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Implementation of Wireless Controlled Shadow Dexterous Hand for Hazardous Environment

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ABSTRACT

In this research paper, implementation of embedded system based robotic hand that can reproduce all the movements of human hand and provides comparable sensitivity is discussed. Moreover, the control system of wireless controlled shadow dexterous hand is presented which can be used for hazardous environments. This hand allows a direct mapping from a human to the robot movement using sensors placed on hand. Sensors placed on hand detect the muscles response of a person and then the responses of corresponding sensors are delivered to the microcontroller. Then Xbee module is used to transfer the wireless signals to the microcontroller, which drives the mechanical hand according to the acquired signal and produces the shadow movement of human hand.

KEYWORDS— Dextrous Hand, Hazardous Environment, Embedded System, Microcontroller, Xbee

I. INTRODUCTION

A mechanical agent which performs different tasks and services either by remote control or by self-guidance is called robot. A robot is actually electro-mechanical structure that can be made intelligent with the help of computer and electronic programming [1]. The implementation of robots for performing different tasks in industry is becoming very common due to the awareness of industrialists. In a developing country where labour is very cheap, workers are supposed to perform different tasks which include lifting of heavy weight, working in environment which is supposed to be hazardous for human health etc. The history of industry is full of incidents where workers lost their lives, got crippled for life those who survived fatal accidents while working in hazardous environment.

Hazardous environment include the environment which contains gases which can cause harm to human life. Example of hazardous environment includes the rise of temperature above the endurance level of human. The processes which involve such a huge rise in temperature involve milk processing units, thermal power plants, nuclear reactors etc [2]. So, in such cases it is advisable to use robots instead of using labour because human life is much more important than any other thing.

Wireless controlled animatronics hand is actually a mechanical robotic hand which mimics the movement of the user's hand. This work lies in the category of remote controlled robots which will isolate the user from the hazardous environment. Block diagram of implemented system is shown in Fig 1.

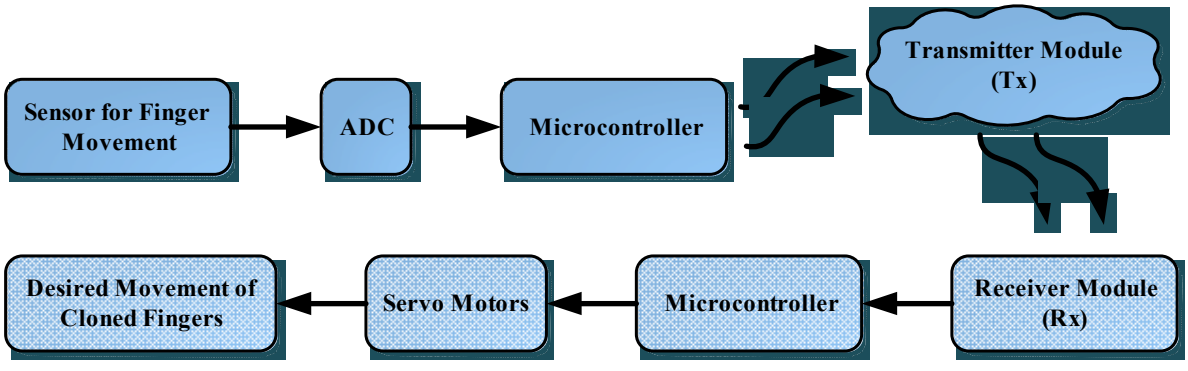

Fig. 1 Block Diagram of System

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The sensors detect the movement of user's hand. The information received from the sensors is transmitted to the robotic unit which perform task on the basis of the received information. The robotic hand includes the complete figure movement with the movement of joints similar to a human hand. The robotic hand motion which mimics the hand movement of the user can be very useful to perform different unpleasant jobs easily.

This research paper is organized as follows: Section II describe the used hardware. Section III introduces the softwares used for designing of robotic hand. Section IV discusses the implementation of system and paper is concluded in Section V.

II. HARDWARE IMPLEMENTATION

Hardware used to implement the system are microcontroller, Xbee Module, flex sensor and servo motors.

