SMART GLOVE USING FLEX SENSORS:

THE HELPING HAND

Project report submitted

in partial fulfillment of the requirement for the degree of

Bachelor of Technology

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(May, 2017)

Dedicated to Department of Electronics, Acharya Narendra Dev College,

University of Delhi

and our family members

APPROVAL SHEET

This project report entitled "SMART GLOVE USING FLEX SENSORS: THE HELPING HAND" by Kiran, Abhijeet, Amrita Kumari, Aman Sharma, Ankit Kumar Baliyan is approved for the degree of B.Tech (Electronics).

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CERTIFICATE

It is certified that the work contained in the project report titled “SMART GLOVE USING FLEX SENSORS: THE HELPING HAND” by “Kiran, Aman Sharma, Abhijeet, Amrita and Ankit Kumar Baliyan” has been carried out under my supervision.

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ABSTRACT

Communication and self-independency are integral parts of human life. But for people who are physically impaired (deaf, dump or physically handicapped), communication and self-independency is a challenge. Communication between speakers and non-speakers of Sign Language can be Problematic, inconvenient, and expensive.

This project attempts to bridge the communication gap by designing a portable glove that captures the user's sign language gestures and outputs the translated text serial monitor. The glove is equipped with flex sensors to measure the flexion of the fingers. The glove's Arduino Mega ADK microcontroller analyzes the sensor readings to identify the gesture from a library of defined gestures.

Deaf and dumb people use sign language to communicate with themselves and with common people. To understand them, one should be able to understand their language i.e. sign language. But it is not possible for everyone to learn sign language. So, sign language translating equipment, which can translate sign messages to normal understandable text or voice form, can be used to overcome this gap to some extent. Though, differently abled people can communicate with ease but they have to be dependent on others for every small needs, because of their inability to move from one place to other without any assistance. If by any means, they can fulfill their needs sitting at one place, then they too can lead a self-independent life. This can be achieved by recognition of their hand gestures, so as to know what they need to do.

Using this device, one day speakers of sign language may be able to communicate with others in an affordable and convenient way.

The project also explores the real-time application of the glove by using it to control the motion of the robot in different directions and to use the same for picking and placing desired objects. This will not only help the differently abled people but will also provide convenience to normal ones.

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DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission and that this work has not been submitted elsewhere for a degree.

I understand that any violation of the above will be cause for disciplinary action by the College and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CHAPTER 1

INTRODUCTION

Figure 1.1: Glove Prototype

Living in the privileged world of intellects and witnessing a technical revolution in everyday life, it is imperative not to contribute to the progress and development of society at large. Communication is fundamental basis for any individual to live a normal life. According to Ministry of Statistics and Programme Implementation (MOSPI), a person who is dumb or whose speech is not understood by a listener of normal comprehension and hearing is considered to have *speech disability* and a person who can't hear at all or can hear only loud sound is considered as *hearing impaired*. Disability static 2002**[1]** by Govt. of India says that 30.62 lakh people suffer from hearing disorder and 21.55 lakh people suffer from speech disorder. According to Japan International Cooperation Agency (JICA) static profile on disability **[2],** India account for 8.36% hearing disorder and 5.06% speech disorder. Government under *The Persons with Disability (PWD) Act*, and provisions contained in the *Persons with Disability (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995*, imposes several obligations on the Central and State Governments for taking up various measures to ensure equal participation of people with disabilities in all walks of life. The solution of such a hurdle lie with the new emerging sector of the country i.e. *technology*. None other than technology could help humanity for such inhuman disaster of society. It can be used to bridge such gaps between the disabled and the others. Dividing our society in numerous parts and in the last few decades it (technology) has evolved enough to bypass the problem or to bridge the gap between these disabled people and the normal ones. Living a normal and independent life is a dream of every individual on this planet, and if technology can be used to fulfill such dreams then it will be one of the biggest gifts to the society ever. Also, access to technology is a major challenge that humanity needs to accept. It would as like

“Water, water everywhere not a single drop to drink” (lines from “*The Rime of the Ancient Mariner*” by Samuel Taylor Coleridge) implying anything available but not accessible. Unless technical gadgets are made available at the door steps of all either rich or poor, either at city or village or whatever the case may be, it would be the biggest failure of technology and the modern world.

The proportion of people with such disability has reached far above the acceptable limits and if not controlled it might get late enough to overcome this rising problem. According to an article by Global Citizen, 80% of the people living with disability live in developing countries and most of them have no access to healthcare **[3]**. In the world history of millions of years trade and profit are the two main key factors driving the whole world. And history has witnessed several incidents in which excess of exploitation has created necessity and this led to innovation which was backed financially. Here situation is not exactly the same but unless and until the developers find it profit making, the interest level would be limited. Helping financially is not the long term solution to any of this kind of problem. This may provide short term benefit. Furthermore, financial help would create a sense of economic disability in them and an abrupt defeat of all the initiative taken by the government. If their unemployment or under-employment can be converted into skillful work then it would work as source of motivation and independence. Also country will be getting hidden talent lying ideal. In this regard government of India has stated several schemes like Vocational training under Deen Dayal Disabled Rehabilitation scheme, Skill Training Programme by National Handicapped Finance Development Corporation (NHFDC) under Department for empowerment of Person with disability, The Pradhan Mantri Kaushal Vikas Yojana target to train 50,000 Persons with Disabilities. Also the number of specially abled person getting benefits of the above scheme of NHFDC has increased by 0.1% over 2012-13 to 2013- 2014 and 9.46% over 2013-14 to 2014-2015 **[4]**.

Today the life of deaf and mute people in India continues to improve with more schools for disabled, educational and training opportunities and several organizations working to help in learning the sign language. Beside all this, encouraging such people and to motivate society to intermingle with disabled, government of several countries including India has been organizing interacting events like workshops, education projects and sports tournament like Paralympics by various International and National organizations like International Paralympic Committee, The International committee of Deaf and Dumb Sports & many more. Government of

India has organized events like National Games for Deaf (March 28-3, 2017), 19th national chess championship of the DEAF (21-25 February, 2017) **[5]**, and many more events and for better result working with the All India Sports Council of Deaf (AISCD). Further several institutes like Rehabilitation Council of India **[6]** provide the training to the interpreter and teachers for these disabled. “Disability should not to be the obstacle to success” Professor Stephen W. Hawking remarked in World Report on Disability 2011 **[7]**. Making disables independent and reducing the communication gap can be the practical solution to this problem and thus reducing the sense of their burden on the society and their caretakers. Unless and until they are uplifted in the society in a productive manner any country shouldn’t be called developed. This is the major problem with the developing countries which has very low employment rate, low per capita income and very less technology. Just like the India’s initiative in International Forum, under International Solar Alliance (ISA), all the countries need to come together to save the lives from suffering due to disabilities with the major contribution by the developing countries. All this was attributed to poverty.

This project will have a major impact on the social status of the differently abled person and help them to reduce their gap from the society of normal peoples in the present scenario as the communication gap that is widened enough will get bridged and the society will become more uniform and the policies like ‘*The Deaf Day*’ on 26th September will not be further required. Furthermore, the only requirement of the differently abled is that the person must know the sign language and read the text so that he/she could handle it without any assistance and comfortably. For this Government measures are required more appropriately so that all could learn the sign language.

Looking ahead for the same ‘SMART GLOVE USIING FLEX SENSORS: THE HELPING HAND’ will be helping the mute person to communicate with the normal one’s just with the glove. The glove will be consisting of the flex sensors and accelerometer that will be monitoring the hand orientation and proceed the same for processing further. The output for the same can either be displayed for the deaf or can be converted to speech for the blind and either one or both for the normal ones.

In the present world, smartphones has become an integral part of our day to day life and using the smartphone in this would make it cost efficient and also handy. The screen will display the message to be communicated and the speaker for the speech of the same. The main aim is to develop a gesture based glove that can recognize the hand gestures and convert it into text and speech output to be understood by common people so as to control the motion of the bot and the gripper attached to it. A camera mounted on the bot will help the user to take decisions for motion and gripper movement control. The use of bots can also be explored in rescue operations. The bot can reach the places where the humans can’t reach and its operation is totally under the control of the user. Also since the decision making is performed by humans and not by any complex algorithms, so there are less chances of error thereby providing flexibility in the rescue operations.

CHAPTER 2

REVIEW OF LITERATURE

Science and technological advancements has taken a lot of steps towards bridging the communication gap between the normal community of the society and the specially abled people. A number of projects have been carried out in this field which incorporates the gesture recognition technique. When it came to gesture recognition, the primary focus of researchers went to designing of smart gloves for the same, since sign language mainly involve the extensive use of hand movements [8]. By looking at the development of data gloves, there were two distinct categories emerged over the years.

1. **Active data glove**: Consisted of few or variety of sensors on the glove to measure flexing of joints or acceleration and had a communication path to the host device using wired or wireless technology. These gloves are known to restrain the user of artistic ability.

2. **Passive data glove:** Consisted only of markers or colors for finger detection by an external device such as a camera. The glove does not have any sensors onboard.

The first glove prototypes to emerge included the Sayre Glove, the Massachusetts Institute of Technology (MIT)-LED glove and the Digital Entry Data Glove [9]. The Sayre Glove which was developed in 1977 used flexible tubes with a light source at one end and a photocell at the other, which were mounted along each finger of the glove. Bending of fingers resulted in decreasing the amount of light passed between the LED and the photodiode. The system thus detected the amount of finger bending using the voltage measured by a photodiode [9].

The first glove to use multiple sensors was offered by the ‘Digital Entry Data Glove’ which was developed by Gary Grimes in 1983. It used different sensors mounted on a cloth. It consisted of touch or proximity sensors for determining whether the user’s thumb was touching another part of the hand or fingers and four “knuckle bend sensors” for measuring flexion of the joints in the thumb, index, and little finger. It also had two tilt sensors for measuring the tilt of the hand in the horizontal plane and two inertial sensors for measuring the twisting of the forearm and the flexing of the wrist [9]. These gloves had limited accuracy and were tethered to computers using cumbersome wiring. They were meant for very specific applications and as proof of concept. They never received any attention beyond experimental tools and were never commercialized.

The first commercially available Data Glove appeared in 1987 [9]. The technology was similar to the one used in Sayre Glove in 1977. However, the 1987 version carried fiber optics instead of light tubes and was equipped with 5–15 sensors increasing its ability to distinguish different gestures. The multiple sensors available on the Data Glove made it popular among researchers of different fields and number of similar devices were developed.

2.1 Machine learning algorithm based Gesture Recognition devices

Various types of algorithms can be used to implement gesture recognition. Machine learning algorithms are algorithms that can learn from or make predictions based on data and can be supervised or unsupervised. Supervised machine learning algorithms may involve data sets which are used for training. This training data is used for the machine to learn the pattern of data that it is monitoring so that the machine can apply these patterns to new data sets [10].

Figure 2.1: Glove by Cornell University Students [10]

In 2014, students from Cornell University designed a sign language glove as their final class project. The device was named as “A glove that helps people with hearing disabilities by identifying and translating the user’s signs into spoken English”. The prototype consisted of flex sensors, copper tape sensors, three-axis gyroscope MPU-6050, ATmega 1284p microcontroller. They developed a machine learning algorithm trained through datasets to calibrate the gloves [11]. The glove was developed beyond the class project.

Even though the prototype is not marketable but is a best example of machine learning for gesture recognition. The design incorporated every possible way to capture gestures more accurately and reliably. Despite the use of a number of sensors, the circuit board was kept as small as possible thereby providing a Slim Form Factor. However, despite of all the best efforts, the device could not be used in everyday situations because the use of PCs has limited the portability of the device. Another development in sign language translation came in 2015 from engineering students at Texas A&M University. The students developed a prototype that used a variety of sensors for sensing purpose including the electromagnetic sensors on the skin, accelerometer and gyroscopes and vision. It also incorporated machine learning algorithm where the user had to go through about 30 minutes of training and each gesture was performed a couple of times during this training period. Their work is still early in its development [12]. However, as with the Cornell's glove, the use of PC limited the portability of the device thereby hindering its use in everyday situations. Furthermore, the extensive use of sensors throughout the arm was helpful for providing a more complete understanding of a signed gesture but it also made the design cumbersome along with an increase in the overall project cost.

The most impressive element of their project was the efforts put into selecting an accurate machine learning algorithm. Several different types of machine learning algorithms were tested by the team, including Naïve Bayes, Nearest Neighbor, decision trees and support vector machines and the accuracy of 40 common gestures were compared. The results were recorded in a research paper presented at the IEEE 12th Annual Body Sensor Networks Conference 2015 in Cambridge, Massachusetts [13].

2.2 Simple Flex Sensors based designs

Figure 2.2: The Microsoft Imagine Cup 2012 Winning Design [10]

Under Microsoft Imagine cup in 2012, the "Enable Talk" project was carried out by a group of students which incorporated a system consisting of a mobile device and a pair of gloves which translated the American Sign Language to text on the mobile device [14]. The gloves were fitted with contact sensors, flex sensors and a microcontroller. The main aim of this work was to demonstrate the use of gloves fitted with sensors in the translation of sign language [15]. Another model was developed which converts signal languages used by dumb people, people suffering from Quadriplegia (disabilities that result from injuries to the spinal cord) and paraplegia (neuromuscular disorders), into speech. It is done based on a narrative hand gesture recognition technique. The solution approach consists of a hardware module and software module. In hardware module, the gesture recognition is done with the help of a sensor glove which consists of 5 accelerometer sensors, a microcontroller and these are best positioned in fingers upon analysis of American Sign Language Signs. The design of glove and the concept of decoding gestures by considering the axis orientation with respect to gravity and the corresponding voltage levels are discussed. The accelerations of a hand motion in three perpendicular directions are detected by accelerometers and acceleration values were transmitted to microcontroller. An automatic gesture recognition algorithm is developed to identify individual gestures in a sequence. As a final point, the gesture is recognized by comparing the acceleration values with the stored templates. According to recognized gesture, respective commands are played through speaker using voice chip [16].

A number of approaches within the field of Artificial Intelligence (AI) have been used to effectively recognize and translate sign language: from Artificial Neural Networks (ANN), Hidden Markov Models (HMM), Artificial Vision, Virtual Reality, and motion capture using data gloves or electromyographic (EMG) sensors [17]. Thus, in general there are two main approaches to recognizing hand gestures: one is based on motion capture of the user's hand, while the other based on artificial vision to determine the gestures made in a specific time. Both the approaches have their pros and cons [18].

