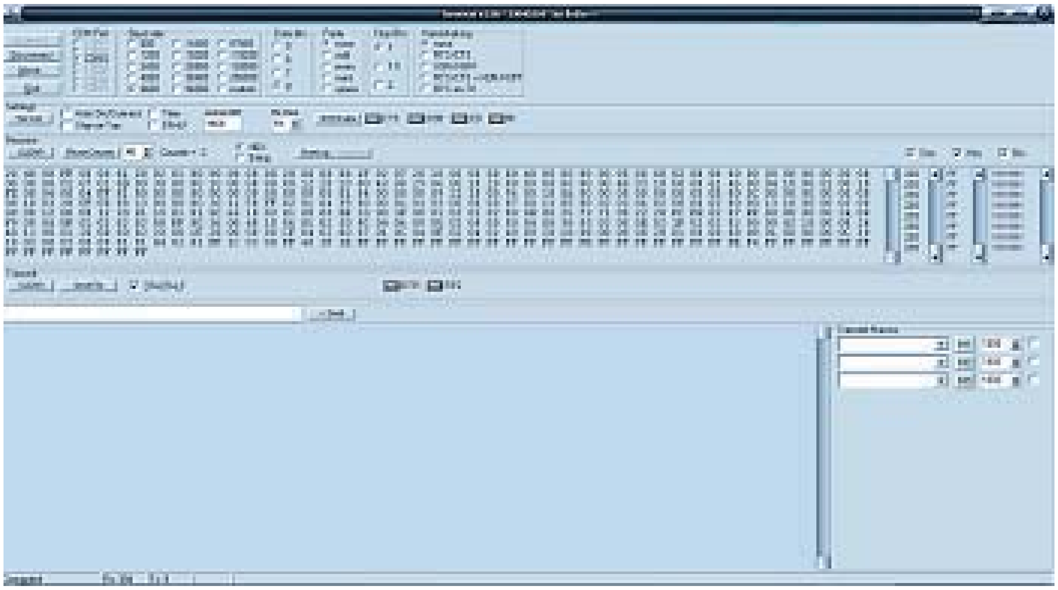


Figure 4. Snap shot of Terminal software

D. Experiments

We have proposed three distinctive movements' Finger fist making, wrist flexion and extension, water bottle take off. Data acquisition was acquired from 5 normal subjects and 2 paralyzed patients. Flex sensors used to detect the fist making movement activity. FSR used to detect the applied force signal response while making finger fist. Accelerometer used to track the motion of water bottle take off and wrist flexion & extension. In order to validate the results we experimented repeatedly for more times and analysis would be carried out according to characteristics of movements. It would may increases the reliable of device performance.

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

Figure 5: Summary of Subject details

III.RESULTS & DISCUSSION

A. Experiment-I,

The signal response of flex sensor has been recorded. Flex sensor is a small strip which resistance value increases according to strip bend more. Flex sensor mounted on cotton glove which would be worn by subjects. We advised to subjects to make finger fist at 5 repetitions per each record totally 5records has been done for 30 seconds.

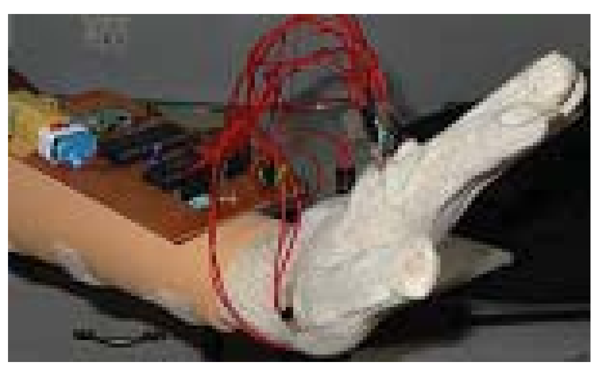

(a) (b)

Figure 6. (a) Monitoring Device Wearied in arm (b) Finger Fist making exercise

In this experiment, we plotted the digital value which has been recorded during finger fist making. Figure 10 shows the graphical representation of finger fist make for normal subjects. When, flex sensor bend inward the resistance value increases according to digital value also increases significantly when, flex sensor become its initial position the resistance value decreases according to digital value also decreases significantly.