A. Arduino UNO

The animatronics hands have already been implemented previously using FPGA and microcontroller. DLR I and DLR II are example of animatronics hands implemented with FPGA [3] [4]. A comparison between FPGA and microcontrollers shows that FPGA can handle complex algorithms as compared to the later [3]. Trade off between cost and accuracy makes microcontroller the preferred choice [5] [6].

In this research work, arduino microcontroller board is used as shown in Fig 2. It has Atmega328 microcontroller which operates on crystal frequency of $16MHz$. This board provides support of 14 digital input/output pins and 6 analog pins having resolution of 10 Bits.

Fig. 2 Arduino UNO (Atmega328)

B. Wireless Transceiver

The wireless transmission of data to the robotic hand unit can be done using Bluetooth or XBEE. IBM introduces Bluetooth in 1994 whereas Xbee first appeared in 1998 as a fruit to tireless efforts of Motorola [7]. Xbee can be used in different topologies such as star, mesh and direct, besides Bluetooth can only be used for direct connectivity. Moreover, Bluetooth consumes more power as it has to be connected all the time to available networks. Therefore, Xbee has a low battery life as it consumes less power than Bluetooth [7]. In Addition, XBEE has more wireless range to transmit data than Bluetooth. So the ultimate choice is to choose Xbee to transmit and receive data and is shown in Fig 3.

Fig. 3 Xbee Module

C. Sensors to Track Movement of Fingers

Flexion of the user's finger can be measured with the flex sensors which have a variable printed resistance as shown in Fig 4. It produces a resistance output, correlated to the bent angle [8].

Fig. 4 Flex Sensor

The replacement of the flex sensor can be either ECG or EEG sensors. Electroencephalography (EEG) sensors record the voltage fluctuation due to the neurons movement in the brain from thinking process [9]. The EEG sensors are mounted on the scalp. This makes the use of EEG sensor unpleasant. Moreover, the limitation of EEG sensors is its spatial resolution. The EEG sensors require a controller which can handle complex algorithms. The cost of EEG sensors is almost 60 times a flex sensor. Thus Flex sensors are preferred because of their flexibility and economical cost.

D. ***Servo Motors***

There are different types of motors such as DC gear motors, stepper motors and servo motors. But servo motors are best to be used in robotics because they can rotate maximum of 180 degrees and provide smooth movement in joints of robotic structure. The servo motor is shown in Fig 5.

Fig. 5 Servo Motor

On Transmission side, five flex sensors are used to measure movement of all 5 fingers and then theses signals are fed to microcontroller to tranmit the signal through Xbee as shown in Fig 6. On receiving side, microntroller receives the signal and drive servo motors of robtic finger to produce shadow movement as shown in Fig 7.

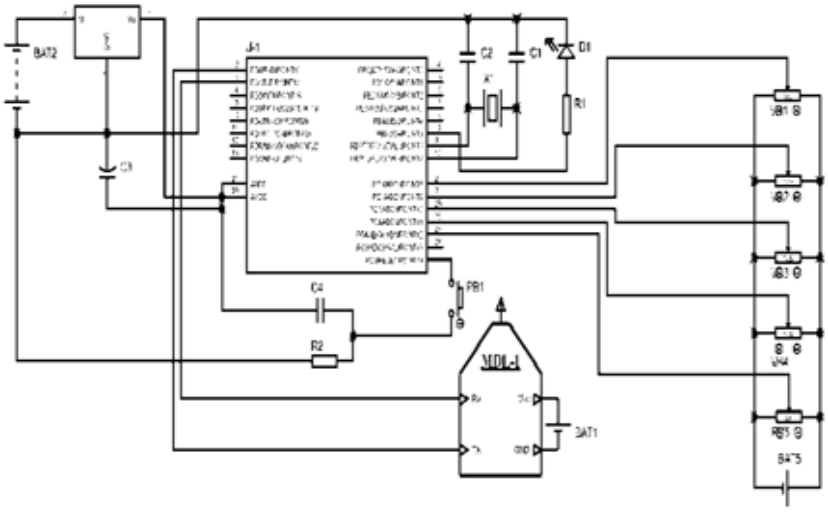

Fig. 6 Schematic Diagram of Transmission Side (Human Hand)