2.3 Gesture recognizing device implemented using MATLAB

Researches under this fields focuses on the problem of gesture recognition in real time that sign language used by the community of deaf people and the problem identified is worked upon by Digital Image Processing using Color Segmentation, Skin Detection, and Image Segmentation, Image Filtering, and Template Matching techniques. This system recognizes gestures of ASL including the alphabet and a subset of its words. The purpose of

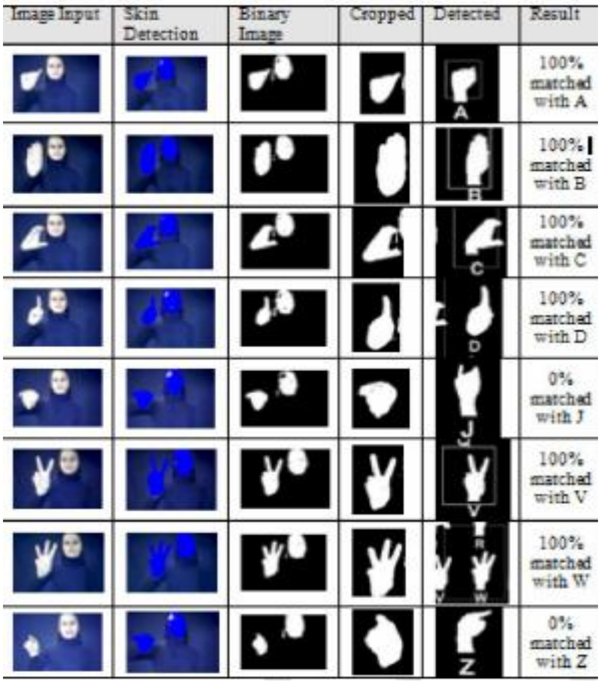

Figure 2.3: Result recorded using MATLAB's Techniques [19]

these applications is to recognize hand gesture with very simple design and the signer doesn't need to wear any type of hand gloves. The design emphasizes to use Template Matching technique as the primary hand gesture sign detection method due to its conceptual simplicity. The Template Matching cross-correlation involves simply multiplying together corresponding pixels of the signer image, here is called the Target image and the Template and then summing the result. For the hand gesture recognizing applications, the brightness of the input image of the signer can vary due to the various environmental conditions like lighting sensitivity, background color, electric or magnetic fields or any other disturbance and exposure conditions of the signer, and hence the images has to be first normalized. The normalization has to be done at every step by subtracting the mean and dividing by the standard deviation. That algorithm is called the cross-correlation of a template [19].

2.4 3D Gesture Recognition Devices

Three-dimensional hand gesture recognition has attracted increasing research interests in computer vision, pattern recognition and human-computer interaction. The emerging depth sensors greatly inspired various hand gesture recognition approaches and applications, which were severely limited in 2D domain with conventional cameras.

There are various aspects of 3D gesture recognition:

1. 3D hand modeling

2. Static hand gesture recognition

3. Hand trajectory Gesture Recognition

4. Continuous Hand Gesture Recognition

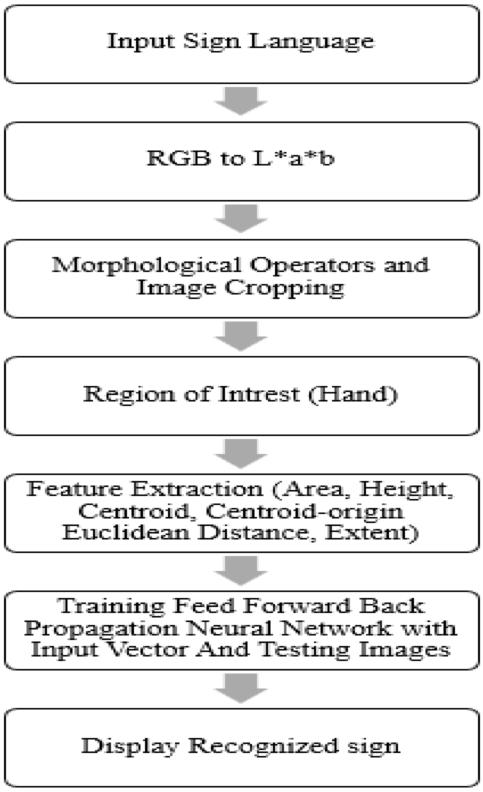

Figure 2.4: Flow Diagram and result for design implemented using Pattern Recognition [20]

The approach is to firstly convert images of static gestures of Sign Language into Lab color space where L is for lightness and (a, b) for the color-opponent dimensions, from which skin region i.e. hand is segmented using thresholding technique. The region of interest (hand) is cropped and converted into binary image for feature extraction. Then height, area, centroid, and distance of the centroid from the origin (top-left corner) of the image are used as features. Finally each set of feature vector is used to train a used to train feed-forward back propagation network [20]. The system was designed on the principle of pattern recognition. Pattern recognition is a process that takes raw data and makes an action based on the category of the pattern.

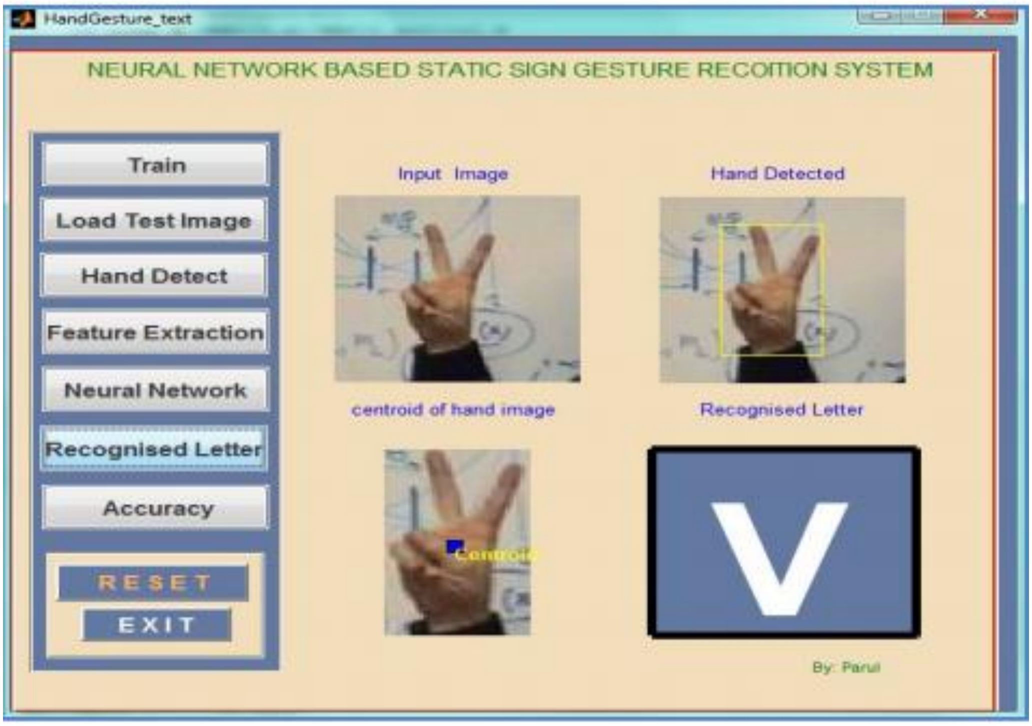

Figure 2.5: Flow Diagram and result for design implemented using Pattern Recognition [20]

2.5 Vision Based Gesture recognizing devices using neural networks

Vision-based gesture recognition relies on image capture by one or more cameras and applying algorithms to extract visual features, in order to recognize the gesture made. The fact that the person making the gesture is totally detached from the system is one of the most important benefits in working with visual recognition. On the other hand, the system can be very susceptible to changes in the environment, like lighting or background figures and colors that could affect the process [10].

Vision Based hand gesture recognition approaches can be categorized into: appearance based approaches, and 3D model based approaches [21]:

a) ***Appearance Based Approaches***: These approaches use features extracted from visual appearance of the input image model the hand, comparing these modeled features with features extracted from input camera or video input [21].

b) ***3D Model Based Approaches*****:** Model based approaches depend on the kinematic hand DOF's of the hand. These methods try to infer some hand parameters like, pose of palm, joint angles from the input image, and make 2D projection from 3D hand model [21].

Neural networks can also be classified into 2 types:

a) Feed Forward Networks

Feed forward Networks are the simplest devised type of artificial neural network in which the information moves in one direction, starting from the input nodes to the output nodes going through the hidden nodes (if any) with no cycles, It can be formed with different types of units [23].

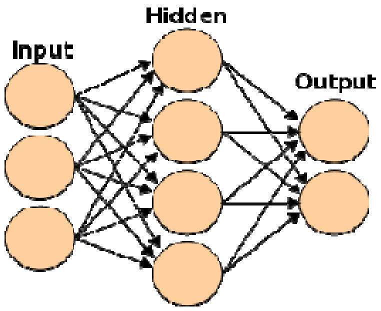

Figure 2.6: Simple Feed Forward Neural Network [23]

b) Feed backward Networks or Recurrent Neural Network

Recurrent neural network can be models with bidirectional data flow [9], which allows connection loops between perceptron [23]. Integration of these two neural networks, in a way, that after receiving data from data glove, the start sampling time is determined and if the data item is considered a gesture, it will be sent to the next network. For checking the sampling data, the system holds a history which decides the end of sign language [24].

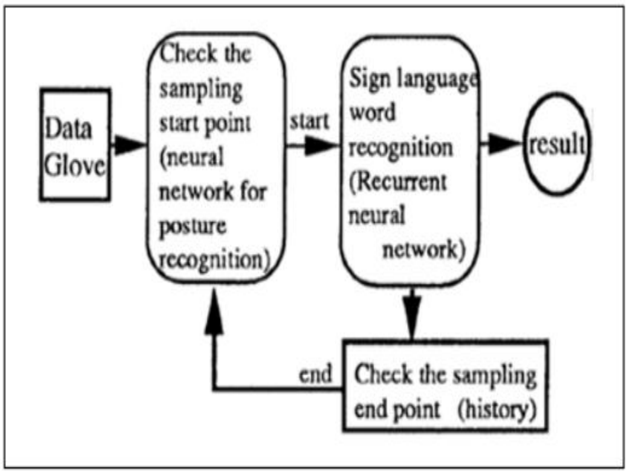

Figure 2.7: Flow Diagram for design implemented using Neural Networks [22]

2.6 Recent trends in Gesture Recognition Devices

Figure 2.8: CyberGlove for motion capturing [9]

CyberGlove has been developed to deliver many data inputs due to different flexing of joints motion from other areas of the hand. The 18-sensor data glove features two bend sensors on each finger, four abduction sensors, and sensors measuring thumb crossover, palm arch, wrist flexion, and wrist abduction. Different version of this glove that contains 22-sensors has three flexion sensors per finger, four abduction sensors, a palm-arch sensor, and sensors to measure wrist flexion and abduction. Each sensor is extremely thin and flexible making the sensors almost undetectable in the lightweight elastic glove [9].

One version of the glove offers open finger tips that would allow a user to type, write and grasp objects easily. The CyberGlove motion capture system has been used in many applications including digital prototype evaluation, virtual reality biomechanics, and animation. The CyberGlove III (MoCap Glove) developed by CyberGlove Systems is a device that aims to record gestures accurately for motion capturing for movie making and graphic animation industry. The device also consists of WiFi for data communication with a transmission range of 30 m. The unit contains 22 sensors and can operate for 2–3 h with the rechargeable battery onboard. The SD memory card offers motion recording option for motion capture animation purposes but the device is not aimed at computer or any other peripheral control [9].

Figure 2.9: 5-D Ultra Data Glove [9]

The 5-D Data Glove Ultra is another glove based gesture recognition device with very high precision flexor resolution. With its arrays of sensors, it provides 10-bit flexor resolution which is aimed at highly natural motion capture for movie industry [25]. The Sensor Glove Ultra is known to produce high data quality with low cross correlation between different sensor metrics for real-time animations using Bluetooth data transfer [9].

P5 Glove has been developed by Mind Flux as a way to provide cheaper alternative to many expensive wired gloves available in the market that can be used for gaming [9]. The P5 incorporates a bend sensor and remote tracking technologies, which provides users intuitive interaction with 3D and virtual environments, such as games, websites and educational software. This is one of the very few technologies currently reaching the user as a means for controlling machines using peripherals other than, mouse, joystick or keyboard. Today these gloves are no longer limited for use in computer human interactions. Some of them are indeed for interacting with a computer for gaming and other natural purposes like communication. The gesture based gloves have also been incorporated to be used in controlling robotic arms, which can therefore provide a number of industrial applications [26]. To demonstrate the evolution of glove technology, surveys have been carried out exploring the advancements in this area [27].

Figure 2.10: P5 Data Glove [9]

Another important consideration in communication devices is safety standards. To bring a device as close as possible to becoming a commercial product, care should be taken to follow all suggested and required standards related to safety. As with any electronic equipment, there is a risk of shorting wires, which can result in injury or fire [28]. One risk common to wearable devices is chemical burns from overheated or poorly constructed batteries [29]. These risks can occur if the batteries are stressed or heated.

The prototype proposed in this project explores the use of glove for deaf, dumb and physically impaired people, converting their hand gestures to desired actions, text and speech output. The prototype uses the android’s TTS feature thus providing better sound quality without the use of costly voice modules. The software implementation allows the user to even use the prototype with a computer, instead of just mobile phones. Mobile app to be developed under this project is an attempt to make a tool similar to already existing app [30], but there are a few features added in the proposed model, like the text to speech feature.

CHAPTER 3

PROPOSED MODEL

The main objective behind this project is to find a robust solution for differently abled people to lower their communication barrier with common persons and to help them carry out their basic work. It is based on the need of developing an electronic **Data Glove** that can perform multiple tasks. The main objectives of this project are:

3.1 GESTURE RECOGNITION

The designed glove recognizes the sign language and translates it into text and speech for the communication to take place between the mute communities and the general public. The designed wireless data glove is a normal cloth driving glove fitted with accelerometer at the top of the hand and flex sensors used along the length of each finger and the thumb. Also, flex sensors were designed to lower the cost of this project [31]. Mute people can use the gloves to convey their messages via hand gestures and it was converted into speech so that normal people can understand. A sign language usually provides signs for all 26 alphabets and numbers and also include commonly used gestured used in day to day life. The programming was done in embedded C coding. Arduino software was used to monitor the working of the program and the hardware circuitry which was designed using microcontroller and sensors.

