Smart Sensor Glove for Rehabilitation of Arthritis Patients

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Abstract : Arthritis is a disabling and agonizing disease. Rheumatoid Arthritis is a disease which affects joints of the body. RA disease results in reduction of physical activity level of the patient. Traditional methods require personal examination for analysis of arthritis rehabilitation. In this paper we presented the design of a smart glove through integration of sensors, processors and wireless technology. The proposed glove facilitates the rehabilitative process by smart technology. The glove uses 6 bend sensors, 2 tri-axial accelerometer to detect joint movement. Sensors are placed on flexible PCB so that the glove does not require calibration for each glove wearer. The four exercises are tested on 10 different patients and it is successful, the accuracy of Glove is 100% for Exercise 1 and 90 % for other 3 exercises which are implemented to rehabilitate patient. The reproducibility error is 2% to 3%.

***IndexTerms* - Rheumatoid arthritis, smart glove, joint movement.**

I. Introduction

Rheumatoid Arthritis (RA) is a chronic which causes the swollen and stiff joints. The disease limit the movement of the affected joints, results in increased physical inactivity of patients. Physical activity is defined as joint movement, produced by skeletal muscles, that requires energy. World Health Organization (WHO) estimated every year 1.9 million deaths because of physical inactivity induced by the disorder. It has been suggested that high intensity Exercise should play a role in disease management .

Regular physical exercise has been associated with health improvements in RA. The important measures of physical activity are number of step counts and energy expenditure. however the disadvantages is need of trained personnel.

II. Literature Survey

Hand RA affects bones, joints which may cause disability and range of movement (ROM). Swelling and pain are common symptoms of hand arthritis. Flexion, extension, adduction and abduction of the metacarpophalangeal (MCP), proximal Interphalangeal (PIP) and distal interphalangeal (DIP) joints of the fingers and thumb in degrees are recorded for the maximum flexion and extension range. Joint stiffness of RA that has been symptom used by radiologists as a parameter to measure the degree of damage caused to a joint to determine how much improvement has occurred after therapy [4].

It is necessary to detect accurate movement of each finger joint so one sensors per finger is required. In rehabilitation, accurate finger joint movement detection for each finger joint. Glove sensors are required for movement detection to match variations of ROM and hand size between glove wearers.

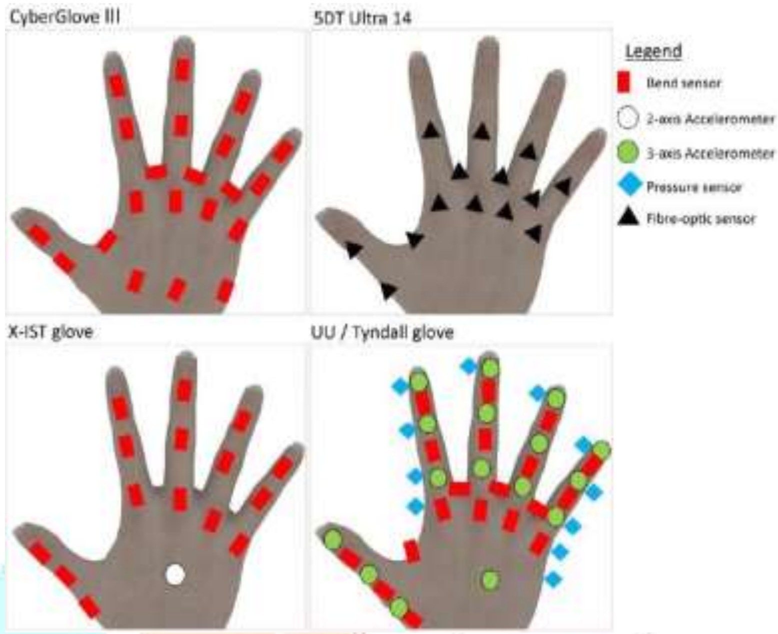


Fig 1 Traditional glove system

III. METHODOLOGY

The main objective of the glove is for the measurement of joint range of the hand, including: flexion, extension, adduction of joints of the fingers and thumb in degrees. The Glove is designed with a total number of 6 sensors and 3 axis accelerometers to capture hand and finger motion.

