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Gesture Controlled Robotic Arm

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Abstract:
Now-a-days robotic arm is used in various areas such as military, defense, medical surgeries, pick and place function in industrial automation applications. Based on the gesture of human hands the robotic arm moves and performs the task and this system replicates the actions of human hands. The arm is very flexible and can be made suitable in places where the environment is not safe for humans like firework manufacturing industry, bomb diffusing etc. There are various techniques for controlling the robotic arm. This paper deals with the accelerometer based gesture recognition for controlling the movements of the robotic arm through wireless control by using zig bee protocol.

Keywords: *Zigbee, Arduino, robotic arm, accelerometer*

1. Introduction

Robotics has created a great impact on our society in this modern era and so reserve its space in all fields like Engineering, Medical, Space Science, and many more. Robots can be used in places where human life is placed at risk such operations are bomb diffusing, fireworks industry. The control of the robotic system can be done by any type of controller like micro-controllers, DSP controllers, Arduino controller and FPGA controller [1]. Arduino controller is one of the easiest way to control the system and it has more control ports when compared to the micro-controllers and the DSP controller. Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. The microcontroller on the board is programmed using the Arduino programming language and the Arduino development environment. Arduino projects can be stand-alone or they can communicate with software running on a computer (e.g. Flash, Processing). The wireless transmission is used for transmitting the signals from one end to the other. Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor and the most common wireless technology used is radio. The wireless transmission must be reliable and it must have a very fast response. The wireless transmission that can be used are Bluetooth, infrared, zigbee and wifi technology. The Zigbee technology is used as it provides wide range of control and the cost is cheap.

2. Operation of Robotic ARM

The system consists of two side one is the sending side and the other is the receiving side. The data is transmitted wirelessly through zigbee protocol [7]. The overall block diagram of the system is as given below

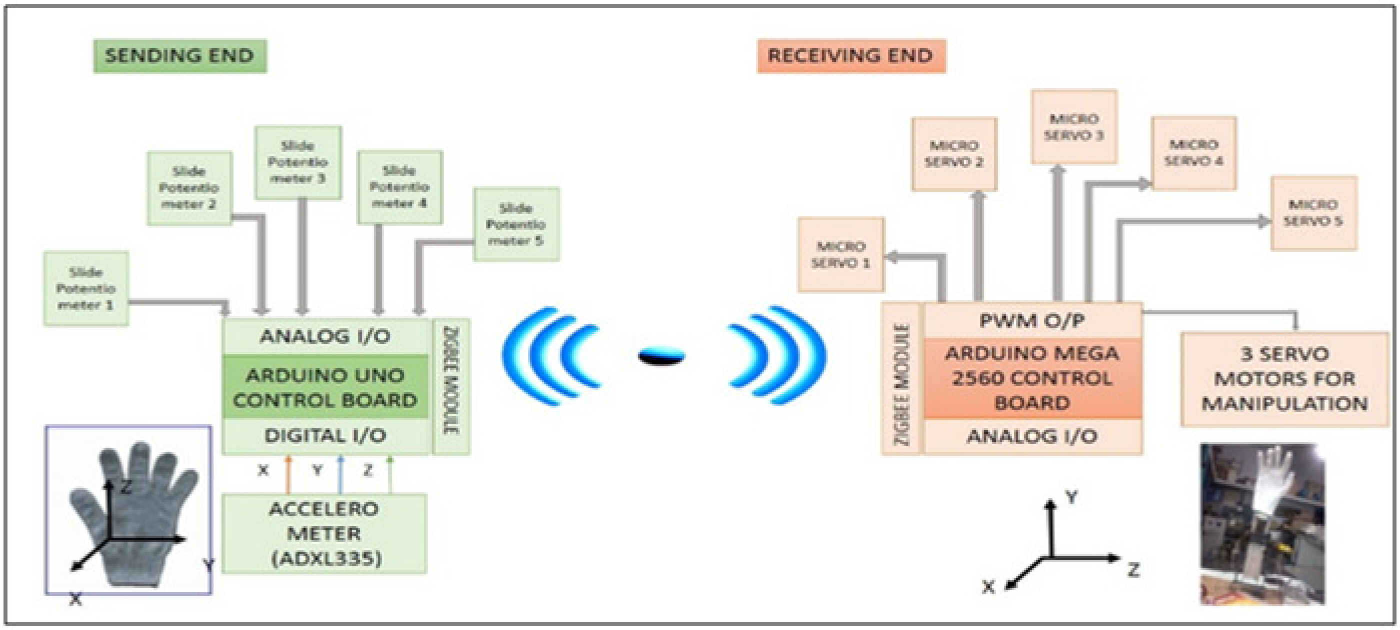


Figure 1: Block diagram of gesture control robotic arm

2.1. Sending End

In the sending end we use accelerometer to detect the movement of robotic arm in 3-axis (x, y, z). This accelerometer is fixed to the sensing glove which is to be worn by human. This accelerometer gives three analog values (x, y, z) based on the movement of human hand. This accelerometer reading is given as input to the analog input pins of Arduino Uno board.