3.2 GESTURE CONTROLLED BOT CONTROL

The hand gestures recognized by the microcontroller were compared with previously defined gestures and was transmitted via Zigbee to robot fitted with mechanical gripper. The glove here operates in 2 modes. In one mode, a few standard gestures (defined by us) were made to control the motion of the robot in different directions. Once the bot has reached the desired place, the glove was made to operate in mode 2. In this mode, the hand movement controlled the movement of the gripper. The gripper simply performs the task of picking up objects from somewhere and transferring it to some different location. The switching of the glove operation in different modes was also controlled by means of a defined switching gestures.

3.3 SOFTWARE IMPLEMENTATION

The proposed Smart Glove using Flex Sensors: The Helping Hand can further be interfaced using Lab VIEW for interpreting the gestures for real time data input [32].

3.4 MOBILE APPLICATION

To further provide assistance to the differently abled people, the project also aimed to develop a mobile application which performed several tasks like:

3.4.1 Virtual notes

This feature enables the deaf to save class lectures, key points from group discussions and meetings. The longer conversations can even be stored on the cloud by means of cloud computing [30].

3.4.2 Text to speech

This feature makes use of Bluetooth to receive text sent from the microcontroller via Bluetooth module HC-05. The text sent from the microcontroller is basically the gesture recognized by it. The feature receives those recognized texts and converts it to speech. So, whatever gesture is recognized by the microcontroller was spoken out loud by the phone.

CHAPTER 4

EXPERIMENTAL FLOW

4.1 METHODOLOGY

The prototype consists of flex sensors which are fabricated with resistive material whose resistance varies depending on the bend [31]. There are 5 flex sensors and they are located on each of the finger. Flex sensors change their resistance depending on the amount of bent on the sensor. They convert the change in bent to electrical resistance-more the bent, more is the resistance value. They work as variable analog voltage divider. When the substrate is bent, the sensor produces a resistance output relative to the bent radius. Flex sensors were self-designed by using resistive material [31]. To differentiate the words properly, the prototype also accommodate a 3-axis MEMS accelerometer which provides 3 axes (x, y, z axis) tilts. Microcontroller will be continuously scanning 8 analog channels at the rate of 10kbps and at the resolution of 14 bit. The above mentioned scanning method is called successive approximation type scanning. Then microcontroller receives the ADC value which will be further used for comparison and processing. For each character, it checks ADC and tilted value with the closed contact and recognize the corresponding characters. This information is conveyed to the other users with the help of a text-to-speech conversion for audible information and LCD for visible information and same process will be repeated all the time. The module works in two modes i.e. Alphabet mode and the General mode.

Wireless transmission is carried out by two means:

I. Using Bluetooth IC HC-05

It is used as an alternate of arduino text to speech module/shield, which are costly. By using this module, text-to-speech conversion is carried out. Arduino converts the recognized hand gesture to text and this text is transmitted via Bluetooth IC to android phones.

II. Using Zigbee

Zigbee was used to transfer the recognized hand gesture to bots for their motion control. The interfacing between the controller section and the Lab VIEW software is done using MAX232 circuit followed by DB9 connector. This output is readable by any person trying to communicate with the disabled person or the patient who cannot speak under critical conditions. The output can be given to voice section also which can play out through speaker, if the sign is matched [32].

4.2 FLOW CHARTS

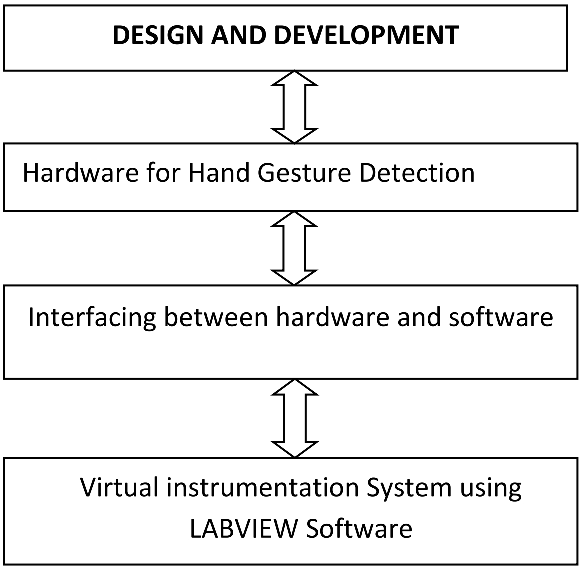

Figure 4.1: Flow Diagram for software implementation [32]

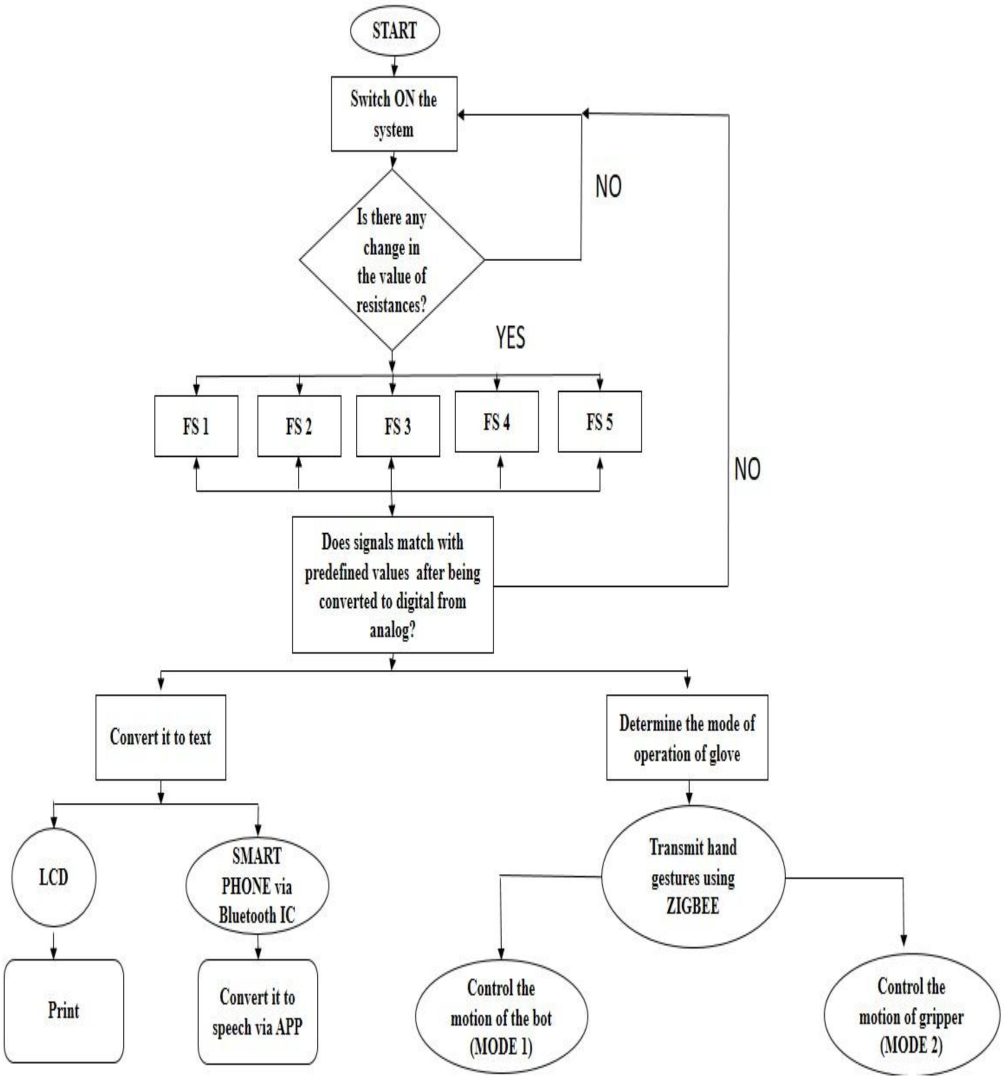

Figure 4.2: Flow Diagram for the project

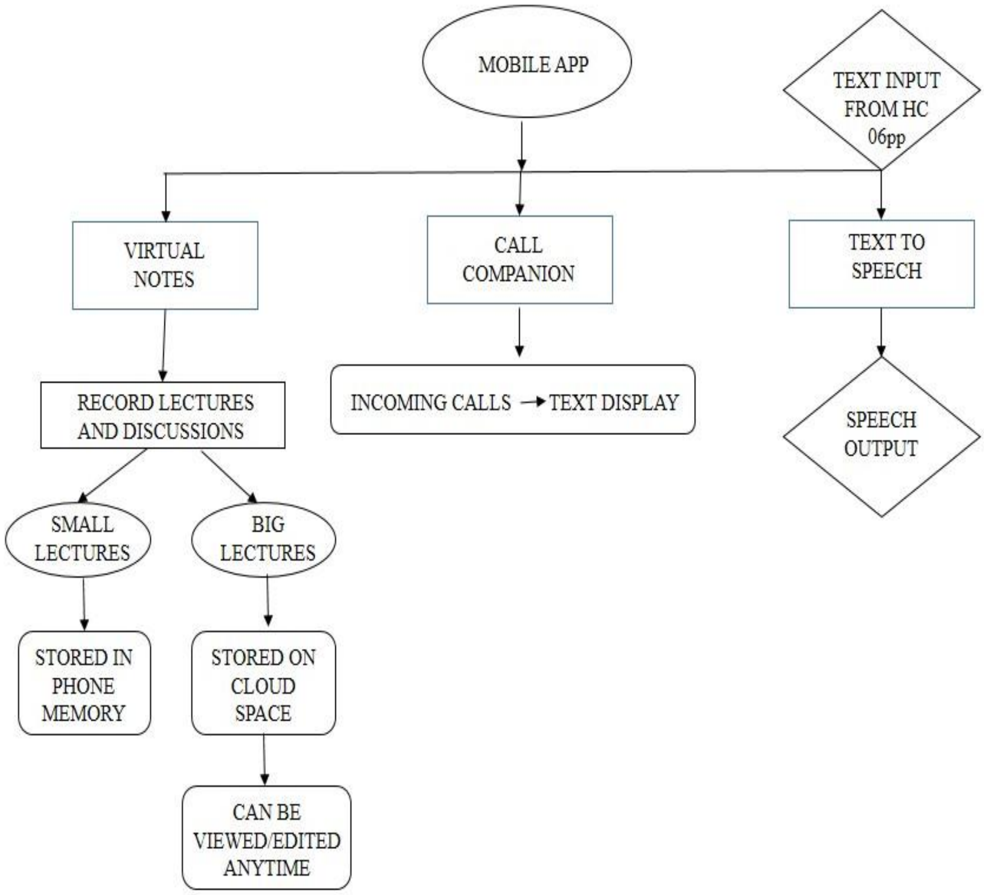

Figure 4.3: Flow Diagram Mobile App

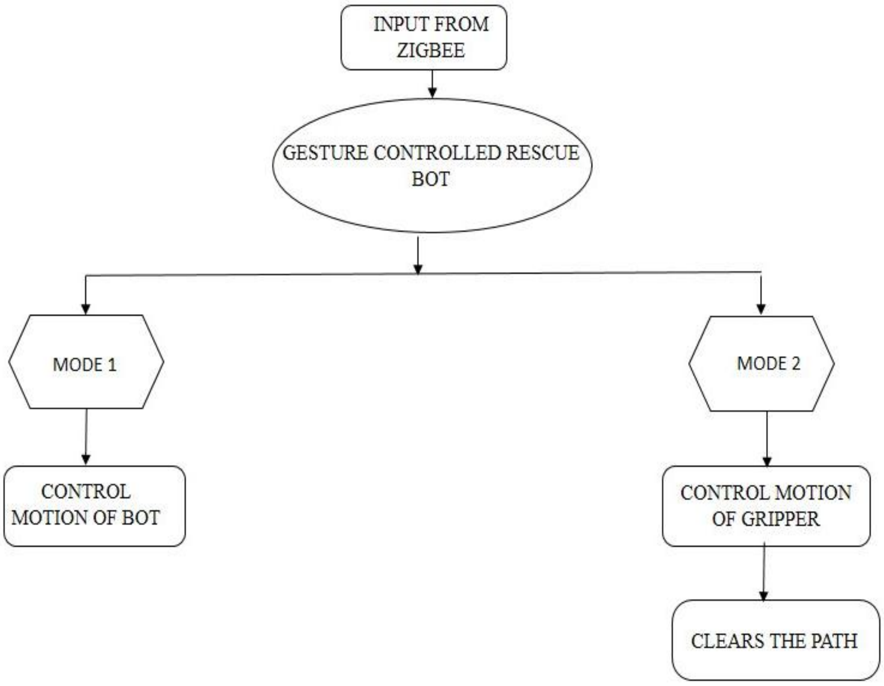

Figure 4.4: Flow Diagram for bot control

CHAPTER 5

HARDWARE AND SOFTWARE USED

5.1 HARDWARE

5.1.1 SENSORS AND ACTUATORS

A sensor is an object whose purpose is to detect events and changes in its environment and sends the information to the computer which then tells the actuators (output devices) to provide the corresponding output. The sensor converts real world data (analog) into data that a computer can understand using ADC (Analog to Digital Converter) [33].

Actuators, on the other hand require a control signal and a source of energy. When the control signal is received, the actuators respond by converting the energy into mechanical motion. The control signal can be any fixed mechanical system, electronic system, a software based system, a human, or any other input. In engineering, actuators are frequently used as mechanisms to introduce motion or to clamp an object so as to prevent motion [34].

The following sensors and actuators are used in this project:

I. Flex sensors
II. Accelerometer
III. Motors (controlling the wheels of the robots and gripping action)

5.1.1.1 FLEX SENSORS

Flex Sensors are made up of a strip of carbon material which have metal pads inside it. The resistance of the flex sensor changes when the metal pads are on the outside of the bend [35]. Flex sensors are passive resistive devices that can be used to detect bending or flexing. As a variable printed resistor, the flex sensor achieves great form-factor on a thin flexible substrate. When the substrate is bent, the sensor produces a resistance output correlated to the bend radius—the smaller the radius, the higher the resistance value As the sensor is flexed, the resistance across the sensor increases. The resistance of the flex sensor changes when the metal pads are on the outside of the bend. Straight (un-flexed) resistance is 25 kohm and 90 degree bend resistance is 75 kohm. This resistance was calibrated and converted into angles and further used for the grabbing purpose in the Robotic Arms.