B. Experiment-2,

The signal response of wrist flexion & extension has been recorded. 3-axis accelerometer has been used for sensing wrist flexion & extension movements. In this proposed method ADXL335 micro machined capacitive accelerometer with selectable range. This accelerometer traces the motion in 3 axis X, Y, Z co-ordination. The accelerometer mounted on extensor digitorum muscle below the wrist joint. In this experiment we traced the wrist flexion and extension this co-ordination variance has been recorded in digital form. When, wrist flexion the positive co-ordination has been recorded. When, wrist extension the negative co-ordination has been recorded and plotted. This experiment conducted for both subjects (normal and patient). Below figure shows the wrist flexion and extension activity monitoring.

(a) (b)

Figure 7. (a) Wrist Joint Flexion (b) Wrist Joint Extension

C. Experiment-3,

The signal response of water bottle take off has been recorded. 3-axis accelerometer has been used for trace the 3-axis motion. In this proposed method ADXL335 micro machined capacitive accelerometer with selectable range. This accelerometer traces the motion in 3 axes X, Y, Z co-ordination. The accelerometer mounted on extensor digitorum muscle below the wrist joint. Below figure 8 shows the water bottle take off activity monitoring. In this experiment, accelerometer used to trace the water bottle take off in 3-axis co-ordination has been recorded in digital form. When, water bottle take from down to up (up to elbow full flexion) the positive co-ordination has been recorded. When, water bottle get down the negative co-ordination has been recorded and plotted. This experiment conducted for both subjects (normal and patient).

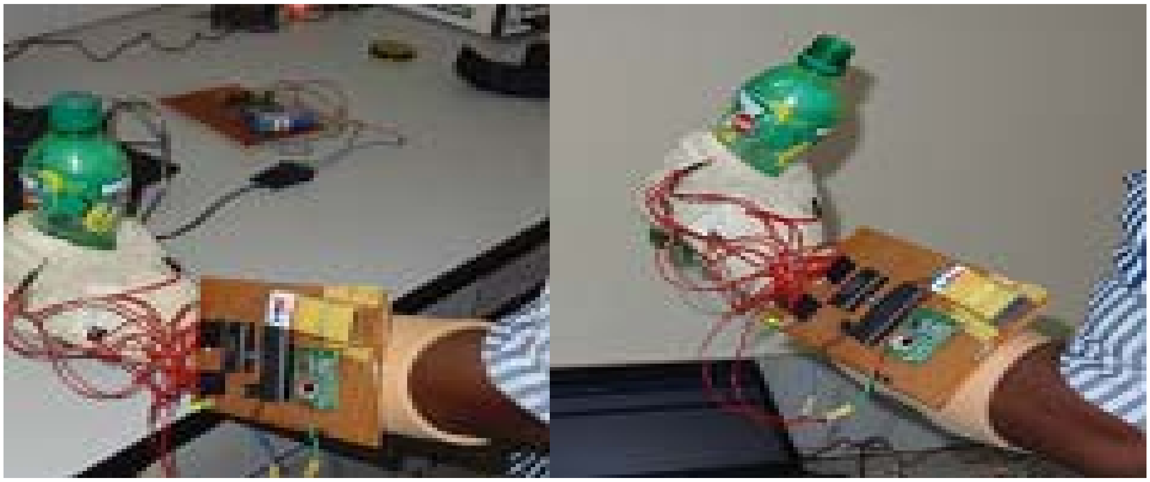


Figure 8. Water Bottle Take off activity

D. Experiment-4

The signal response of FSR sensor has been recorded. Force sensitive resistor sensor used to detect the applied force which composed of polymer thick film. When its active surface is touched it would give the resistance value. The FSR varies its resistance depending on how much pressure is applied to the sensing area. In this experiment subjects were asked to make finger fist at several repetitions per each record totally 2 records has been done. FSR sensor has fixed on center of hand palm Figure 9 shows the finger fist making force detection. In this experiment, we plotted the digital value. During fist making finger will touché the FSR sensor this applied force signal response has been collected. When, finger touches the FSR sensor the resistance value decreased according to digital value also decreased significantly. When, finger relax there is no force on FSR sensor the resistance value increased according to digital value also increased significantly. In this experiment, data has been acquired from both subjects (normal and patients).