Slide potentiometers are attached to the fingers of the sensing glove. And they are also given as input to the analog pins of Arduino board. When the fingers are moved, the slide potentiometer value changes and this can be used to recognize the actions of fingers

A Zigbee module is attached to the Arduino board with the help of Arduino shield and then the data obtained from the slide potentiometer and the accelerometer are sent wirelessly through the zigbee module [8]. Zigbee module sends the data wirelessly to another zigbee module which is placed on the controller in the robotic arm.

2.2. Receiving End

At the receiving end the data is received through zigbee module which is attached to Arduino Mega using zigbee shield. Then with the data received from the zigbee, the movements on the motors are made with the help of Arduino mega board. For the actuation techniques we use servo motors. The PWM signal for the servo motors are given through the PWM output pins of Arduino Mega. The PWM is given based on the values received from zigbee module attached to it.

Five micro servos of 1kg capacity are used to actuate the fingers of the robotic arm and three 6 kg servo motors are used to give the movement of the arm in all axis.

3. Design of Sensing Gloves

Slide potentiometer are attached to a PCB and were given a common supply from Arduino board. The variable pin of each slide potentiometer is given to analog inputs of the Arduino board. Accelerometer is directly attached to Arduino analog pins. Both accelerometer and slide potentiometer are given 5V supply from Arduino boards. Both the PCB containing slide potentiometer and Arduino board is attached to the glove which can be worn by human [3]. The finger tip of glove is attached to the varying point of slide potentiometer. If the finger is moved, it will pull the moving point of slide potentiometer, thereby sensing the motion of the fingers. Zigbee is attached to the Arduino board which acts as sender to send the data of slide potentiometer and accelerometer. To obtain gesture the slide potentiometers and accelerometers are used which is shown in the below figure.

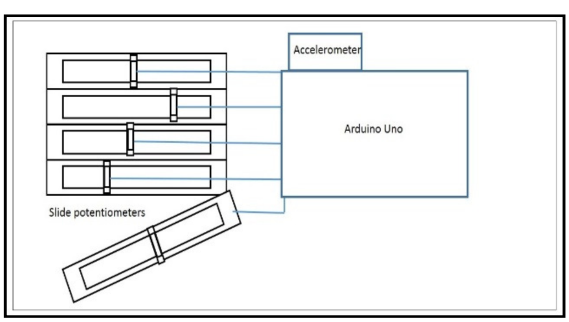


Figure 2: Structure of Sensing gloves

3.1. Accelerometer (ADXL 335)

The accelerometer ADXL335 can measure the static acceleration of gravity in tilt sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration. The bandwidth of the accelerometer is determined using the C_X, C_Y, and C_Z capacitors at the X_{OUT}, Y_{OUT}, and Z_{OUT} pins. Bandwidths can be selected to suit the application. The functional block diagram of the accelerometer is given as in the figure.

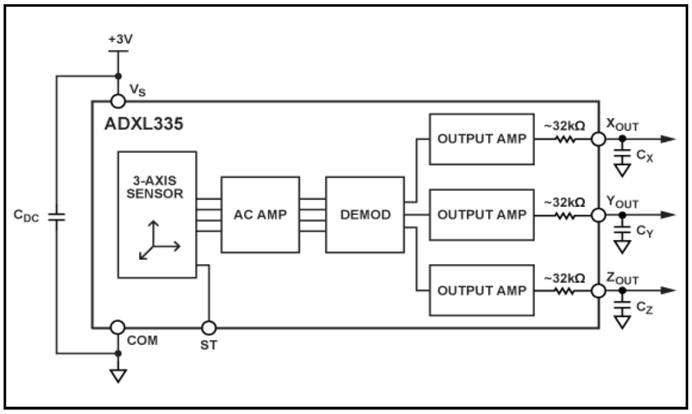


Figure 3: Functional diagram of Accelerometer (ADXL335)

The ADXL335 is a complete 3-axis acceleration measurement system. The ADXL335 has a measurement range of ±3 *g* minimum. It is a small, low profile, 4 mm × 4 mm × 1.45 mm, 16-lead, plastic lead frame chip scale package. It contains a polysilicon surface-micro machined sensor and signal conditioning circuitry to implement an open -loop acceleration measurement architecture. The output signals are analog voltages that are proportional to acceleration. The accelerometer measures the static acceleration of gravity in tilt-sensing applications as well as dynamic acceleration resulting from motion, shock or vibration.

Polysilicon springs suspend the structure over the surface of the wafer and provide a resistance against acceleration forces. Deflection of the structure is measured using a differential capacitor that consists of independent fixed plates and plates attached to the moving mass. The fixed plates are driven by 180° out-of-phase square waves. Acceleration deflects the moving mass and unbalances the differential capacitor resulting in a sensor output whose amplitude is proportional to acceleration. Phase-sensitive demodulation techniques are used to determine the magnitude and direction of the acceleration. The demodulator output is amplified and brought off-chip through a 32 kΩ resistor. The ADXL335 uses a single structure for sensing the X, Y, and Z axes.