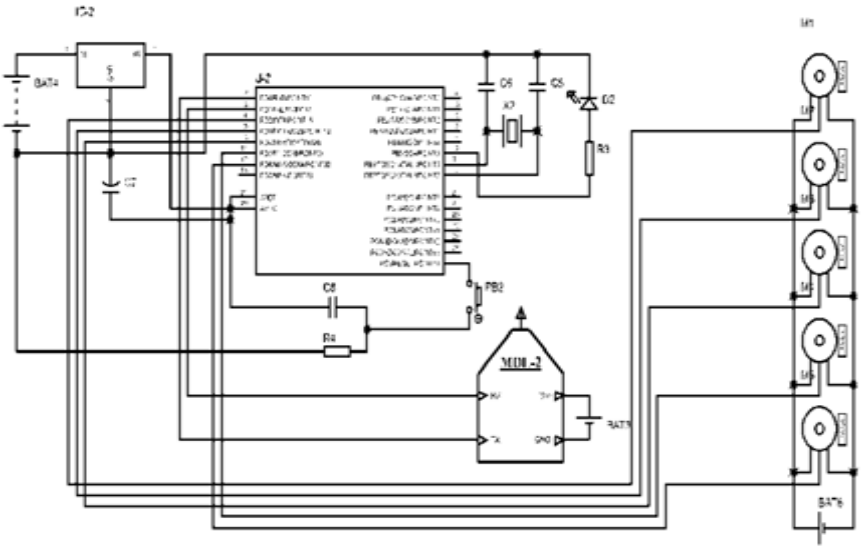

Fig. 7 Schematic Diagram of Reception Side (Robotic Hand)

III. SOFTWARES SETUP

This section briefly discusses the detail of all the software used in the system.

A. PTC Creo Parametric

Designing a mechanical hand which resembles human hand is the main demand of the system. PTC Creo Parametric is a 3D-CAD tool and provides very powerful yet flexible 3D-CAD tool to design structures. Interface of PTC Creo is shown in Fig 8 that is taken from Creo website [10]. So design of robotic hand is designed in this software.

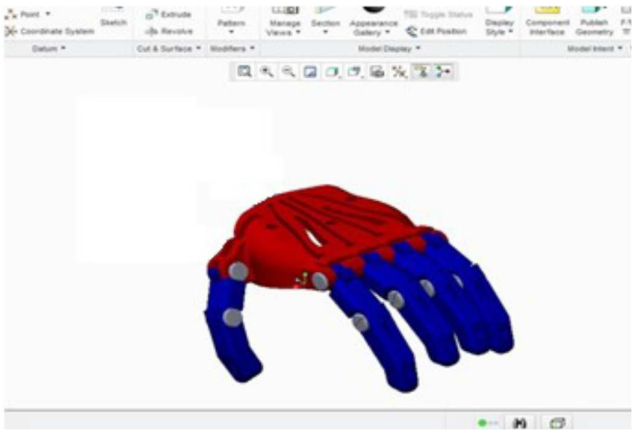

Fig. 8 Interface of PTC Creo [10]

B. Auto CAD

The use of Auto CAD in this implementation is that the Laser CNC which is used to cut the pieces of acrylic to obtain the structure of hand is compatible with .dxf file format (Format of AutoCAD). The 3*D* files produced in Creo are converted into .dxf file. This software for the LASER CNC produced g-codes from the .dxf files.

IV. SYSTEM IMPLEMENTATION

Initially, single flex sensor is tested. Flexion of the user's finger can be measured with the flex sensors which have a variable printed resistance, which produces a resistance output correlated to the bent angle. As, flex sensor is a simple variable resistor

so simple configuration of voltage divider can be used to measure change in resistance according to flexion of finger as shown in Fig 9 and Fig 10.