Figure 9: FSR force detection during fist making

Below graphical representation shows the signal response of three distinctive rehabilitation activities. In this proposed method 5 normal subjects and 2 upper limb paralyzed patients were participated. Here, one normal subject and one paralyzed patients data has been shown. Comparing of this result with both subjects (normal and patient) it obviously shows signal co-ordination variance.

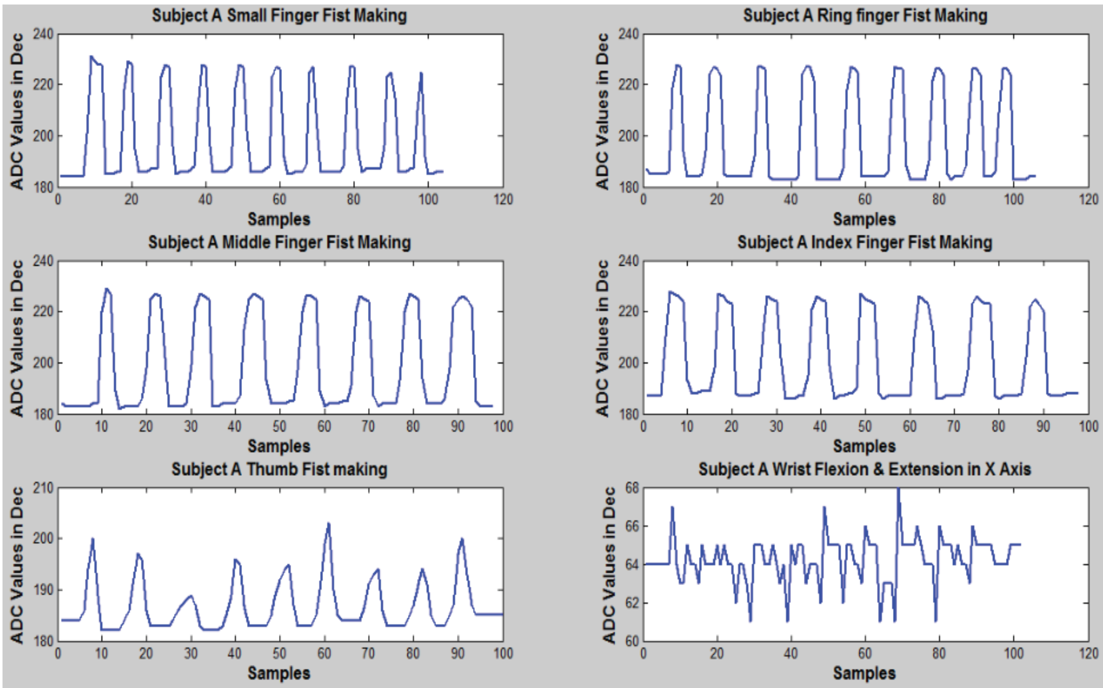


Figure 10: Normal subject finger fist making &wrist flexion and extension signal response

Above graphs represents the normal subject each finger fist making and wrist flexion & extension in X-axis coordination.