The accelerometer is calibrated to detect the position of our arm. The human hand movement is consolidated at three main positions. They are upright position, down position and slant position. The values of accelerometer output at every position is tabulated as follows

POSITION	X	Y	Z
UPRIGHT	350	420	350
SLANT	400	350	350
DOWN	450	300	350

Table 1: Calibrated Readings of accelerometer

3.2. Sliding Potentiometer

This slide potentiometer is a linear variable resistor with a total resistance of 10k. When the lever from one side to the other is moved, its output voltage will range from 0 V to the VCC you apply. It has four grove pins, 3 of which are connected to VCC, GND and the ADC IN on the slide, while the remaining pin is connected to a green indicator LED. The indicator LED is used to visually display the change on the potentiometer. The model of the slide potentiometer is given in the below figure.

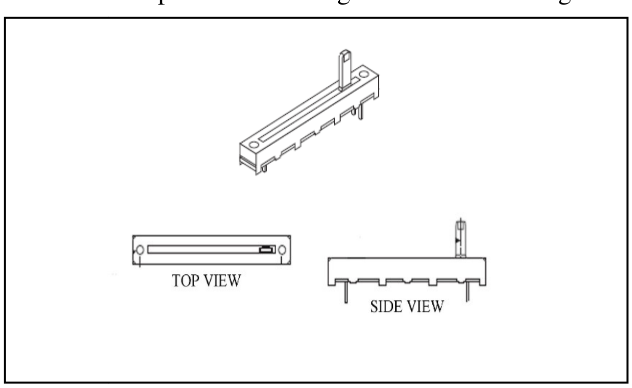


Figure 4: Model of slide potentiometer

The slide potentiometer is calibrated according to the position of our fingers. The values of accelerometer output at every position is given in the below table.

S. No.	LENGTH	VALUES
1	1.00	0.59
2	2.00	1.14
3	3.00	2.5
4	4.00	3.2
5	5.00	4.6

Table 2: Readings of slide potentiometer

The sensing glove needs a controller to process all the data from accelerometer and slide potentiometer. It also needs to communicate with zigbee module so that the data can be wirelessly sent. Arduino UNO board is used for the control function.

The Arduino Uno is a microcontroller based control board which is used as a controller that can be programmed to execute set of instructions based on the inputs given to the board. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. Pre-programmed into the on-board microcontroller chip is a boot loader that allows uploading programs into the microcontroller memory without needing a chip (device) programmer. The Arduino Uno has 14 digital input/output pins wherein 6 used as PWM outputs and 6 analog inputs, 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, a reset button

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer.

Specification of Arduino UNO	
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32KB - 0.5KB used by boot loader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

Table 3: Specification of Arduino UNO

The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer. A Software Serial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication.

The ATmega328 on the Arduino Uno comes pre-burned with a boot loader with which new code can be uploaded to it without the use of an external hardware programmer. It communicates using the original STK500 protocol. The Arduino Uno has a resettable poly-fuse that protects your computer's USB ports from shorts and overcurrent. The fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed. The connection diagram of the Arduino and the accelerometer is given in the below figure.

