# Design and Development of Medical Sensor Networks for Differently Abled Persons

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***Abstract*— 13% of the global population is elderly and that percentage is estimated to increase to 16.4% by 2030 as life expectancy keeps increasing due in a great part to modern medical technologies. Serving the elderly and the paralytic persons is a noble cause; it is our responsibility to respect, care and fulfill their needs. Communication for a person having a speech disorder thoroughly relies upon the movement of their fingers, hands and articulations. In this paper, we propose a glove based Sign To Speech (STS) system that uses gestures of fingers and hand to convert the American Sign Language (ASL) into a Speech Signal synthesized to adapt for English and different Indian languages. To improve the services to the people in need of mobility assistance, a Sensor Controlled Wheelchair (SCW) is proposed with capabilities of navigating, detecting obstacles and moving automatically by utilizing Gesture and Ultrasonic Sensors that establish Ad-hoc Sensor Networks. The wheelchair is intended for elderly, medically challenged and paralytic patients, so they can lead a peaceful and satisfying life.**

***Keywords-Sign to Speech; American Sign Language; Sensor Controlled Wheelchair.***

## I. INTRODUCTION

Wheelchair assistive technology provides the opportunity for people with mobility impairments, such as imperfect limbs, weakness, muscle atrophy, stroke and other symptoms, to move through indoor and outdoor environments [1]-[3]. Depending on the lifestyle and mobility of the wheelchair user, there are many types of wheelchairs available including basic, lightweight, folding, multi-function, special types, etc. Wheelchairs can be divided into manual wheelchairs and automatic wheelchairs. Sensor Controlled Wheelchairs designed as traditional and automatic wheelchairs are not always suitable for elderly people.

Muteness is commonly referred to as an inability to speak often caused by speech disorders and hearing loss. Normally, people have the ability to freely communicate between each other vocally without any barriers but cannot communicate with people with a speech disorder. Researchers have been focusing on hand gestures detections and have been developing applications in the field of robotics [4]-[6], in the extended area of artificial or prosthetic hands, that can mimic the behaviour of a natural human hand using American Sign Language (ASL).

American Sign Language is a natural predominant sign language that has the same linguistic properties as spoken languages with grammar that differs from the English expressed by movements of the hands and face. It is the primary language of Deaf and Mute communities in the United States and Canada. The dialects of ASL and ASL-based creoles are used in many countries around the world. The movement of fingers is converted into alphabets using American Sign Language, as shown in Figure 1.

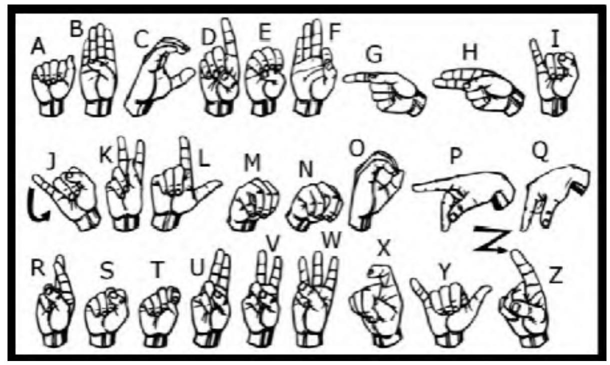


Figure 1. American Sign Language Alphabets [6].

Gesture recognition is classified into a pair of main categories: vision and glove based techniques. The vision based system fails during no visible light and it includes challenges in image and video processing in varying lighting conditions, backgrounds, field of scan constraints and occlusion.

Our proposed system adopted a glove based technique and will efficiently translate each gesture into speech. Thus, it can be used by patients who are not able to speak, but are able to move their fingers and hand.

The paper is organized as follows. Section II presents a brief literature review and its implications. Section III presents the proposed system for differently abled persons based on Medical Sensor Networks. The model presented in this section includes block diagrams. Section IV presents the system implementation. The model presented in this section includes a flowchart of Sign to Speech and Sensor Controlled Wheelchair. Section V presents some of the results obtained from the hardware module described in Section IV. Conclusion and future scope are presented in Sections VI and VII.