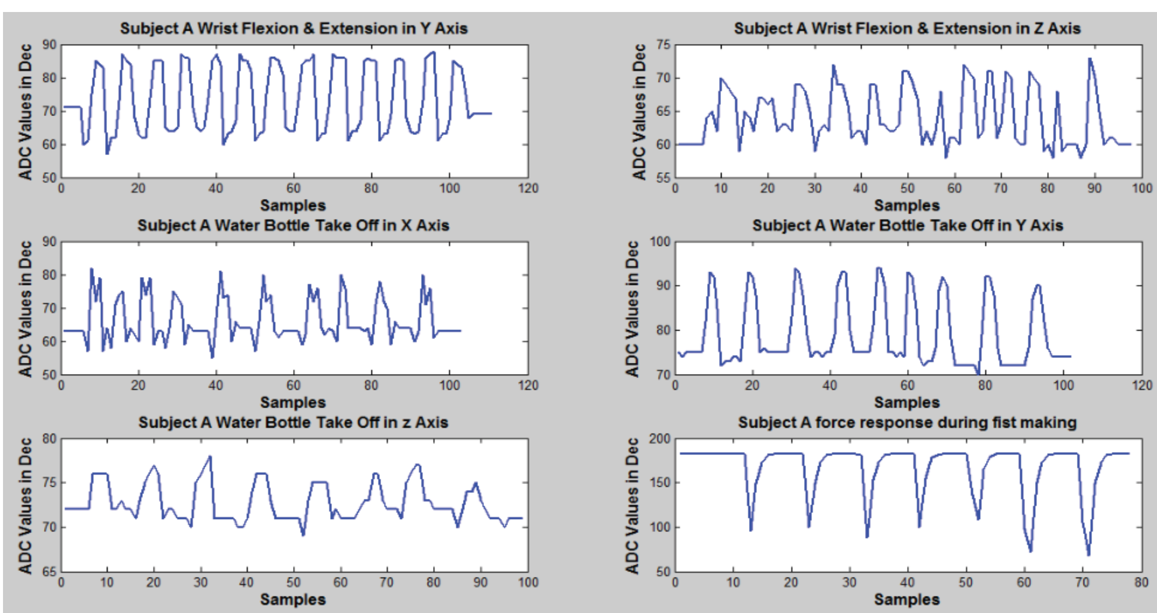


Figure 11: Normal subject water bottle take off and FSR force response during fist making signal response

Above graphs represents the normal subject water bottle take off from elbow extension position to elbow flexion with X, Y, Z co-ordination and wrist flexion & extension Y, Z co-ordination signal response. For normal subject co-ordination of pattern waveform increasing and decreasing according to variation wrist extension and flexion.

Figure 12 Graphical representation of each finger fist making signal response and wrist flexion & extension in X axis co-ordination.
This graph obviously shows the time delay due to slow process of patient and co-ordination variation compared with normal subject.