Block Diagram

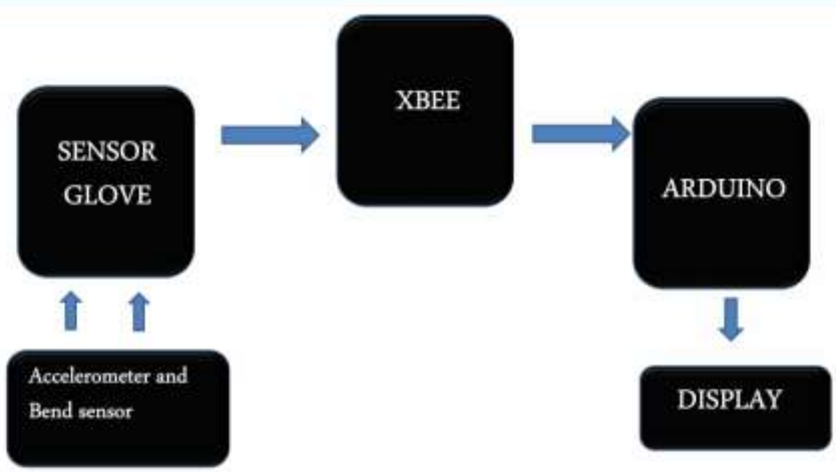


Fig.2 Block diagram of smart

Elements of smart glove

1. Bend sensors
2. 3 axis accelerometer
3. Arduino uno
4. LCD Display
5. Glove

6. XBEE PRO

1) BEND SENSOR

Fig.3a Bend sensor

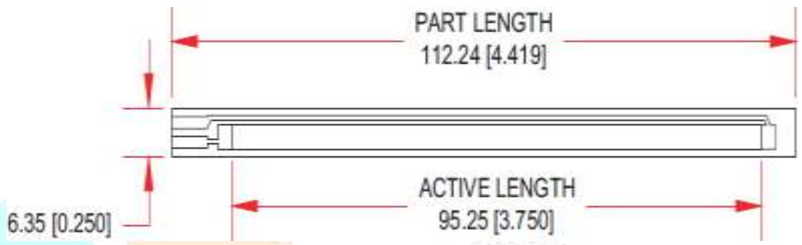


Fig. 3b Dimension of sensor

The flexion of the fingers is measured by bend sensors on each finger and thumb. The bend sensor used is the flexible bend sensor and it consists of a thin, flexible plastic material (e.g. polyimide) that is coated with carbon/polymer ink that changes in electrical conductivity as it is bent. The position of the bend sensors crosses over the DIP, PIP and MCP joints. Each joint has its own sensor to record accurate angular joint movement.

In addition to the angular joints angle, bend sensors are also used to account for the splaying of the fingers so that, abduction angles are also recorded.

2) ACCELEROMETER

The MMA8451Q is a low-power, three-axis, capacitive, micro machined accelerometer with 14 bits of resolution. This accelerometer contains embedded functions with flexible user programmable options.

3) XBEE

The XBee-PRO RF Modules were engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. The modules require minimal power and provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin- for-pin compatible with each other.

4) ARDUINO UNO

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital. Input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.
The smart sensor glove is build with the intention to motivate the patient to perform exercises regularly. This will help him to recover faster from the disease. We as per our study developed 4 exercises for the patient and have named the as follows

1) Four finger warm-up
2) Kapandji exercise
3) Wrist swivel horizontal
4) Wrist swivel vertical

These exercises were designed taking each and every bone development into consideration. The sensors are used such that it could give the measurement of almost any movement of our hand.

Types of sensors used :

- 5 Bend sensors - attached to the glove's thumb, index finger , middle finger , ring finger and little finger.
- 1 Accelerometer(ADXL345) - attached to the palm for good sensitivity.
- 1 LCD for interactive interface.
- 1 Buzzer to alert the arthritis patient.

Circuit board

The main board is powered with a 9V battery which is converted to 5V using a LM7805 and 3.3V using LM317. The microcontroller used is Atmega 32.

Interfacing bend sensor:

The bend sensor actually is a variable resistor. It changes its resistance according to the bend offered by the finger. A 10k resistance is attached and the change in voltage potential is measured. The change in this voltage is then converted into a scale of 1023 by the in-build ADC in the microcontroller.