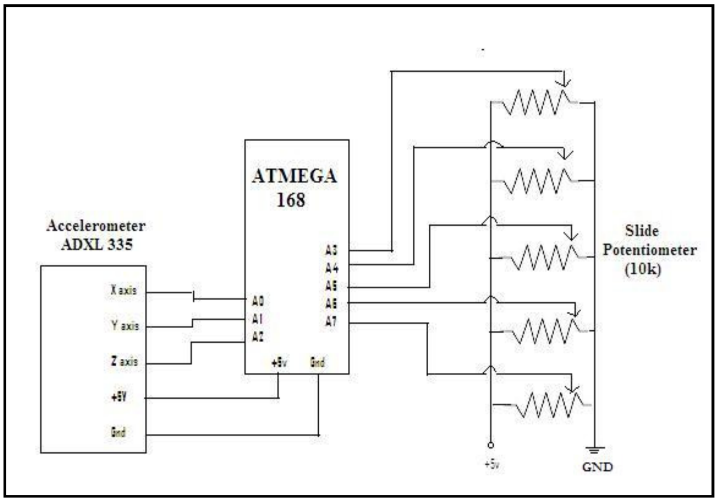
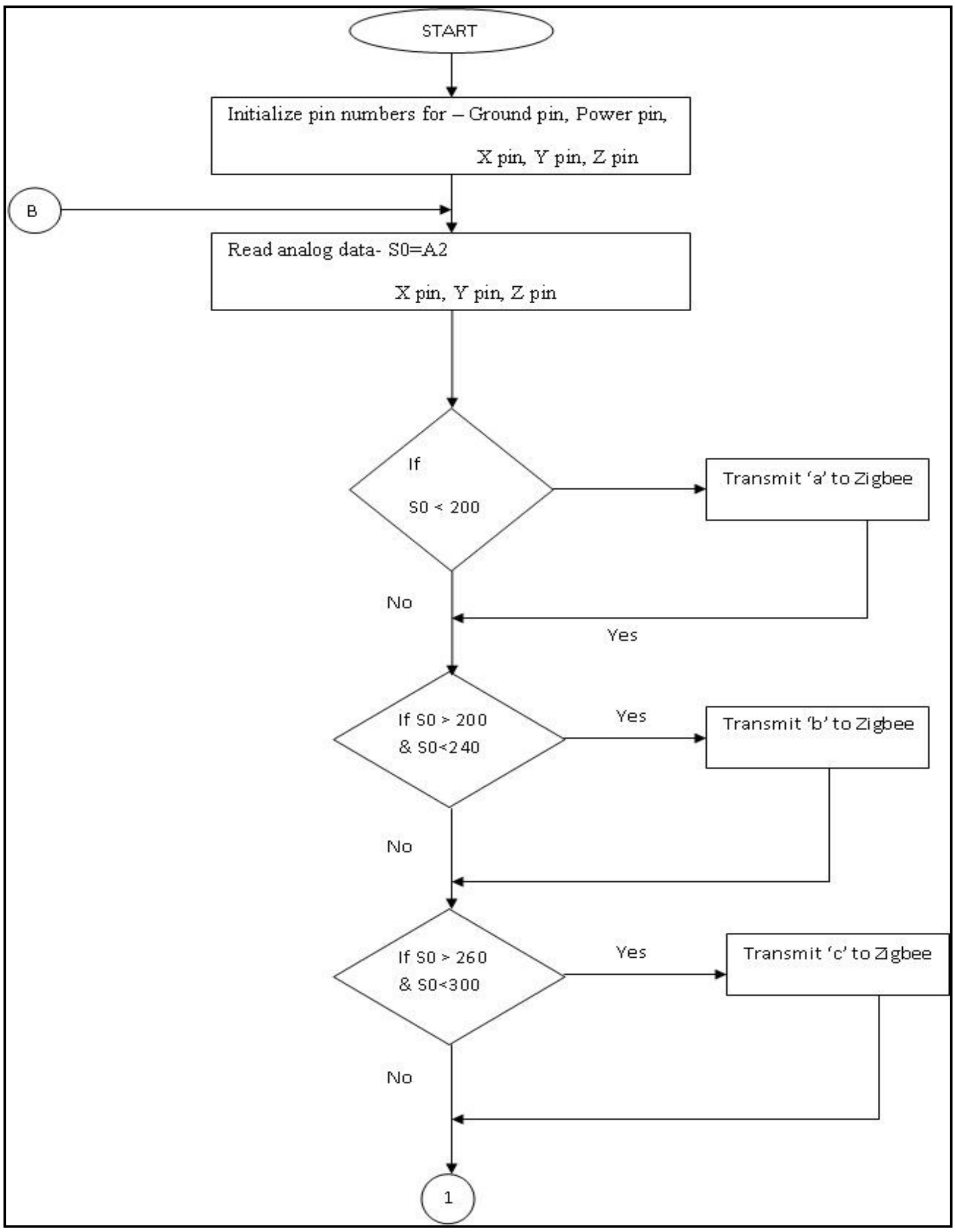