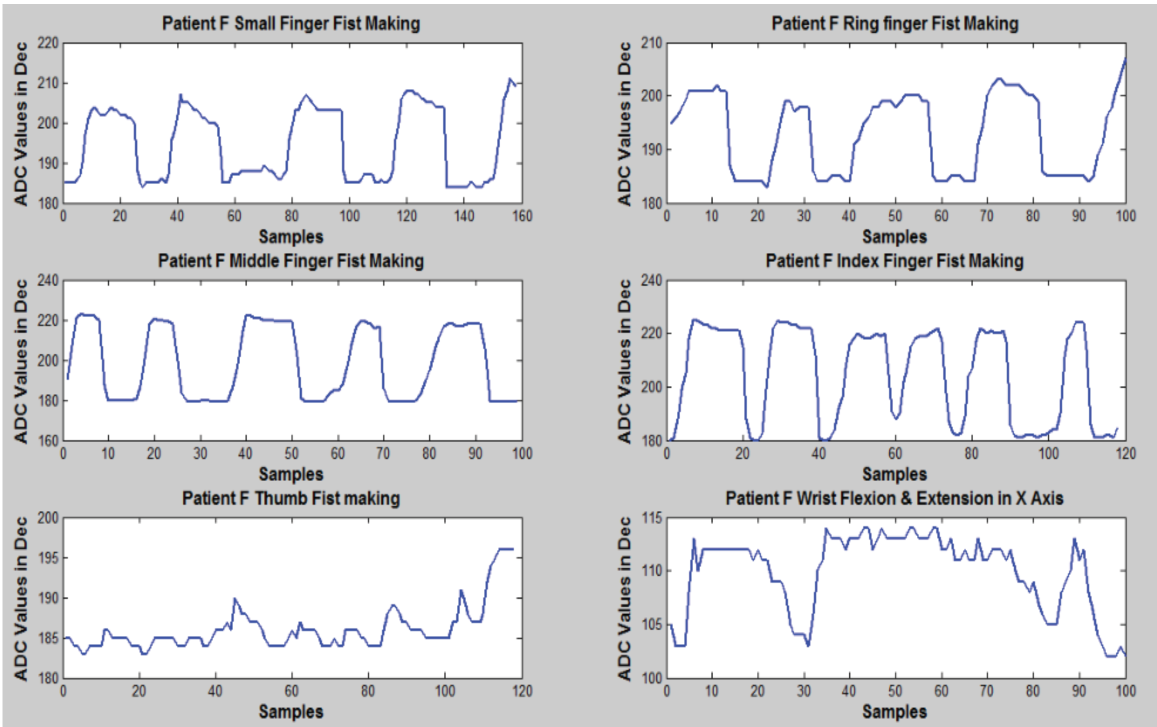


Figure 12: Paralyzed patient finger fist making & wrist flexion and extension signal response.

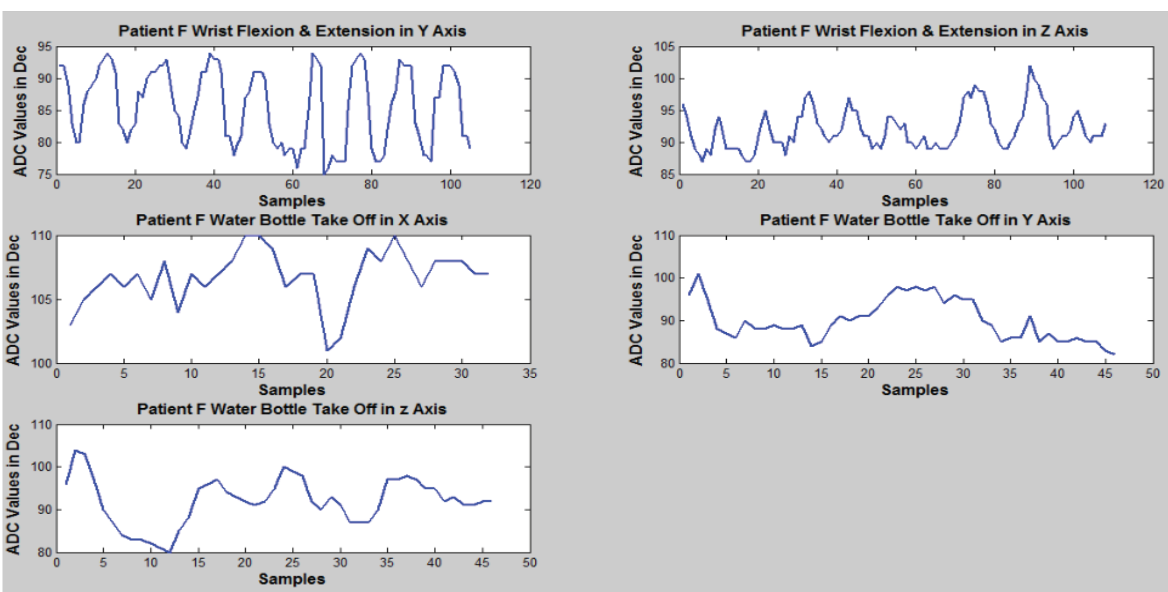


Figure 13: Paralyzed patient water bottle take off signal response

Above figure represented the co-ordination of wrist flexion & extension in X and Y axis. Paralyzed patients are unable to do wrist flexion and extension at right co-ordination because of spasticity. So that, above figure obviously shows the co-ordination variance compared with normal subjects. Particularly, this paralyzed patient unable to touch fingers on palm during fist making therefore FSR force response could not recorded.

IV.CONCLUSION

In this article, wearable sensor accelerometer, and FSR sensor) has been developed for monitoring the rehabilitation activity. In this project, wireless data transmission has been achieved using ZIGBEE 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 has 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 data has 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.

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