A property of bend sensors worth noting is that bending the sensor at one point to a prescribed angle is not the most effective use of the sensor. As well, bending the sensor at one point to more than 90˚ may permanently damage the sensor. Instead, bend the sensor around a radius of curvature. The smaller the radius of curvature and the more the whole length of the sensor is involved in the deflection, the greater the resistance will be (which will be much greater than the resistance achieved if the sensor is fixed at one end and bent sharply to a high degree

A typical bend sensor has the following basic specifications:

- **Range of deflection**
  Determines the maximum angle of deflection that can be measured (as opposed to the maximum angle the sensor can be bent).

- **Uni- directional and bi-directional sensing**
  Some flex sensors increase the resistance when bent in either of two opposing directions. However, there is no difference in the measurement with respect to the direction.

- **Uni-polar and bi-polar sensing**
  A bi-polar flex sensor measures deflection in two opposing directions yielding different measurements.

- **Range of resistance (nominal to full-deflection)**
  Bend sensors can vary largely (even the same product) in terms of their range of resistance, measured as the difference from nominal resistance to resistance at full deflection.

A typical bend sensor is of following types:

- Conductive Ink-based
- Fiber-optic
- Conductive Fabric/Thread/Polymer based

PIN CONFIGURATION

The resistance varies with the sensor's degree of bend and the voltage output changes according to the bend. They require a 5-volt input and provide output between 0 and 5V. The sensors are connected to the device via three pin connectors (ground, live and output). The device can activate the sensors from sleep mode, enabling them to power down when not in use and thereby greatly decreasing power consumption.

Pin	Name	Details
1	GND	Power Supply Ground
2	+5V	Power Supply Positive Input
3	OUT	Analog Output

Table 5.1: Flex Sensor Pin Configuration

Flex sensor are sensors that change in resistance depending on the amount of bend on the sensor. They convert the change in bend to electrical resistance. More the bend, more is the resistance value. They are usually in the form of a thin strip from 2.2" long that vary in resistance. They can be made uni-directional and bi-directional.

Parameter	Value
Operating voltage	+5V DC regulated
Operating current	100mA
Output	Analog output
Flex bending	Nominal, 45 Degree, 90 Degree

Table 5.2: Flex Sensor Specifications

5.1.1.2 ACCELEROMETER

Accelerometers are devices that measure acceleration, which is the rate of change of the velocity of an object. They measure in meters per Second Square (m/s^2) or in gravitational forces (g). A single G-force for us here on planet Earth is equivalent to 9.8 m/s^2, but this does vary slightly with elevation (and will be a different value on different planets due to variations in gravitational pull). Accelerometers are useful for sensing vibrations in systems or for orientation applications [36].

Figure 5.1: Accelerometer Pin-out [37]

Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Accelerometers are used to detect and monitor vibration in rotating machinery. Accelerometers are used in tablet computers and digital cameras so that images on screens are always displayed upright. Accelerometers are used in drones for flight stabilization. Coordinated accelerometers can be used to measure differences in proper acceleration, particularly gravity, over their separation in space; i.e., gradient of the gravitational field. This gravity gradiometry is useful because absolute gravity is a weak effect and depends on local density of the Earth which is quite variable. Single and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration, as a vector quantity, and can be used to sense orientation (because direction of weight changes), coordinate acceleration, vibration, shock and falling in a resistive medium (a case where the proper acceleration changes, since it starts at zero, then increases). Micro machined accelerometers are increasingly present in portable electronic devices and video game controllers to detect the position of the device or provide for game input.

PRINCIPLE OF ACCELEROMETER

An accelerometer measures proper acceleration which is the acceleration it experiences relative to free fall and is the acceleration felt by people and objects [38]. Put another way, at any point in space time, the equivalence principle guarantees the existence of a local inertial frame and an accelerometer measures the acceleration relative to that frame [39].Such accelerations are popularly denoted g-force, i.e., in comparison to standard gravity. An accelerometer at rest relative to the Earth's surface will indicate approximately 1 g *upwards* because any point on the Earth's surface is accelerating upwards relative to the local inertial frame (the frame of a freely falling object near the surface). To obtain the acceleration due to motion with respect to the Earth, this "gravity offset" must be subtracted and corrections made for effects caused by the Earth's rotation relative to the inertial frame. The reason for the appearance of a gravitational offset is Einstein's equivalence principle [40], which states that the effects of gravity on an object are indistinguishable from acceleration. When held fixed in a gravitational field by, for example, applying a ground reaction force or an equivalent upward thrust, the reference frame for an accelerometer (its own casing) accelerates upwards with respect to a free-falling reference frame. The effects of this acceleration are indistinguishable from any other acceleration experienced by the instrument, so that an accelerometer cannot detect the difference between sitting in a rocket on the launch pad, and being in the same rocket in deep space while it uses its engines to accelerate at 1 g. For similar reasons, an accelerometer will read *zero* during any type of free fall. This includes use in a coasting spaceship in deep space far from any mass, a spaceship orbiting the Earth, an airplane in a parabolic "zero-g" arc, or any free fall in vacuum. At terminal velocity the accelerometer will indicate 1 g acceleration upwards. For the same reason a skydiver, upon reaching terminal velocity, does not feel as though he or she were in "free-fall", but rather experiences a feeling similar to being supported (at 1 g) on a "bed" of up-rushing air. Acceleration is quantified in the SI unit meters per Second Square (m/s^2) or popularly in terms of standard gravity (*g*). For the practical purpose of finding the acceleration of objects with respect to the Earth, such as for use in an inertial navigation system, knowledge of local gravity is required. This can be obtained either by calibrating the device at rest, or from a known model of gravity at the approximate current position.

A three axis accelerometer detects linear accelerations in three perpendicular directions. If it helps, picture a ball inside a box with pressure sensitive walls. As you shake the box around, the ball presses against different walls, which tells you the direction of acceleration. If the accelerometer is not moving, the ball will still push against the walls simply due to gravity. By comparing the readings on the x, y and z axis, we can work out the orientation of a stationary object.

WORKING OF ACCELEROMETER

Accelerometers measure acceleration, often caused by motion. But when they are standing still, the only acceleration the accelerometer senses is due to gravity pulling down on it. Imagine a box that has little springs sticking straight out from the sides of the box and that the accelerometer measures how hard gravity is stretching out those springs. The springs on the side bends with the same amount, the spring on the bottom is all stretched out and the one at the top is not stretched at all (because the spring is pull back into itself), so the accelerometer sees it as feeling no gravity, or 0g (gravity).

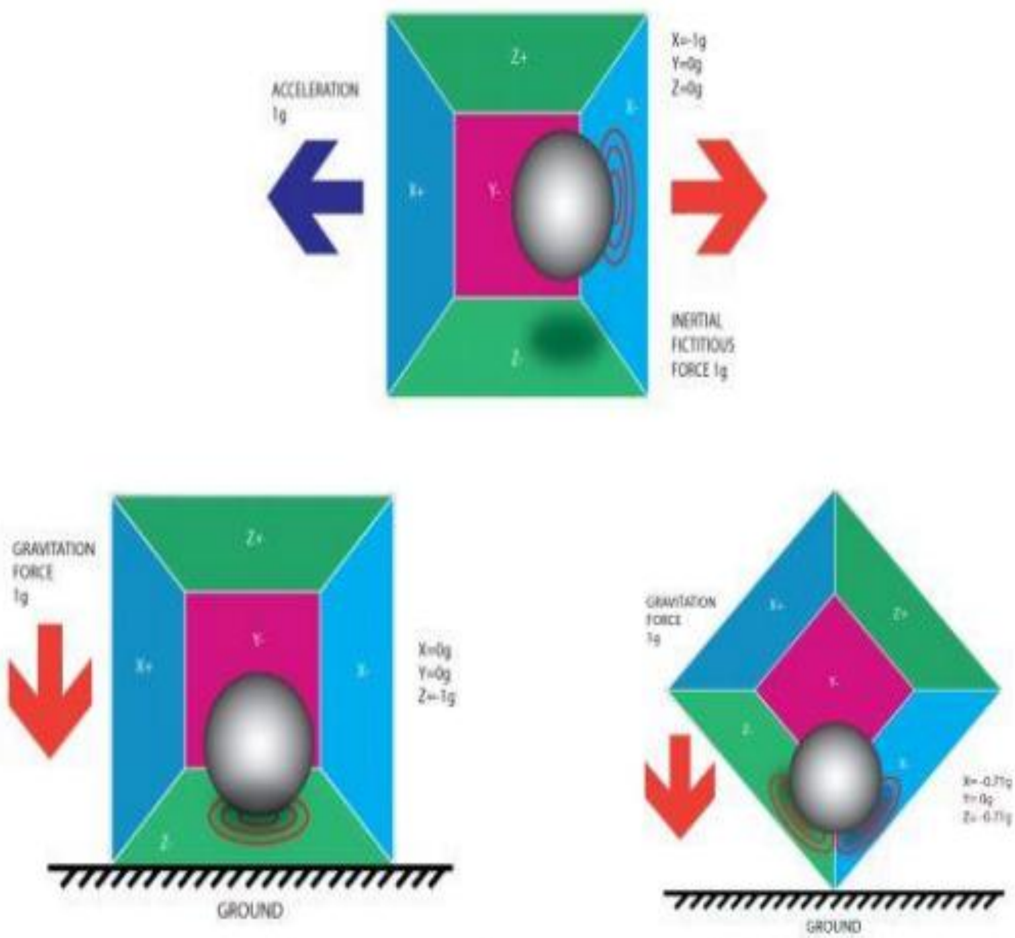

Figure 5.2: Accelerometer in different orientations [41]

If you rotate the box 90º and follow the spring on the top. It is now on the side and is hanging down some and the sensor sees it now feels 0.5g. Rotate 90º again, and it is at the bottom, stretched out and it feels 1g. Rotate again 90º and we are at the side again, with it feeling 0.5g, and 90º rotation again, we are back at the top and it feels 0g. So, we made a full rotation and the accelerometer saw this: 0g-> 0.5g -> 1g -> 0.5g -> 0g.

deg	X	Y	Z
0/360°	0.5g	0.5g	1.0g
90°	0.5g	1.0g	0.5g
180°	0.5g	0.5g	0.0g
270°	0.5g	0.0g	0.5g

Table 5.3: Sensed gravity during rotation about X-axis [42]

5.1.1.3 MOTORS

To accomplish the task of picking and placing the along with the motion of the robot, we used different actuators listed below:

- **SERVOMOTOR**

Servo motors (or servos) are self-contained electric devices that rotate or push parts of a machine with great precision [43]. Some changes that must be made to any motor that is designed as a servomotor includes the ability to operate at a range of speeds without overheating, the ability to operate at zero speed and retain sufficient torque to hold a load in position and the ability to operate at very low speeds for long periods of time without overheating [44].

WORKING PRINCIPLE OF SERVOMOTOR

A servomotor is an electromechanical device in which the electrical input given determines the position of motor armature. It comprise of four major components: a normal DC motor, a gear reduction unit, a position-sensing device and a control circuit. Firstly, gear assembly is used to reduce RPM and to increase torque of motor. Let, initially position of servo motor shaft and the position of the potentiometer knob is such that there is no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to another input terminal of the error detector amplifier. Then the difference between these two signals (one from potentiometer and another from other source), will be processed in feedback mechanism and output will be provided in term of error signal. This error signal acts as the input for motor and motor starts rotating. Motor shaft is now connected with potentiometer and as motor rotates so the potentiometer and it will generate a signal. So as the potentiometer's angular position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at a position that the output of potentiometer is same as external signal provided. At this condition, there will be no output signal from the amplifier to the motor input as there is no difference between external applied signal and the signal generated at potentiometer and in this situation motor stops rotating.

CONTROLLING SERVO MOTOR

All motors have three wires coming out of them. Out of which two are used for Supply and the other is used for receiving control signals from MCU called control wire. Servo motor works on PWM principle means its angle of rotation is controlled by the duration of applied pulse to its Control PIN. High speed force of DC motor is converted into torque by Gears. Potentiometer is connected to the output shaft of the Servo, to calculate the angle and stop the DC motor on required angle. Servo motors are chosen for the designing the robotic arm because they have various suitable advantages including working at any angle. Servo motor can be rotated from 0 to 180 degree, but it can go up to 210 degree depending on the manufacturing, while for practical purposes 0- 160° is preferred. This degree of rotation can be controlled by applying the Electrical Pulse of proper width, to its Control pin. All servo motors work directly with your +5V supply rails but we have to be careful on the amount of current the motor would consume. The servo motors require no current in the hold position with any static loads [45].

DC Servo Motors become an important device in a wide range of industrial applications that require high dynamics on position control such as numerically controlled machinery, robotics, automation and other mechanism where the starting and stopping functions are quickly and accurately [46][47]. These applications require a high-speed control accuracy and good dynamic respond. In robotic applications, servo motors are used to move the robotic arm to a relevant position by means of controllers in the automated manufacturing lines of industries [48][49]. Low rotor inertia increases the capability of immediately starting and stopping during the on-off conditions. Servo motor is also important for the application at the industries due to its ability of quick response and precise positioning but motor is expensive [46].

- **DC GEARED MOTOR**

DC geared motors are essentially a DC shunt motor which has been specially designed for low inertia, symmetrical rotation and smooth low-speed characteristics. Geared motor is a motor with a closed feedback system in which the position of the motor will be communicated back to the control circuit in the motors. Geared motors are formed from four different elements: a DC motor, a position-sensing device (a potentiometer), a gear reducing part and a control unit. All of these components work together to make the motor to accept control signals that represent the desired output of the motor shaft and power the DC motor until its shaft is turned to the right position. The shaft in geared motors doesn't rotate as freely as those in regular DC motors. The position-sensing device in a geared motor determines the rotation of the shaft and thus the way the motor needs to turn in order to arrive at the desired position [50].

We used two 75 RPM DC geared motors in differential drive configuration along with the third caster wheel for the support. Robot has top speed of about 24cm per second. Using this configuration, the robot can turn with zero turning radius by rotating one wheel in clockwise direction and other in counterclockwise direction. Position encoders are mounted on both the motor's axles to give a position feedback.