Figure 5: Circuit Connection diagram of sensing glove

The flow chart for the control of the glove circuit is given below



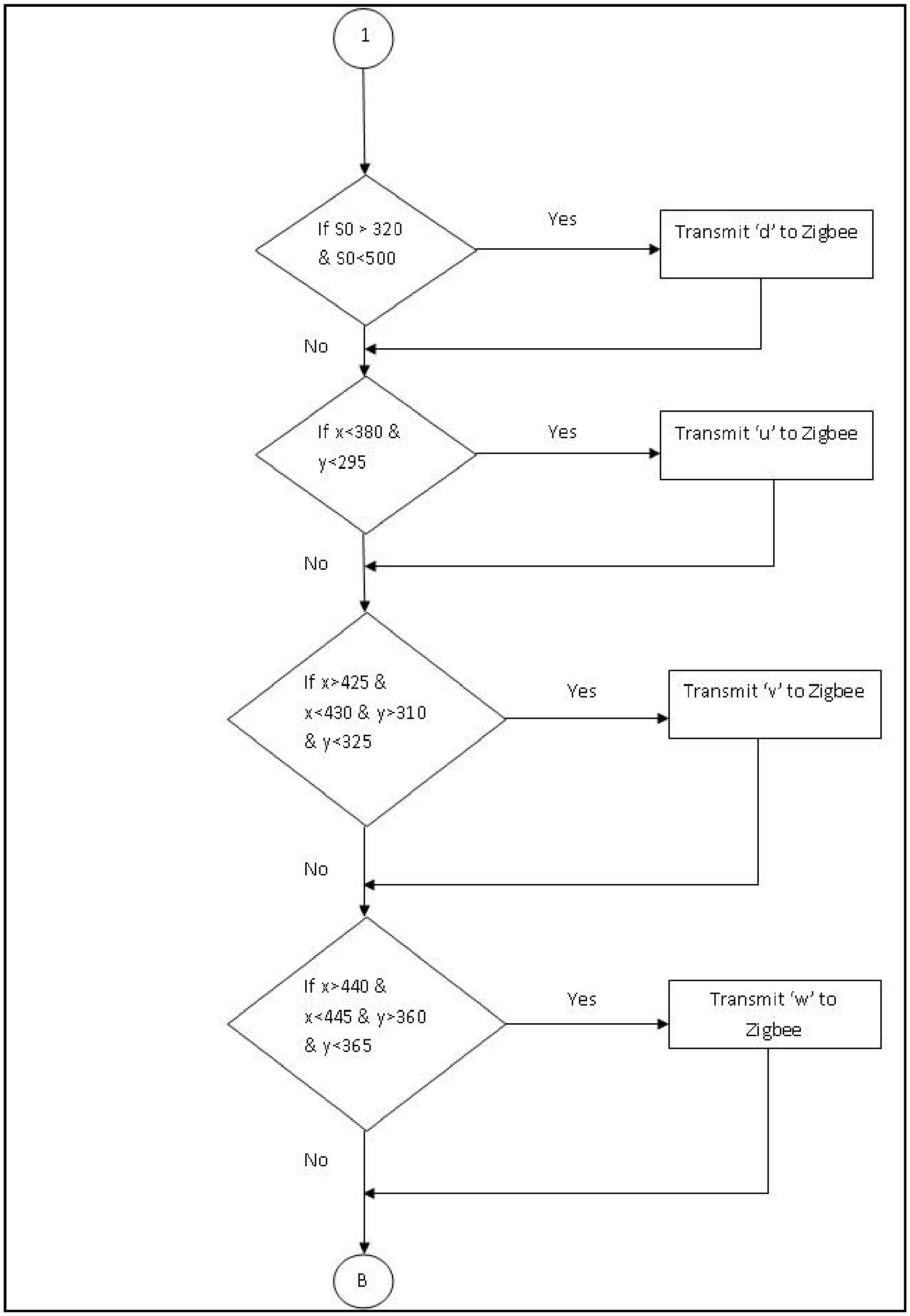


Figure 6: Flow chart for control of sensing gloves

4. Design of Robotic Arm

The construction of the mechanical assembly consisted of design of the arm and the design of the fingers. The arm was constructed by having a metal plate as its base. Two clamps on two sides which supports the arm with the base were fixed with the help of screws. The upper end of the clamps was given with the servo motors and these motors are responsible for the up and down movement of the arm. The entire body of the arm were constructed by thick aluminum plates which is light weight in construction and it supports the weight of the palm and the fingers. The fingers move in a way such that the entire hand can pick an object. So the weight of the finger should be as light as possible and also the structure should be stiff and not fragile. The springs were used for the structure of the fingers. At the tip of each fingers the metal strings were attached so that the fingers can be actuated. Then the strings are then attached the servo motors which is placed in the body of the arm. To cover the entire hand and to have aesthetic look, the entire fingers and palm is covered with gloves.

The major operation of the arm is

- up and down movement of the arm
- finger movement of the hand

(i) Actuation for the up and down movement of the arm is given by servo motors and its shafts. The shaft of the servo is attached directly to the body of the arm.

(ii) The strings from the fingers are directly attached to the servo shaft and so when the shaft of the servo is moved, the finger starts to move in a definite position.

The servomotor used is a rotary actuator that allows for precise control of angular position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. It is just a regular motor with a sensor installed, typically to measure angular position during operation. Servomotors are used in Applications such as robotics, CNC machinery or automated manufacturing.

A Servomotor works on a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is some signal, either analogue or digital, representing the position commanded for the output shaft. The motor is paired with an encoder to provide position and speed feedback. The measured position of the output is compared to the command position, the external input to the controller. If the output position differs from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the positions approach, the error signal reduces to zero and the motor stops. This type of servomotor is not widely used in industrial motion control, but it forms the basis of the simple and cheap servos used for radio-controlled models. Servomotors can be enhanced with a PID control algorithm for more precise control with less overshooting [5].

RC servos are remote control devices servos typically employed in radio-controlled models, where they are used to provide actuation for various mechanical systems such as the steering of a car, the control surfaces on a plane, or the rudder of a boat. RC servos are composed of an electric motor mechanically linked to a potentiometer.