Interfacing adxl345 :

The adxl works on a voltage of 3.3V. Hence we need to use a level converter that takes 9V as input and gives 3.3V in output. Adxl345 works on MEMS principle. It has a poly-silicon surface suspended over a silicon wafer using poly-silicon springs. The ADXL345 is a small, thin, ultra-low power, 3-axis accelerometer with high resolution (13-bit) measurement at up to ±16 g. Digital output data is formatted as 16-bit twos complement and is accessible through either a SPI (3- or 4-wire) or I2C digital interface.
We are using spi 4 wire protocol. Where

- SS is connected to chip select (CS)
-MOSI is connected to serial data input (SDA)
-MISO is connected to serial data output (CS)
-SCK is connected to serial clock (SCL)

SOFTWARE :
The controller calls 4 exercises one by one. It does not jump to the next exercise unless and until the previous one is completed.

EXERCISE 1 :
When we bend the first four fingers the bend sensor changes its value which was initially at 750 to a new value which extends more than 800. Taking this reference a full bend of 4 fingers increases the value by 50 units. A do-while loop is used to for the same exercise to be performed repeatedly. When all the fingers are bent the program enters in a if condition where buzzer is beeped and count is increased. This in repetition of 5 counts gives the exercise complete output on the LCD SCREEN.

EXERCISE 2 :
In this exercise a combination of 2 bend sensors sets up the flag . 4 flags are defined and when these flags are set up , set 1 gets completed. A repetition of such exercise twice completes this exercise

EXERCISE 3:
In this exercise accelerometer helps us with its y axis co ordinates. The y axis gives a value of -360 on first swing and a value of almost -270 on second swings. Using this reference the controller sets up a flag on each swing. 3 such repetition completes the whole exercise.

EXERCISE 4:
In this exercise flag is set when all the flex sensors are bend. At this time the controller sets up in a loop in which it monitors x axis of adxl. When X axis reaches positive values counts are increased. 5 such counts completes the exercise.

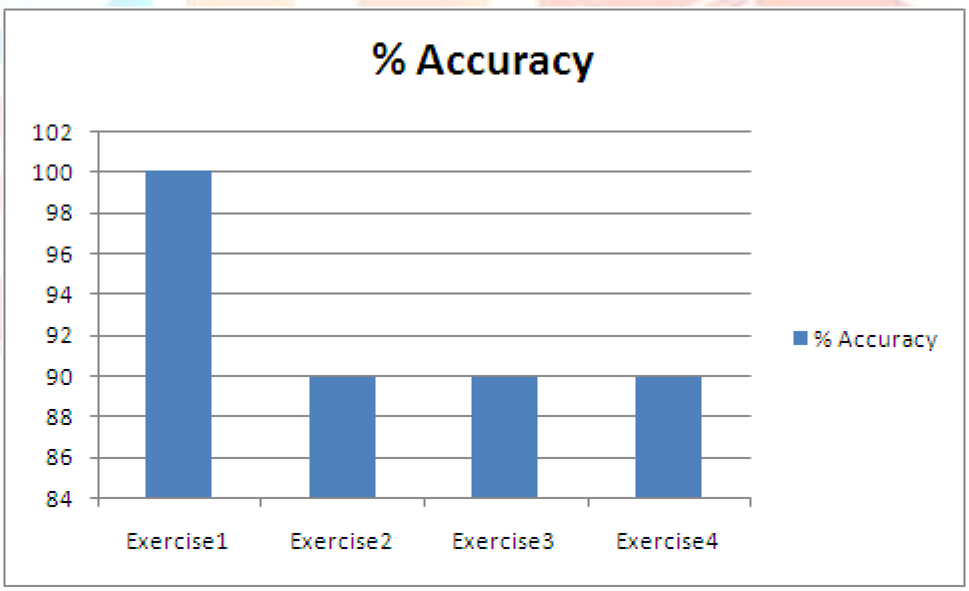
IV. RESULT

The implementation of smart sensor glove facilitates the exercise of arthritis patients. This glove will help to quantify joint stiffness and allow for joint stiffness to be dynamically and empirically monitored.

Fig.4 Design of Hand glove with bend sensors

Table 1 Accuracy in Percentage of hand exercises

Exercise	% Accuracy
Exercise 1	100
Exercise 2	90
Exercise 3	90
Exercise 4	90



The four exercises are tested on 10 different patients and it is successful, the accuracy of Glove is mentioned in percentage. The reproducibility error is 2% to 3%.

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