PULSE WIDTH MODULATION FOR VELOCITY CONTROL:

Pulse width modulation is a process in which duty cycle of constant frequency square wave is modulated to control power delivered to the load i.e. motor. Duty cycle is the ratio of 'T_{ON}/ T', where 'T_{ON}' is ON time and 'T' is the time period of the wave. Power delivered to the motor is proportional to the 'T_{ON}' time of the signal. In case of PWM the motor reacts to the time average of the signal. PWM is used to control total amount of power delivered to the load without power losses which generally occur in resistive methods of power control.

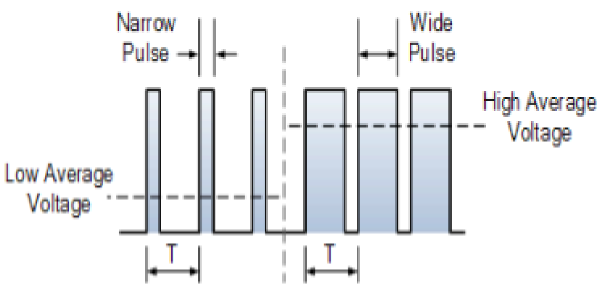

Figure 5.3: PWM in DC Motor

5.1.2 WIRELESS TRANSMITTING DEVICE

5.1.2.1 ZIGBEE

XBee devices communicate with each other over the air, sending and receiving wireless messages. The devices only transfer those wireless messages; they cannot manage the received or sent data. However, they can communicate with intelligent devices via the serial interface [51].

Figure 5.4: XBEE Module [51]

XBee devices transmit data coming from the serial input over the air and they send anything received wirelessly to the serial output. Whether for communication purposes or simply for configuring the device, a combination of both processes makes XBee communication possible. In this way, intelligent devices such as microcontrollers or PCs can control what the XBee device sends and manage incoming wireless messages. The range of XBee module is around 30-35metres.

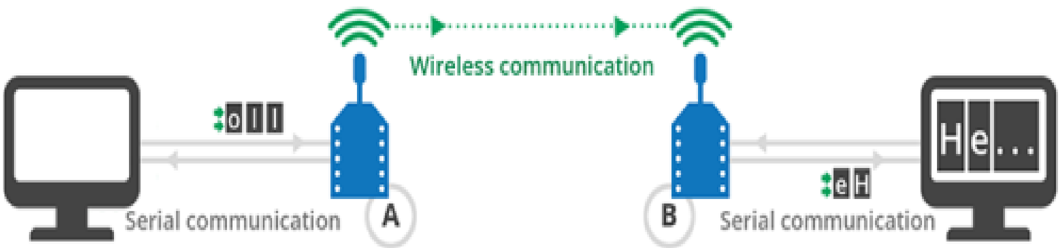

Figure 5.5: Serial Communication via XBEE Module [52]

With this information, we can identify the two types of wireless data transmission in an XBee communication process:

i. **Wireless communication:** This communication takes place between XBee modules. Modules that are supposed to work together need to be part of the same network and they must use the same radio frequency. All modules that meet these requirements can communicate wirelessly with each other.

ii. **Serial communication:** This communication takes place between the XBee module and the intelligent device connected to it through the serial interface.

XBee alliance defined two types of physical devices in order to lower the costs. Full Function Device (FFD) allows building any topology. It can take a role of a network coordinator and is able to communicate with any other XBee device. In a network it takes a similar role to a master unit in Bluetooth, however the physical design is different to the other type of device (in Bluetooth the devices are in general the same anyone can take the role of a network coordinator). Reduced Function Device (RFD) can be used only in a star topology and only as a distant unit. It is controlled by an FFD and can communicate only with it after. The implementation of an RFD is strongly simplified comparing to FFD, which significantly lower the cost of the whole system.

NETWORK FORMATION

Zigbee defines three different device types: coordinator, router and end device. **Coordinator:** Start a new Personal Area Network (PAN) by selecting the channel and PAN ID. Allow routers and end devices to join the PAN, transmit and receive RF data transmission and route the data. .

Router: Transmit and receive RF data transmission, and route data packet through the network.

End Device: Cannot assist in routing the data transmission but transmit or receive RF data transmission and intended to be battery powered devices [53].

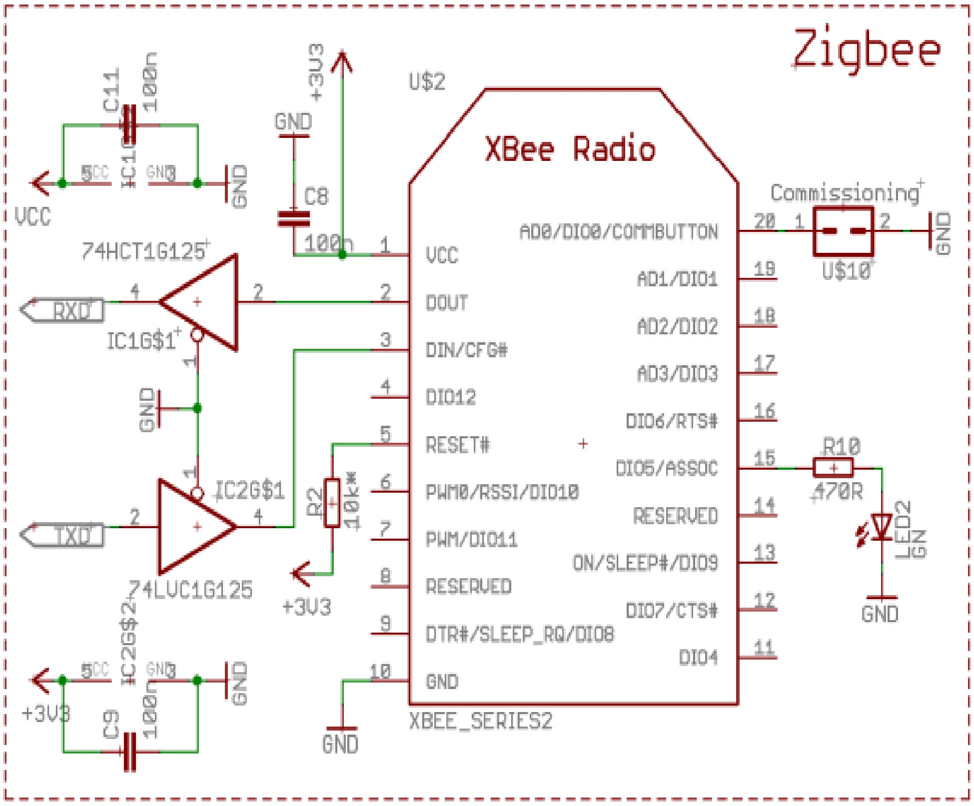

Figure 5.6: XBee Pin-out [54]

5.1.2.2 BLUETOOTH MODULE HC-05

The Bluetooth module HC-05 is a MASTER/SLAVE module. By default the factory setting is SLAVE. The Role of the module (Master or Slave) can be configured only by AT COMMANDS. The slave modules cannot initiate a connection to another Bluetooth device, but can accept connections. Master module can initiate a connection to other devices. The user can use it simply for a serial port replacement to establish connection between MCU and GPS, PC to your embedded project, etc. HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04- External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). It has the footprint as small as 12.7mmx27mm.

Hardware Features

- Typical -80dBm sensitivity
- Up to +4dBm RF transmit power
- Low Power 1.8V Operation ,1.8 to 3.6V I/O
- PIO control
- UART interface with programmable baud rate
- With integrated antenna
- With edge connector

Software Features

- Slave default Baud rate: 9600, Data bits:8, Stop bit:1,Parity:No parity.
- Auto-connect to the last device on power as default.
- Permit pairing device to connect as default.
- Auto-pairing PINCODE:”1234” as default.

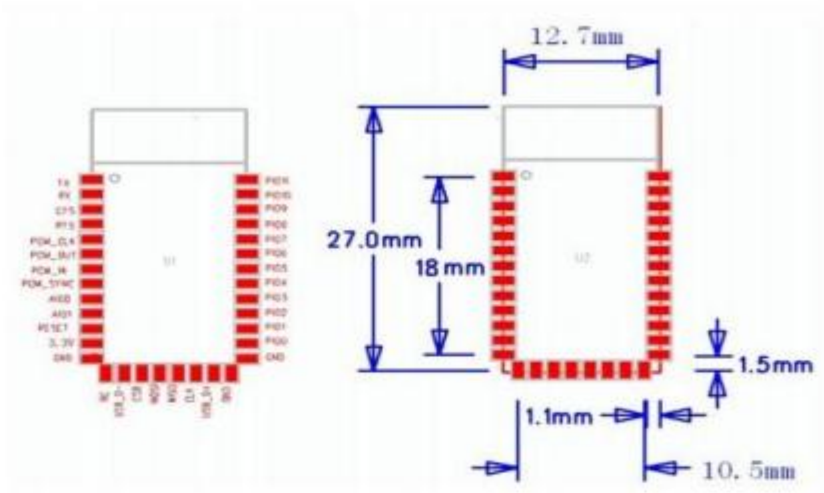

Figure 5.7: HC 05 Architecture [55]

PIN DESCRIPTION

The HC-05 Bluetooth Module has 6pins. They are as follows:

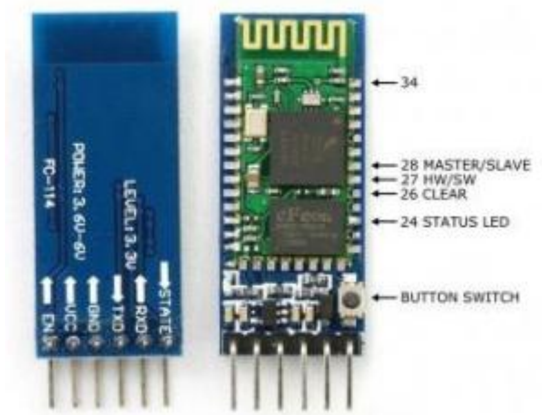

Figure 5.8: HC 05 Pin-out [56]

ENABLE:

When enable is pulled LOW, the module is disabled which means the module will not turn on and it fails to communicate. When enable is left open or connected to 3.3V, the module is enabled i.e. the module remains on and communication also takes place.

Vcc:

Supply Voltage 3.3V to 5V

GND:

Ground pin

TXD & RXD:

These two pins acts as an UART interface for communication

STATE:

It acts as a status indicator. When the module is not connected to paired with any other Bluetooth device, signal goes Low. At this low state, the led flashes continuously which denotes that the module is not paired with other device. When this module is connected to/paired with any other Bluetooth device, the signal goes High. At this high state, the led blinks with a constant delay say for example 2s delay which indicates that the module is paired.

BUTTON SWITCH:

This is used to switch the module into AT command mode. To enable AT command mode, press the button switch for a second. With the help of AT commands, the user can change the parameters of this module but only when the module is not paired with any other BT device. If the module is connected to any other Bluetooth device, it starts to communicate with that device and fails to work in AT command mode.

5.1.3 BOARDS AND MICROCONTROLLERS

5.1.3.1 ATMEGA 2560

The ATmega2560 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega2560 achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. The device is manufactured using the Atmel high-density nonvolatile memory technology. The On-chip ISP Flash allows the program memory to be reprogrammed in-system through an SPI serial interface, by a conventional nonvolatile memory programmer, or by an On-chip Boot program running on the AVR core. Software in the Boot Flash section will continue to run while the Application Flash section is updated, providing true Read-While-Write operation. By combining an 8-bit RISC CPU with In-System Self-Programmable Flash on a monolithic chip, the Atmel ATmega2560 is a powerful microcontroller that provides a highly flexible and cost effective solution to many embedded control applications. The ATmega2560 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, in-circuit emulators, and evaluation kits [57].

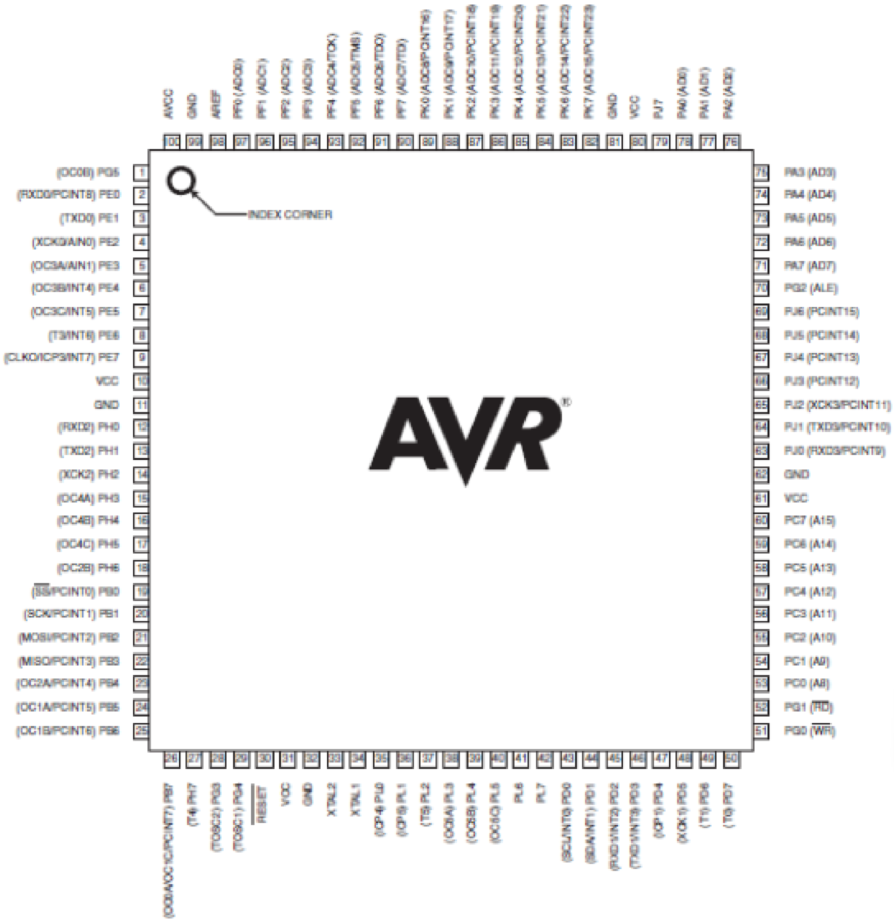

Figure 5.9: ATMEGA 2560 Pin-out [58]

5.1.3.2 ARDUINO MEGA ADK

The Arduino MEGA ADK is a microcontroller board based on the ATmega2560. It has a USB host interface to connect with Android based phones, based on the MAX3421e IC. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button [59]. The MEGA ADK is based on the Mega 2560.