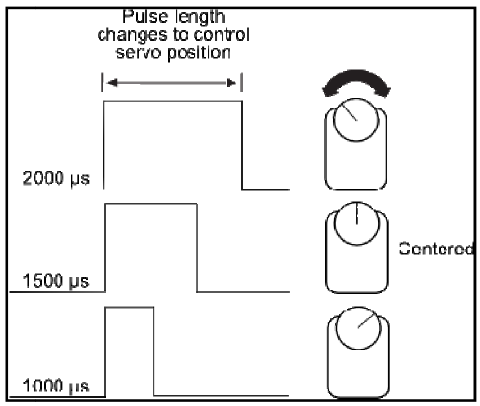


Figure 7: Mechanism of servo actuation

A controller sends pulse-width modulation (PWM) signals to the servo. The electronics inside the servo translate the width of the pulse into a position. When the servo is commanded to rotate, the motor is powered until the potentiometer reaches the value corresponding to the commanded position.

The control technique of the arm is implemented by the Arduino mega board. The servos which are used for the up and down motion and the servos which are used for finger motions are connected to this mega board. Mega board gives the PWM inputs to the servo. The Arduino Mega 2560 is a microcontroller is used for control function which is compatible with most shields. It has 54 digital input/output pins where 15 used as PWM outputs and 16 analog inputs. It has a 16 MHz crystal oscillator. The Arduino Mega 2560 uses serial communication. The specification of the Arduino Mega 2560 is given in the below table.

Specification of ATmega2560	
Operating Voltage	5V
Input Voltage	7-12V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
AC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz

Table 4: Specification of ATmega2560

The ATmega2560 on the Arduino Mega comes preburnt with a bootloader that allows to upload new code and use without an external hardware programmer. It communicates using the original STK500 protocol. The circuit connection of the robotic arm is given in the below figure.

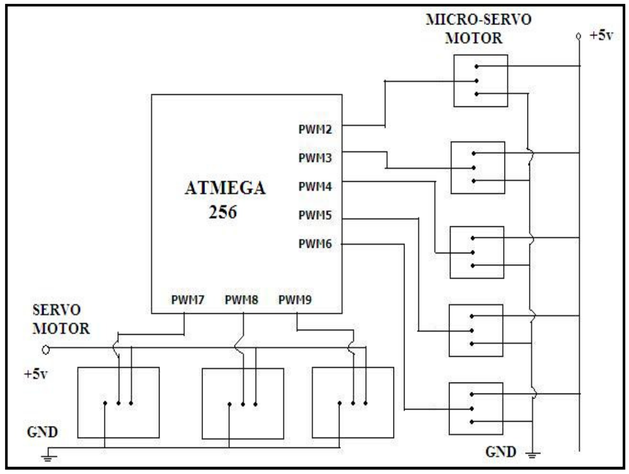
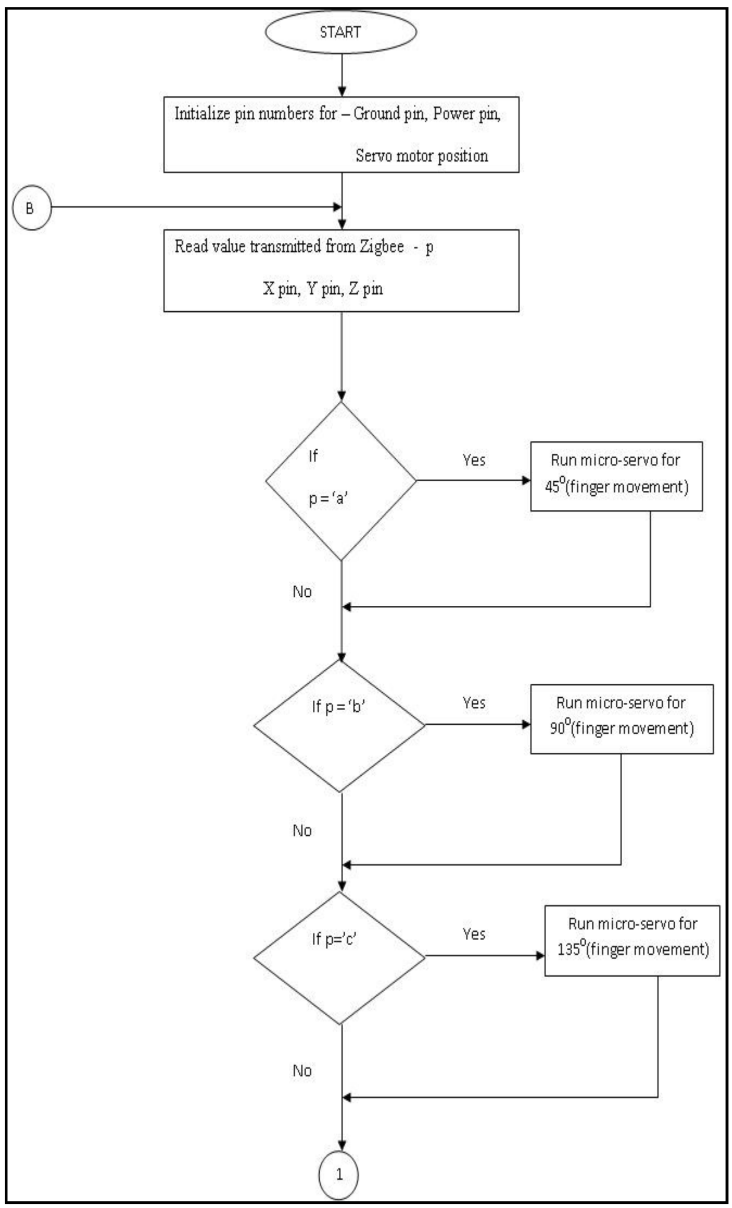