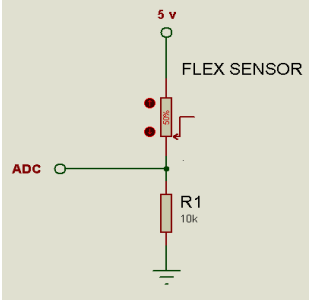

Fig. 9 Flex Sensor Output to MicroController

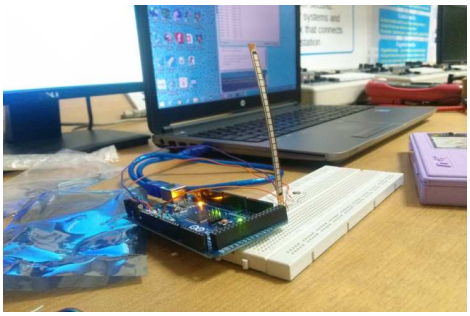

Fig. 10 Testing of Flex Sensor

Output of this configuration is fed to ADC of arduino UNO, where resolution of analog inputs of ADC is 10 bits which corresponds to step size is of 0.0048. Table I shows that flexion of flex sensor (in degrees) varies the value of resistance and voltage drop.

Table I Bending versus Resistance

Bend Degree	Resistance ($K\Omega$)	Voltage Drop (V)
5	12.2	2.73
10	12.4	2.84
15	13.6	2.97
20	14.4	3.01
25	15.9	3.08
30	17.1	3.15
35	17.5	3.19
40	18.6	3.23
45	19.5	3.32
50	21.8	3.37
55	22.2	3.43
60	22.6	3.52
65	23.3	3.58
70	23.9	3.62
75	24.5	3.68
80	25.2	3.71
85	27.8	3.75
90	28.5	3.81

The corresponding graphs for finger bending to the value of resistance and voltage drop can be seen in Figure 11 and Figure 12.