Technical Specifications

Operating Voltage	5V
Input Voltage (Recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	40mA
DC Current for 3.3V Pin	50mA
SRAM	8KB
EEPROM	4KB
Clock Speed	16MHz
USB Host Chip	MAX3421E
Length	101.52mm
Width	53.3mm
Weight	36g

Table 5.4: Arduino Mega ADK specifications

Power

The Arduino MEGA ADK can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter

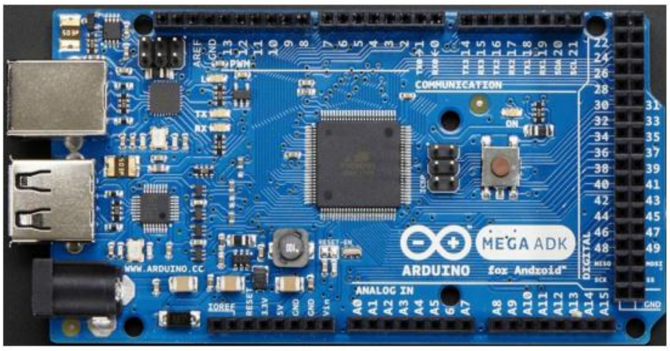

Figure 5.10: ARDUINO MEGA ADK

(wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector. The board can operate on an external supply of 5.5 to 16 volts. The recommended range is 7 to 12 volts [60].

The power pins are as follows:

Vin: The input voltage to the Arduino board when it's using an external power source. We can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V).

3.3V pin: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

GND: Ground pins.

IOREF: This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

Memory

The MEGA ADK has 256 KB of flash memory for storing code 8 KB of SRAM and 4 KB of EEPROM Input and Output Each of the 50 digital pins on the MEGA ADK can be used as an input or output, using pin Mode (), digital-Write (), and digital-Read () functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 KOhms.

In addition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2). These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. PWM: 2 to 13 and 44 to 46. Provide 8-bit PWM output with the analog-Write () function.

SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS). These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.

USB Host: MAX3421E.

The MAX3421E communicate with Arduino with the SPI bus. So it uses the following pins:

Digital: 7 (RST), 50 (MISO), 51 (MOSI), 52 (SCK). None broken out on headers: PJ3 (GP_MAX), PJ6 (INT_MAX), PH7 (SS).

LED: There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

TWI: 20 (SDA) and 21 (SCL). Support TWI communication using the Wire library. Note that these pins are not in the same location as the TWI pins on the Duemilanove or Diecimilia.

The MEGA ADK has 16 analog inputs, each of which provides 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analog-Reference () function.

There are a couple of other pins on the board:

AREF: Reference voltage for the analog inputs. Used with analog Reference ().

Reset: Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino MEGA ADK has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a.inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2/16U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1). The ATmega2560 also supports TWI and SPI communication. The Arduino software includes a Wire library to simplify use of the TWI bus; see the Wire library for details. For SPI communication, use the SPI library. The USB host interface given by MAX3421E IC allows the Arduino MEGA ADK to connect and interact to any type of device that have a USB port. For example, allows you to interact with many types of phones, controlling Canon cameras, interfacing with keyboard, mouse and games controllers as Wiimote and PS3 [61]. Programming the Arduino MEGA ADK can be programmed with the Arduino software. The ATmega2560 on the Arduino MEGA ADK comes preburned with a bootloader .It communicates using the original STK500v2 protocol The ATmega8U2 firmware source code is available in the Arduino repository. Automatic (Software) Reset Rather than requiring a physical press of the reset button before an upload, the Arduino MEGA ADK is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow us to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload [62]. The MEGA ADK contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". We can also disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line [63]. The maximum length and width of the MEGA ADK PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins. The MEGA ADK is designed to be compatible with most shields designed for the Uno, Diecimila or Duemilanove.

Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on both the MEGA ADK and Duemilanove / Diecimila [63].

5.1.4 LCD (LIQUID CRYSTAL DISPLAY)

It is used to display the numeric and alphanumeric data. We used 16×2 LCD which has 16 Columns and 2 Rows. There are a lot of combinations available like, 8×1, 8×2, 10×2, 16×1, etc. but the most used one is the 16x2 LCD.

4-BIT AND 8 BIT OF LCD

The LCD can work in two different modes, namely the 4-bit mode and the 8-bit mode. In 4 bit mode we send the data nibble by nibble, first upper nibble and then lower nibble (a group of four bits), so the lower four bits (D0-D3) of a byte form the lower nibble while the upper four bits (D4-D7) of a byte form the higher nibble. This enables us to send 8 bit data. Whereas in 8 bit mode we can send the 8-bit data directly in one stroke since we use all the 8 data lines. 8-bit mode is faster and flawless than 4-bit mode. But the major drawback is that it needs 8 data lines connected to the microcontroller. This will make us run out of I/O pins on our MCU, so 4- bit mode is widely used. No control pins are used to set these modes. It's just the way of programming that change.

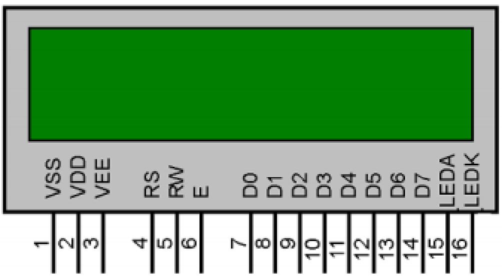

Figure 5.11: 16X2 LCD Pin-outs [64]

The black circles on the back of LCD consist of an interface IC and its associated components to help us use this LCD with the MCU. Because our LCD is a 16*2 Dot matrix LCD and so it will have 32 (16*2) characters in total and each character will be made of 5*8 Pixel Dots. We know that each character has 40 (5*8) Pixels and for 32 Characters we will have (32*40) 1280 Pixels. Further, the LCD should also be instructed about the Position of the Pixels. It will be a hectic task to handle everything with the help of MCU, hence

Figure 5.12: 16X2 LCD Interface IC

an Interface IC is used which is mounted on LCD Module itself. The function of this IC is to get the Commands and Data from the MCU and process them to display meaningful information onto our LCD Screen [64].

5.2 SOFTWARE

5.2.1 LABVIEW

Laboratory Virtual Instrument Engineering Workbench (**LabVIEW**) is a system-design platform and development environment for a visual programming language from National Instruments. The graphical language is named "G"; not to be confused with G-code. Originally released for the Apple Macintosh in 1986, LabVIEW is commonly used for data acquisition, instrument control, and industrial automation on a variety of operating systems (OSs), including Microsoft Windows, various versions of Unix, Linux, and MacOS. The latest version of LabVIEW is 2016, released in August 2016.

Figure 5.13: LABVIEW Preview

DATAFLOW PROGRAMMING

The programming language used in LabVIEW, named G, is a dataflow programming language. Execution is determined by the structure of a graphical block diagram (the LabVIEW-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, G can execute inherently in parallel. Multi-processing and multi threading hardware is exploited automatically by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution.

GRAPHICAL PROGRAMMING

LabVIEW integrates the creation of user interfaces (termed front panels) into the development cycle. LabVIEW programs-subroutines are termed virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector panel. The last is used to represent the VI in the block diagrams of other, calling VIs. The front panel is built using controls and indicators. Controls are inputs: they allow a user to supply information to the VI. Indicators are outputs: they indicate, or display, the results based on the inputs given to the VI. The back panel, which is a block diagram, contains the graphical source code. All of the objects placed on the front panel will appear on the back panel as terminals. The back panel also contains structures and functions which perform operations on controls and supply data to indicators. The structures and functions are found on the Functions palette and can be placed on the back panel. Collectively controls, indicators, structures, and functions will be referred to as nodes. Nodes are connected to one another using wires, e.g., two controls and an indicator can be wired to the addition function so that the indicator displays the sum of the two controls. Thus a virtual instrument can be run as either a program, with the front panel serving as a user interface, or, when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program. The graphical approach also allows nonprogrammers to build programs by dragging and dropping virtual representations of lab equipment with which they are already familiar. The LabVIEW programming environment, with the included examples and documentation, makes it simple to create small applications. This is a benefit on one side, but there is also a certain danger of underestimating the expertise needed for high-quality G programming. For complex algorithms or large-scale code, it is important that a programmer possess an extensive knowledge of the special LabVIEW syntax and the topology of its memory management. The most advanced LabVIEW development systems offer the ability to build stand-alone applications. Furthermore, it is possible to create distributed applications, which communicate by a client–server model, and are thus easier to implement due to the inherently parallel nature of G language.

5.2.2 ARDUINO IDE

A program for Arduino can be written in programming language for a compiler that produces binary machine code for the target processor. The Arduino project provides the Arduino integrated development environment (IDE), this application is written in the programming language Java. It has in-built code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting. It gives mechanism of one-click to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. A program written with the IDE for Arduino is called a sketch. Sketches are saved on the development computer as text files with the file extension .ino. Arduino Software (IDE) pre-1.0 saved sketches with the extension .pdf. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU tool chain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.

5.2.3 AVR STUDIO 4

AVR Studio AVR Studio is an Integrated Development Environment (IDE) for writing and debugging AVR applications in Windows 9x/ME/NT/2000/XP/VISTA/WIN 7 environments. AVR Studio provides a project management tool, source file editor, simulator, and assembler and front-end for C/C++, programming, emulation and on-chip debugging AVR Studio 4 has a modular architecture which allows even more interaction with 3rd party software vendors. GUI plug-ins and other modules can be written and hooked to the system. Introduction AVR Studio 4 is a large piece of software, it supports several of the phases you usually go through AVR Studio supports the developer in the design, development, debugging and verification part of the processing when you create a new product based on an AVR microcontroller.

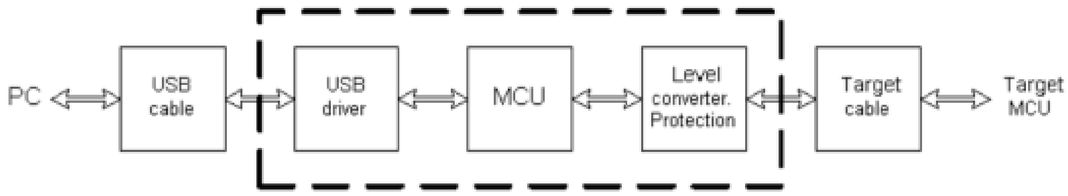

Figure 5.14: Block Diagram for data transfer from PC to Arduino

5.2.4 IP WEBCAM MOBILE APP

IP Webcam App turns the Android Phone into a network camera by streaming the phone's camera over its Wi-Fi connection for remote viewing.

Requirements

Both the computer and your android phone should be connected to the same network with android connected via Wi-Fi [1]. That means we can either –

- Connect both your phone and computer to the Internet using a wireless router.
- Or connect your Android to the pc internet using virtual router (Only for windows 7)
- Or connect your Android to the PC with a shared Wi-Fi network (needs rooted phone with ad-hoc networking enabled).

Once the phone is connected to the same PC network via WiFi, the following steps need to be followed [70]:

1. From android market in your phone, install IP Webcam.
2. Open the app and you will get the configuration screen where you can set the options for port, sound, video quality and username/password.
3. The default options are good enough, so scroll down and click on the "Start server" option.
4. IP Webcam will now open your camera and start streaming the video to a particular IP address and port. "*http://10.42.43.89:8080*".

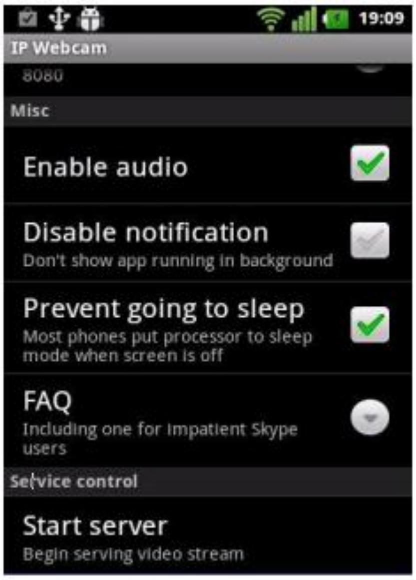

Figure 5.15: IP WEBCAM APP Preview [70]

5. Note this address down and type it in your PC VLC media player. The video recorded from mobile phone will be streamed on the PC.

CHAPTER 6

DESIGNING ASPECTS

6.1 FLEX SENSOR DESIGNING

6.1.1 DESIGN 1

We first designed "**low price flex sensor**" using the following materials:

1. Adhesive tape

2. 2.5mm copper wire

3. Aluminium tape

4. Pencil

5. Paper.

First of all, we cut a strip of paper of 21cm x 1.7 cm. Then fold it half, paint the first half of the paper. We need to cut two stripes of aluminium tape, but we replaced with food wrapping aluminium foil. Put the cable at one end of another half of the strip and cover it with strips of aluminium. After it, repeat this at the other end of the strip. Stretch the adhesive and paste the first half of the paper on it. Fold the paper to paste it and remove the excess of tape [3]. It is an alternate method of detecting contact by using conductive foil, such as aluminum or copper. When two of these conductive surfaces make contact, a short circuit is completed, making the input and output voltages equal. If one of the surfaces is connected to a voltage source, the output will be equal to the source voltage when contact is made and zero when it is not. Contact between various sensors may also be possible by alternating which of the foils is active high and which is receiving. The advantage of this method is the amount of flexibility in the shapes and sizes of the sensor, unlike the other types of contact sensor. Otherwise, a weak pull-down resistor will keep the voltage output at ground. In this way, contact may be detected by determining whether the output voltage is the input voltage or zero, indicating that there is either contact or no contact respectively. After interfacing of low price flex sensor with arduino, it works but not for different angles and gives some absurd values. Therefore, we switched to another method of making flex sensors -“DIY Bend Sensor (Using only Conductive Bags and Masking Tape).

6.1.2 DESIGN 2

This method of designing included the following steps:

i. MATERIALS AND TOOLS

Materials

Anti-Static Bags 10x15cm (Vermason Conductive Bags), Cable Tie (20 - 25cm is great), Masking Tape (2.4cm and 1.1cm), Jumper Wires (20cm length)

Tools

- Pen Knife
- Wire Stripper

ii. PREPARING THE CONDUCTIVE BAGS

The 10x15cm size bags are taken length wise to get the pieces. Trim off the edges (just the little bit of edge) along the 15cm side. Cut on the border line with a pen knife and lay it on the conductive bags length wise, and use a pencil to draw the lines using the stencil as guide. Cut 2 pieces of 0.8cm by 15cm, and 1 piece of 1.7cm by 15cm.

iii. PREPARING THE JUMPER WIRES

- Measure 5cm of the wire and strip it. Twist / Twine the multi-core strands so they're easier to handle,
- Make a loop back down to the base where the insulation starts, and twist the wires together a little so that it stays there.
- We have a nice loop.
- Do the same for all.