Figure 8: Circuit connections of robotic arm

The flow chart for the control of robotic arm is shown in the below figure.



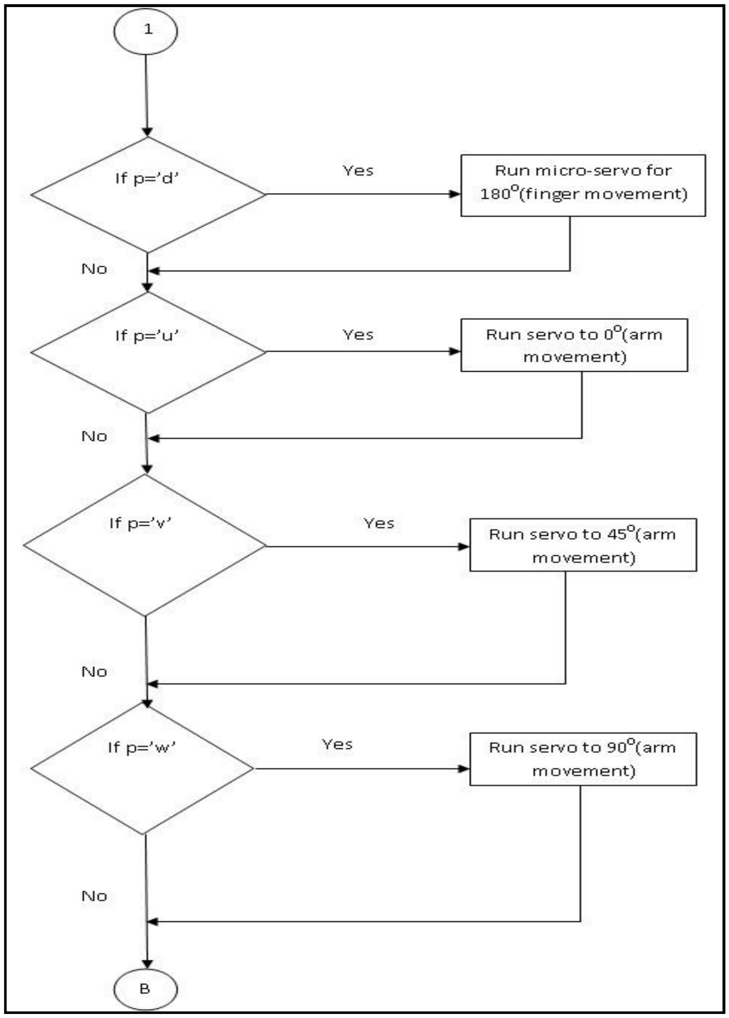


Figure 9: Flow chart for control of robotic arm

5. Wireless Communication

Zigbee is a high level communication protocols used to create personal area networks built from small, low-power digital radios. Zigbee is based on an IEEE 802.15 standard [8]. Zigbee devices can transmit data over long distances by passing data through intermediate devices to reach more distant. Data transmission rates vary from 20 kilobits/second in the 868 MHz frequency band to 250 kilobits/second in the 2.4 GHz frequency band. The Zigbee network layer natively supports both star and tree typical networks, and generic mesh networks. Zigbee builds upon the physical layer and media access control. Zigbee consumes less power and have long battery life. ZigBee is used in applications that require only a low data rate, low power consumption, long battery life, and secure networking.

The components of a Zigbee communication system includes

- *ZigBee Coordinator (ZC)*

The Coordinator forms the root of the network tree and bridge to other networks. There is exactly one ZigBee Coordinator in each network.

- *ZigBee Router (ZR)*

A Router can act as an intermediate router, passing on data from other devices.

- *ZigBee End Device (ZED)*

Contains functionality to talk to the parent node. (Either the Coordinator or a Router)

The *ZDO*, (Zigbee Device Object (ZDO), a protocol in the ZigBee protocol stack, is responsible for overall device management, and security keys and policies), is responsible for defining the role of a device as either coordinator or end device. The *application support sub layer* (APS) is the other main standard component of the layer, and as such it offers a well-defined interface and control services. It works as a bridge between the network layer and the other components of the application layer: it keeps up-to-date binding tables in the form of a database, which can be used to find appropriate devices depending on the services that are needed and those the different devices offer. As the union between both specified layers, it also routes messages across the layers of the protocol stack.