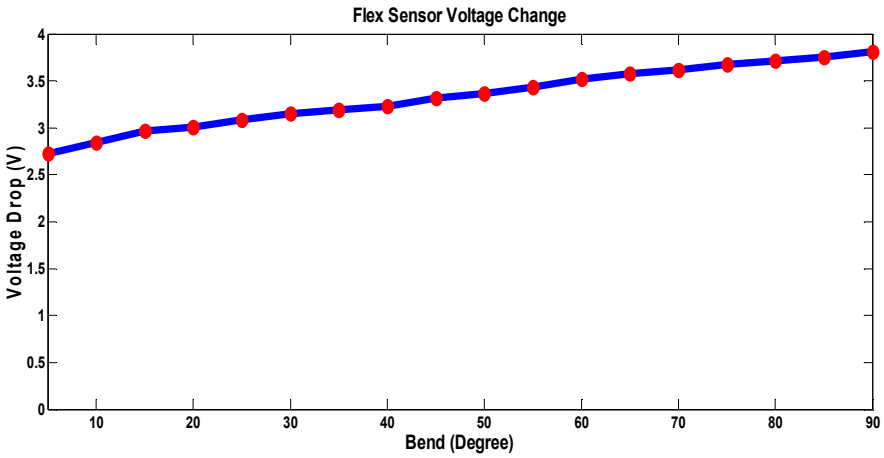

Fig. 11 Bending versus Voltage Drop

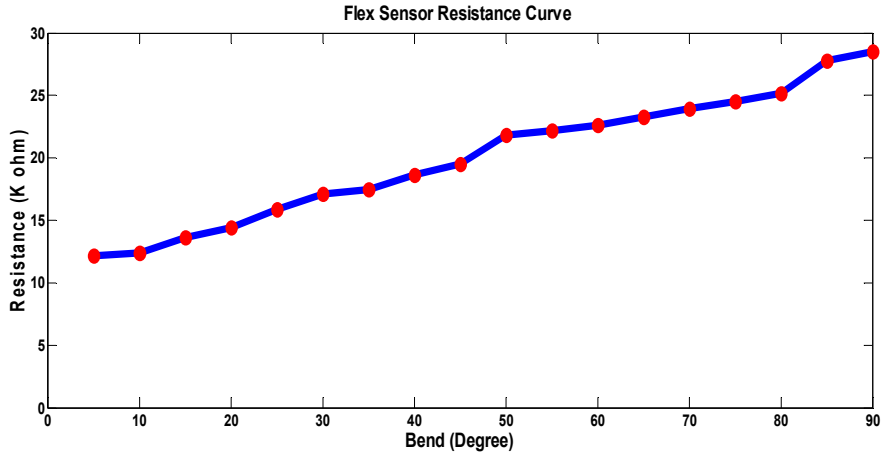

Fig. 12 Bending versus Resistance

So after testing of flex sensor, single flex sensor is attached on a glove and interfaced with microcontroller. Servo motor of mechanical grabber is derived successfully according to flexion of finger as shown in Fig 13.

Fig. 13 Opening and Closing of Grabber According to Movement of Finger

After successful initial prototype, flex sensors are attached on every finger of glove as shown in Fig 14. Xbee module is used to transmit these bending values of sensor to receiver side and drive all five servo motors of robotic structure as shown in Fig 15. The performance of this prototype is quite satisfactory in both conditions when both are in line of sight of each other and when they are not.

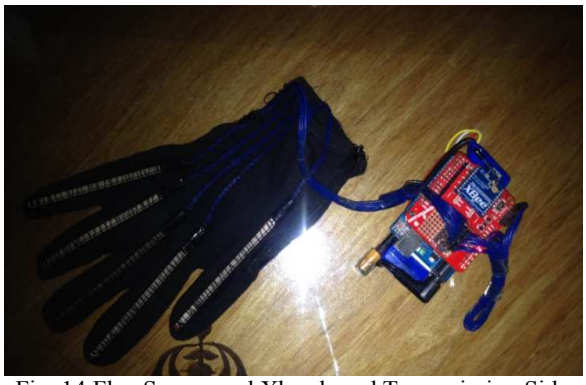

Fig. 14 Flex Sensor and Xbee based Transmission Side

Fig. 15 Robotic Hand on Receiving Side

V. DISCUSSION

Different robotic structure may lead to different control solution and it is a difficult task to control robotic structure to make it follow the assigned geometrical position in accurate manner. In this work, a wireless robotic hand is controlled by flex sensors based glove. Using flex sensors, movements of fingers are translated as commands for robotic hand to mimic. Xbee transceivers are used for wireless transmission and receptions of commands.

There are few constraints to be considered for improvement of prototype. First of all, the wearable glove (having microcontroller, sensors, transceiver and battery) should be lightweight. This issue can be resolved by selecting appropriate lightweight components like arduino UNO can be replaced with small version of board like arduino Nano or Mini having same crystal frequency and same numbers of analog pins for flex sensors. Second constraint to be considered is the channel overlapping problem in Xbee sensor networks. Xbee transceivers use limited number of channels and in an environment having heavy transmission/reception load, problem of longer delay causing loss of data can be occurred. In our system, just one transmitter and one receiver is used, so by choosing appropriate channel this problem can be avoided.

In proposed hardware, all fingers of robotic hand are controlled using servo motor. Servo motor can be controlled in position and velocity mode. So, position and movement of fingers are mimicked using servo motors. By using flexible robotic structure having high degree of freedom and placing other sensors on human body (EEG headset, EMG sensors, Accelerometer) movement of complete human arm can be mimicked.

Flex sensors are widely used for glove based devices but results show that flex sensors have problem of low sensitivity at small angels. To use wireless dexterous hand for critical operations where high sensitivity is required, optical sensors can be used for measurement of angles.

VI. CONCLUSION

Wireless controlled dexterous hand can be used to isolate human beings from the hazardous environment. This hand can be operated from a distance of 30 meters in case of any objects that is in line of sight and 90 meters in case when there is no objects in the line of sight. The economical mechanical structure of the hand is made from acrylic, because acrylic is best when it comes to make prototypes. Moreover, the cost to LASER cutting of acrylic is also low as compared to any other material.

Some modifications can be done in this system to improve the performance by sensing the finger movement using image processing algorithms, by using structure of hard material as aluminium or steel and this system can be mounted on a robot to carry it to hazardous environment.

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