Using the thinner masking tape (1.1cm) with the sticky side facing up, place the conductive bag piece that we just cut, right in the middle of it. Make sure there's a border of sticky tape all around. Smooth it out. The conductive bag piece should have the nice black side facing up. Take one of the jumper wire connectors and place it slightly off-center. The exposed loop wire should be kept within the black conductive piece. Allow a 0.5cm of insulated wire part to be within the black piece as well. Take the large conductive bag piece that we cut just now (the one that is 1.7cm in width), and fold it in half, lengthwise. Align the 2 thin pieces and match the sticky border together. Place the large piece that we just folded into half into the sandwich.

6.1.3 DESIGN 3

The sensor designed using second method was too flimsy, and because masking tape will fold rather than bend nicely, we'll need to reinforce it with a cable tie so that the cable tie provides it with a nice bend.

This method of designing consist of the following steps:

- Take the thicker masking tape piece and with the sticky side up, place the cable tie right in the middle of it as shown. Smooth side facing up.
- Trim off the excess cable tie that is sticking out.
- Place the sensor on top of the cable tie, right smack in the middle.
- Fold the sticky edges up of the thicker masking tape onto the sensor.
- We'll see a gap in the middle.
- Take the roll of thin (1.1cm) masking tape, and cover it up the gap nicely.
- Leave a bit excess to fold down to the back.
- Near the jumper wire connectors, 1cm from the edge, fold down (towards the back) at an angle as shown in the illustration.
- Slip a shrink tube (1.5cm in length, 1.1cm in width before shrinking) that covers the 1cm where you just folded and leave the 0.5cm for the wire connectors.
- Shrink the tubing using a soldering iron or a lighter. Use the lighter because it's quick and even.

6.2 GLOVE AND GRIPPER DESIGNING

The basic prototype of this project consisted of a gesture recognizing glove fitted with flex sensors and an accelerometer. The glove used is a normal fabric glove. To detect the bending of each fingers, flex sensors are fitted on each of them, in proper orientation so as to accurately record the bending of the fingers. The length of the flex sensors used is 2.7 inches and each sensor was adjusted over the knuckle without getting slipped over. To keep the sensors in place, they were stitched over the finger properly. The output terminal pins of the flex sensors placed on adjacent fingers were properly insulated from each other so as to avoid any kind of short-circuiting which provides less resistance than the actual value. Each of the flex sensor terminals were connected with jumper wires so as to be used in further connections. For calibration of flex sensors, voltage divider network to be used was soldered on a PCB to which the sensors were connected so as to get proper biasing. For recording the alignment of the hand, accelerometer was placed at the center of the palm, recording the hand orientations in only two dimensions.

Gripper is used basically to pick and place the objects. Gripper is designed using the hard cardboard and the thin aluminum sheet. In designing of gripper, we used single servo motor in order to reduce the power requirements.

CHAPTER 7

RESULT AND DISCUSSION

Communication and self-independency are integral parts of human life. But for people who are physically impaired (deaf, dump or physically handicapped), communication and self-independency is a challenge.

A gesture is a form of non-vocal communication in which visible bodily actions communicate particular messages either in place of or in conjunction with speech. Sign language is a language which, instead of acoustically conveyed sound patterns, uses manual communication and body language to convey meaning. On the other hand, the message conveyed by deaf and dump people through sign language cannot be easily understood by common people. To understand them, one should be able to understand their language i.e. sign language. But it is not possible for everyone to learn sign language. So, sign language translating equipment, which can translate sign messages to normal understandable text or voice form, can be used to somewhat bridge this gap.

Though, differently abled people can communicate with ease but they have to be dependent on others for every small needs, because of their inability to move from one place to other without any assistance. If by any means, they can fulfill their needs sitting at one place, then they too can lead a self-independent life. This can be achieved by recognition of their hand gestures, so as to know what they need to do. The project thereby aimed to develop a prototype for recognizing hand gestures and those gestures were put to use for sign language recognition and robot control. It also explores the real time application of the prototype developed. It is based on the need of developing an electronic **data glove** that can perform multiple tasks.

This project is a small step taken towards those differently abled people to bridge the gap between them and the society. The main objective behind this project is to find a robust solution for differently abled people to lower their communication barrier with common persons and to help them carry out their basic work. The solution is to develop a gesture based glove that can recognize the hand gestures and convert it into text and speech output, to be understood by common people. Besides this, a gesture controlled robot is also developed, that will convert the hand gestures recognized by the glove to respective defined actions, so as to control the motion of the bot and the gripper attached to it.

The sensors and actuators used in this project are flex sensors, accelerometer, DC geared motors (controlling the motion of the wheels of the bots), servomotor (controlling the motion of the grippers attached to the bots). This project also incorporates the use of wireless communication techniques using Bluetooth IC HC-05 and XBee.

There are 5 flex sensors and they are located on each of the finger. Flex sensors are fabricated with resistive material whose resistance varies depending on the bend. To differentiate the words properly, the prototype also accommodate a 3-axis MEMS accelerometer which provides 3 axes (x, y, z axis) tilts.

Bluetooth IC HC-05 is used as an alternate of arduino text to speech module/shield, which are costly. By using this module, text-to-speech conversion is carried out. Arduino converts the recognized hand gesture to text and this text is transmitted via Bluetooth IC to android phones. ZigBee is used to transfer the recognized hand gesture to robots for their motion control and gripping action.

CHAPTER 8

SUMMARY AND CONCLUSION

The project consisted of Smart glove for recognizing the hand gestures. This smart glove was put to use in Sign Language recognition and its real time application was also explored. The glove consisted of flex sensors for recording the bend of the fingers. The flex sensor calibration was carried out using Arduino. The resistance values of all the sign language was defined and the bend of all the fingers was compared with the previously defined valued and accordingly the various gestures were recognized.

The design for Sign Language Recognition was made to operate in two different modes: Alphabet mode and general mode. In alphabet mode, the gestures for all the alphabets were defined, and in General Mode, the gestures for all the numeric characters and a few common gestures were defined.

Besides the sign language recognition, the glove was also put to be used in robot control. Again the operation was defined in two different modes: Motion mode and Gripper Mode. In motion mode, the glove was used to control the direction of motion of the robot using hand gestures, and in Gripper mode, the glove was used to control the motion of the gripper.

For programming purpose, firstly python was chosen as coding platform along with raspberry-pi board for interfacing. But due to its unavailability and its quite expensive price, the choice was shifted to Arduino Board with embedded C as the coding platform.

The project also incorporated the designing of flex sensors using various methods and the accuracy of each of the designed sensors were compared but due to ineffective and random output, the designed sensors were replaced with the ready-made flex sensors.

For text to speech conversion, Arduino was used. The text input was provided to Arduino which was connected to an external circuitry consisting of amplifier and filter which amplified the speech output provided by Arduino and filtered out the noise components. However, despite of all this amplification and filtering action, the speech output provided by Arduino was very poor to be even understood by anyone. So few of the voice shields were looked upon as an alternative but again their high cost posed a problem. So, we switched to the use of Bluetooth module HC -05 as an alternate. The text was transmitted from Arduino to the Android phones, by using the module and the android was chosen as the platform for text to speech conversion.

Few of the TTS apps like LCD display shield were searched and one of them was used for converting the received text to speech output. The sound quality provided by Android's TTS feature was far better than that provided by Arduino.

Apart from the designed hardware, the project also consisted of designing of Mobile App which performs two tasks: Text-to-Speech (TTS) conversion and recording virtual notes. The TTS feature simply converts the typed text to speech output and the Virtual notes feature records the ongoing discussion or classes and the provide the same in written format thus providing accessibility to the specially abled people.

FUTURE SCOPES

The project can further be extended to use the smart glove to control robots that can be used in rescue operation. The gestures can be defined to control the motion of the robot and the gripper and the gripper can be used for clearing of path and for picking and placing heavy objects at the place of disaster. Besides robot control, the prototype can also be used to control the motion of the quad copters that are used in various military and surveillance applications.

The mobile application made in this project can be further extended to incorporate additional features like Call companion which will convert an incoming call to text in real time and face to face chat using the same text-to-speech conversion property.

The Smart Glove can be even put to use in gaming applications where the hand movement will control the moves of the gamer. The Glove can also be seen as a learning tool which will help the differently abled people to learn the sign language.

The glove can also be used for home automation, where the gestures of the hand will control the switching of the devices.

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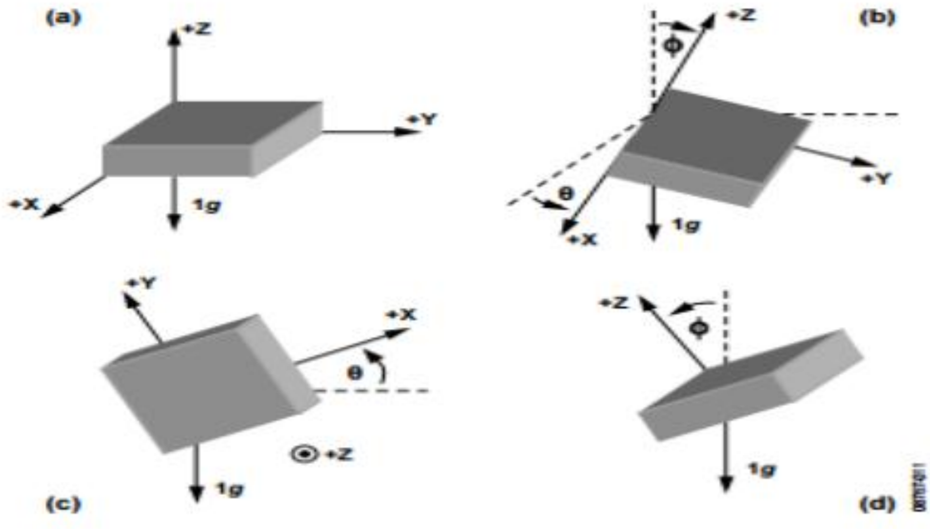
APPENDIX I

TILT CALCULATION

When a third axis is introduced, the orientation of the sensor can be determined in a complete sphere. The classical method of rectangular (x, y, z) to spherical (ρ, θ, φ) conversion can be used to relate the angle of tilt in the xy-plane, θ, and the angle of inclination from the gravity vector, φ, to the measured acceleration in each axis, as follows:

$$\theta = \tan^{-1}\left(\frac{A_{X,OUT}}{A_{Y,OUT}}\right)$$

$$\phi = \cos^{-1}\left(\frac{A_{Z,OUT}}{\sqrt{A^2_{X,OUT} + A^2_{Y,OUT} + A^2_{Z,OUT}}}\right)$$



The measurement of φ corresponds to the measurement of the inclination angle for the single-axis solution, along with the method for determining the minimum accelerometer resolution needed for a specific inclination angle resolution over a desired range. The difference is that the use of the inverse cosine functions to determine φ results in a maximum incremental sensitivity when φ is 90° and a minimum incremental sensitivity at 0° and 180° [71].

APPENDIX II

XBEE PIN CONFIGURATION

(Low-asserted signals are distinguished with a horizontal line above signal name.)

Pin #	Name	Direction	Description
1	VCC	-	Power supply
2	DOUT	Output	UART Data Out
3	DIN / **CONFIG**	Input	UART Data In
4	DO8*	Output	Digital Output 8
5	**RESET**	Input	Module Reset (reset pulse must be at least 200 ns)
6	PWM0 / RSSI	Output	PWM Output 0 / RX Signal Strength Indicator
7	PWM1	Output	PWM Output 1
8	[reserved]	-	Do not connect
9	$\overline{\text{DTR}}$ / SLEEP_RQ / DI8	Input	Pin Sleep Control Line or Digital Input 8
10	GND	-	Ground
11	AD4 / DIO4	Either	Analog Input 4 or Digital I/O 4
12	**CTS** / DIO7	Either	Clear-to-Send Flow Control or Digital I/O 7
13	ON / **SLEEP**	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	Associate / AD5 / DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	**RTS** / AD6 / DIO6	Either	Request-to-Send Flow Control, Analog Input 6 or Digital I/O 6
17	AD3 / DIO3	Either	Analog Input 3 or Digital I/O 3
18	AD2 / DIO2	Either	Analog Input 2 or Digital I/O 2
19	AD1 / DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0 / DIO0	Either	Analog Input 0 or Digital I/O 0

Table:: XBEE Pin Configuration [71]

APPENDIX III

LCD PIN CONFIGURATION

Sr. No	Pin No.	Pin Name	Pin Type	Pin Description	Pin Connection
1	Pin 1	Ground	Source Pin	This is a ground pin of LCD	Connected to the ground of the MCU/ Power source
2	Pin 2	VCC	Source Pin	This is the supply voltage pin of LCD	Connected to the supply pin of Power source
3	Pin 3	V0/VE E	Control Pin	Adjusts the contrast of the LCD.	Connected to a variable POT that can source 0-5V
4	Pin 4	Register Select	Control Pin	Toggles between Command/Data Register	Connected to a MCU pin and gets either 0 or 1. 0 -> Command Mode 1-> Data Mode
5	Pin 5	Read/ Write	Control Pin	Toggles the LCD between Read/Write Operation	Connected to a MCU pin and gets either 0 or 1. 0 -> Write Operation 1-> Read Operation
6	Pin 6	Enable	Control Pin	Must be held high to perform Read/Write Operation	Connected to MCU and always held high.
7	Pin 7-14	Data Bits (0-7)	Data/Command Pin	Pins used to send Command or data to the LCD.	<u>In 4-Wire Mode</u> Only 4 pins (0-3) is connected to MCU <u>In 8-Wire Mode</u> All 8 pins(0-7) are connected to MCU
8	Pin 15	LED Positive	LED Pin	Normal LED like operation to illuminate the LCD	Connected to +5V
9	Pin 16	LED Negative	LED Pin	Normal LED like operation to illuminate the LCD.	Connected to ground

APPENDIX IV

Technical specifications for ATmega 2560

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 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
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g

Table:: Technical specifications of ATMega 2560 [72]