5.1. XBEE S-2 Module

XBEE module is a ZigBee wireless module technology. It is an inter-serial device to communicate with the microcontroller. Xbee is a 2.4G's XBEE wireless module [7]. This module uses the 802.15.4 protocol stack through serial interface between the microcontroller and other devices to communicate. This module is simple and convenient.

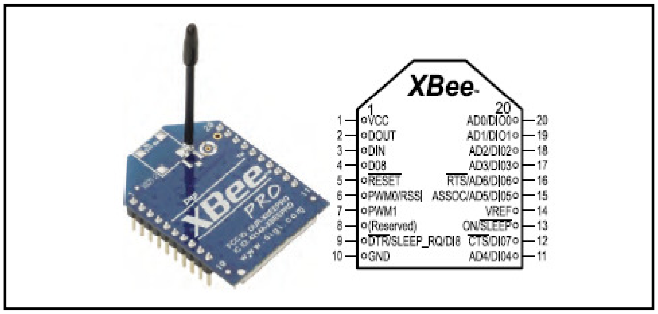


Figure 10: Pin diagram of XBEE S2 module

The specification of XBEE S-2 module is given in the below table.

Specification of XBEE S-2 Module	
Outdoor Range	90 m
Indoor range	30 m
Data rate	250 kbps
Band frequency	2.4 Ghz
Digital I/O pins	8
ADC conversion pins	6
Channels	16
Bit encryption	128
Voltage	2.8 to 3.4 VDC
Current	50mA

Table 5: Specification of XBEE S-2 module

5.2. XBEE Shield

XBEE Shield is an enhanced Zigbee XBEE Series module breakout board for Arduino, it can be directly plugged in with Arduino, and we can use any pin of the basic board to connect with the XBEE module serial port. allows an Arduino board to communicate wirelessly using Zigbee.

Figure 11: Arduino XBEE Shield

XCTU is a developer tool used for communicating between the Arduino and the XBEE shield. XBEE can be configured through the X-CTU utility software. X-CTU is a Windows-based application provided by Digi. XCTU is a free multi-platform application designed to enable developers to interact with Digi RF modules through a simple-to-use graphical interface.

6. Hardware Structure

The hardware structure of the sensing glove is made up of potentiometer and Arduino UNO board which is shown in the below figure.

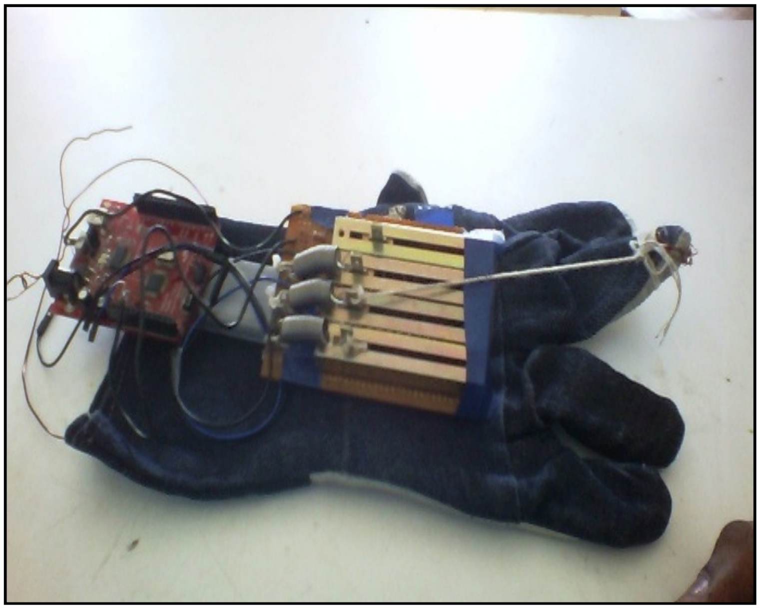


Figure 12: Hardware structure of sensing gloves

The hardware Structure of Robotic arm consists of metal arm part with servo motors and Arduino ATMega and it is shown in the below figure.

Figure 13: Hardware structure of robotic arm

7. Future Scope

The future scope of this project can be controlling the arm from a distant location with the help of camera and high range wireless transmission modules. By this we can still accurately perform the task and the arm can be fixed to a rover which moves wirelessly and performs the task. This will be very useful in bomb diffusion applications.

8. Conclusion

Thus the gestures of human hand can be replicated in the easier and cheapest way and then the robotic arm is controlled based on the gestures. It also involves the implementation of Zigbee protocol to send the data wirelessly from human hand to the robotic arm. The coding is done in Arduino Software and configuration of XBEEs were done using X-CTU software. This can be used in various applications like fireworks handling and bomb diffusing where the human life is at risk, also it can be used in industries to yield more production rate with utmost accuracy. Gesture controlled robotic arm is a low cost solution to problems faced in fireworks industry and it helps to save the lives of human.

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