APPENDIX V

FLEX SENSORS READINGS FOR ALPHABETS

ALPHABET	FLEX SENSOR RANGE (in kΩ)				
	THUMB	INDEX FINGER	MIDDLE FINGER	RING FINGER	PINKEY FINGER
A	70-93	125-165	140-182	125-165	85-120
B	95-135	65-85	60-85	65-85	40-65
C	70-130	95-130	100-140	95-130	40-85
D	110-150	55-85	120-155	120-155	70-120
E	100-145	120-175	110-155	120-175	70-105
F	100-160	120-150	55-85	55-85	30-60
G	85-105	65-85	145-175	145-175	95-120
H	70-110	55-85	55-95	75-105	75-105
I	80-105	130-160	135-155	130-160	40-60
J	NOT CALIBRATED DUE TO UNAVAILABILITY OF CONTACT SENSORS				
K	80-105	130-160	135-155	40-60	40-60
L	60-95	55-75	150-200	150-200	90-130
M	90-125	125-150	130-160	130-160	45-90
N	65-100	105-145	115-155	115-155	60-105
O	135-165	105-155	105-145	105-155	75-95
P	120-160	45-85	85-120	85-125	85-125
Q	70-105	55-95	160-200	85-120	85-120
R	NOT CALIBRATED DUE TO UNAVAILABILITY OF CONTACT SENSORS				
S	110-151	140-180	145-185	140-180	80-120
T	100-140	105-120	110-140	110-140	90-115
U	NOT CALIBRATED DUE TO UNAVAILABILITY OF				

V	CONTACT SENSORS				
W					
X	145-180	115-150	115-150	115-150	85-110
Y	65-105	150-180	160-200	150-180	45-85
Z	NOT CALIBRATED DUE TO UNAVAILABILITY OF CONTACT SENSORS				

FLEX SENSORS READINGS FOR NUMERALS

NUMBERS	**FLEX SENSOR RANGE (in kΩ)**				
	THUMB	**INDEX FINGER**	**MIDDLE FINGER**	**RING FINGER**	**PINKEY FINGER**
1	90-125	55-85	165-195	165-195	85-125
2	100-135	55-75	55-85	80-125	80-125
3	55-85	55-75	55-85	80-125	85-125
4	105-125	55-75	55-85	55-75	45-65
5	55-80	55-75	55-85	55-75	45-65
6	90-130	55-85	155-195	55-85	40-65
7	NOT CALIBRATED DUE TO UNAVAILABILITY OF CONTACT SENSORS				
8	90-130	55-85	155-195	55-85	40-65
9	100-160	130-170	55-85	55-85	30-80

FLEX SENSORS READINGS FOR COMMON GESTURES

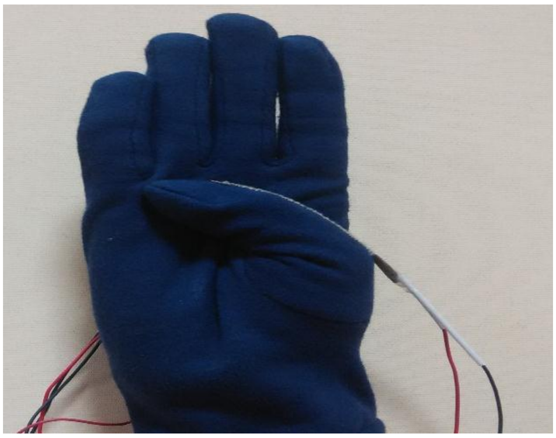
COMMON GESTURES	FLEX SENSOR RANGE (in kΩ)				
	THUMB	**INDEX FINGER**	**MIDDLE FINGER**	**RING FINGER**	**PINKEY FINGER**
HELLO	95-135	65-85	60-85	125-165	40-65
YES	100-141	140-190	155-190	120-175	90-125
NO	75-105	60-95	80-105	85-120	85-105
SORRY	70-93	125-160	130-162	120-175	85-115
WELCOME	50-93	80-120	80-120	125-165	45-85

APPENDIX VI

GESTURES USED IN THIS PROJECT

A

B



C

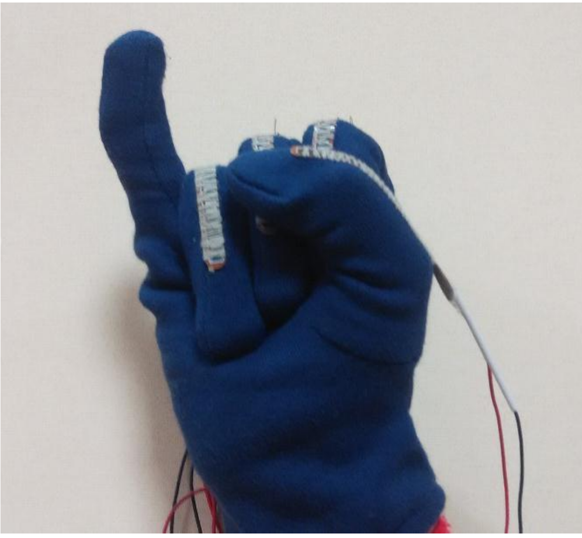
D

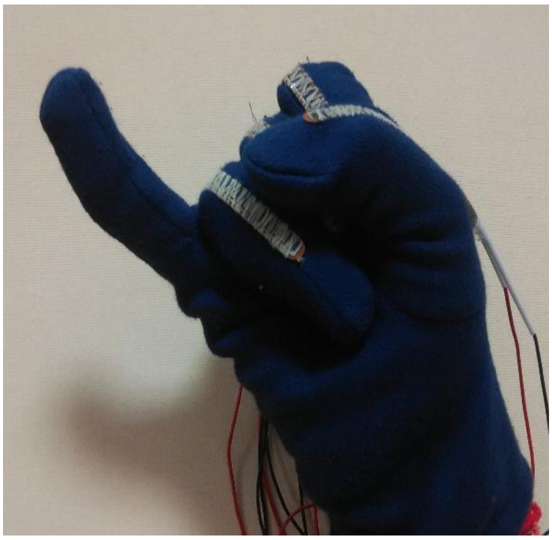
E

F

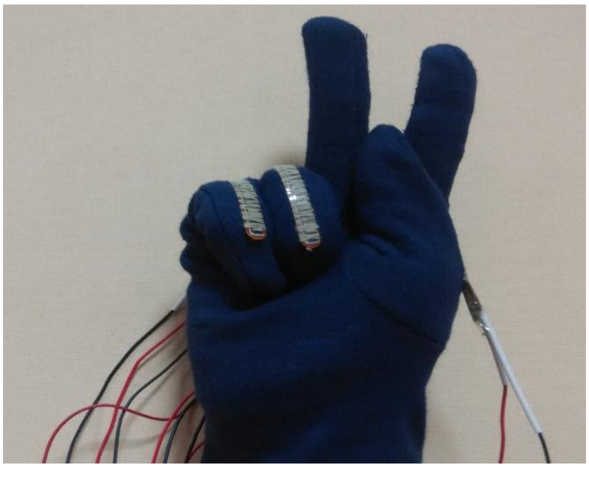
G **H**

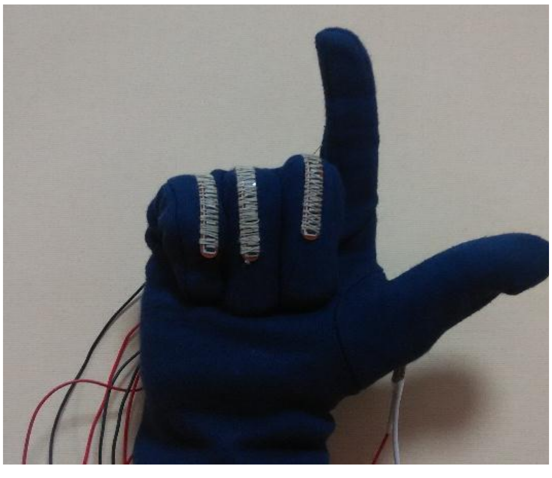
I **J**





K **L**





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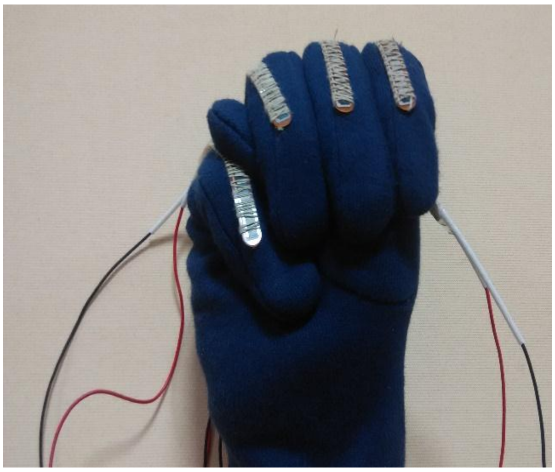

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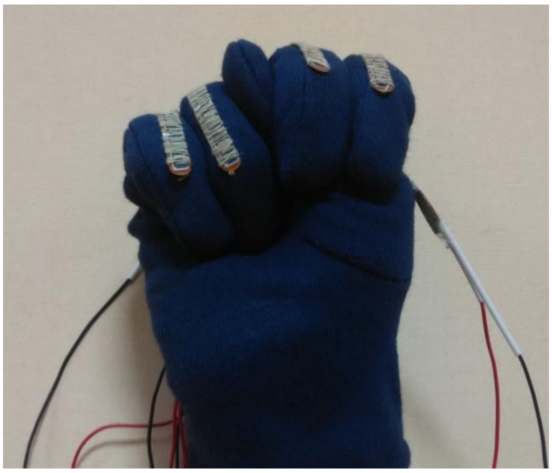
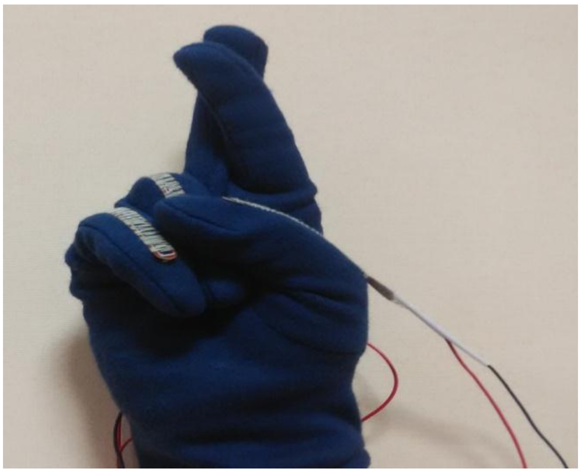


O

P

Q

R



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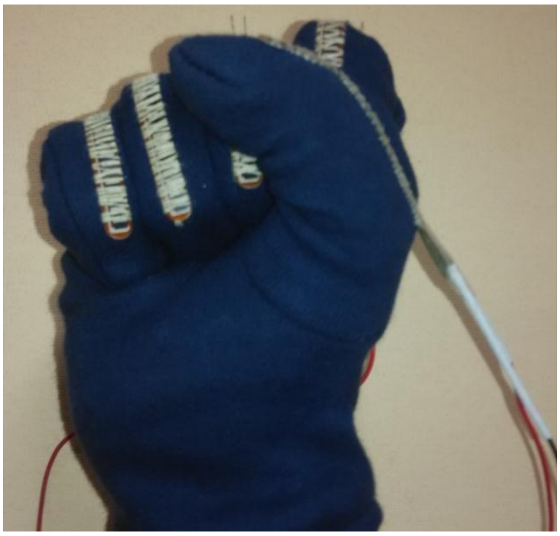

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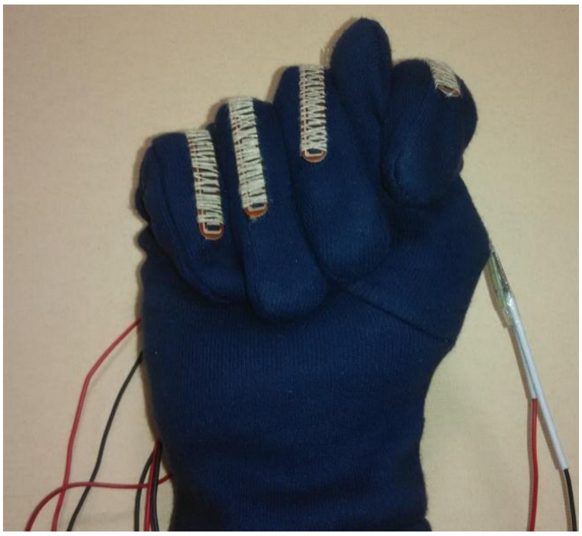

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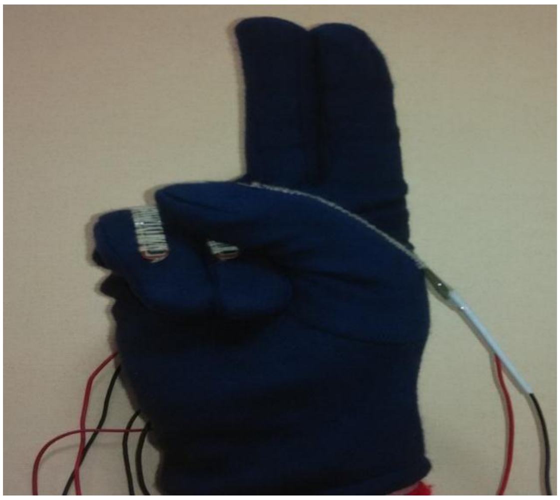
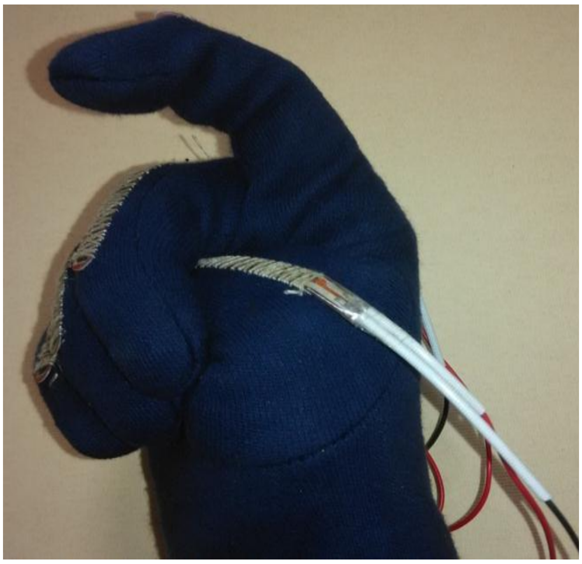


V

W

X



Y

Z