## II. LITERATURE REVIEW

A. Hartman et al. [1] has proposed autonomous vehicle technology in the field of medical mobility where wheelchair users can advance their movement using a smart human and machine interface. The research focused on the design of such robotic wheelchair, which is a multilayered task incorporating hardware and software with sensor technology, computer processing and power distribution. The system described the design and development of a smart wheelchair for autonomous path planning and high- performance computing for real time data processing.

S. Umchid et al. [2] have developed a Voice Controlled Automatic Wheelchair. In general, due to many reasons such as injury from accident, age and health problems, physical disability occurs. The wheelchair is needed for handicapped people travelling to other places by themselves; however, people with hands and arms impairment find it difficult to use a typical wheelchair. The system's objective was to design, develop and construct a voice controlled automatic wheelchair.

T. Gomi et al. [3] have developed an Intelligent Wheelchairs for the handicapped. A standardized autonomy management system that can be installed on readily available power chairs, which have been well-engineered over the years, has been developed and tested. A behavior based approach was used to establish sufficient onboard autonomy at minimal cost and material usage while achieving high efficiency, sufficient safety, transparency in appearance and extendibility.

S. Faiz Ahmed et al. [4] have described Electronic Speaking Glove for Speechless Patients. The electronic speaking glove was designed to facilitate easy communication through synthesized speech for the benefit of speech impaired patients. Commonly, a mute person communicating through sign language is not understood by the majority of people. The gesture of fingers of a user is converted into synthesized speech to convey an audible message to other people.

M. M. Abdel-Aziz et al. [5] have invented a Smart Communication System as deaf and mute people find a difficulty in communicating with normal people. The sign language translator system is used for reducing the communication barrier between the deaf-mute people and the people who do not have this impairment. The system deals with all these problems and supports the Arabic sign language and Arabic vocal language as well as efficient and friendly communication between deaf-mute people and the rest.

A. Al Mamun et al. [6] have described a Flex Sensor Based Hand Glove for deaf and mute people. As sign language is the only way to communicate for listening and talking with disabled people, the designed system uses a hand glove that will make the sign language understandable to all. An Android mobile phone app is used to receive a voice, which will generate a speech signal and send it to the hand glove through a wireless communication system.

## III. PROPOSED WORK

The proposed Medical Sensor Networks (MSN) based system provides an opportunity for elderly people with mobility impairment to move through indoor and outdoor environments and enables communication for persons having a speech disorder, i.e. mute people. The Medical Sensor Networks based system has a Sign to Speech node and Sensor Controlled Wheelchair node.

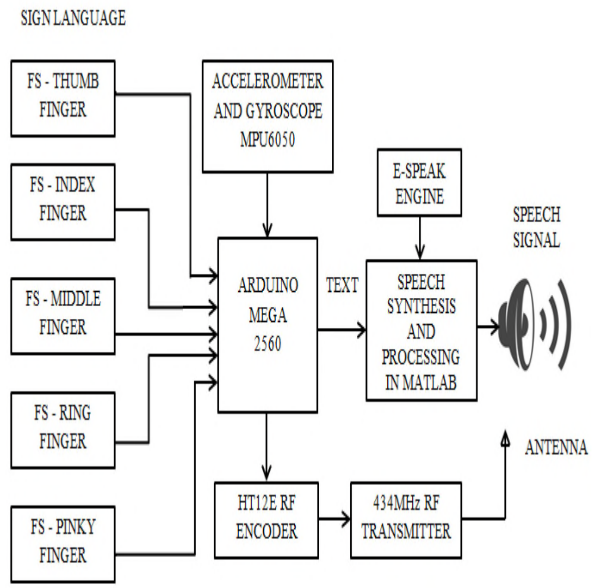


Figure 2. Block diagram of Sign to Speech system.

The Sign to Speech system starts with obtaining a signal proportional to the movement of fingers. Fingers can interpret different hand gestures. Research showed that Flex and MPU6050 sensors based on finger and hand gesture are best suited to convert sign to the text as it is more reliable and cost effective solution. However, to convert the obtained text into a speech signal, the E-Speak Synthesis Engine enables the user to get a speech signal in English, or predefined different Indian language, as shown in Figure 2.

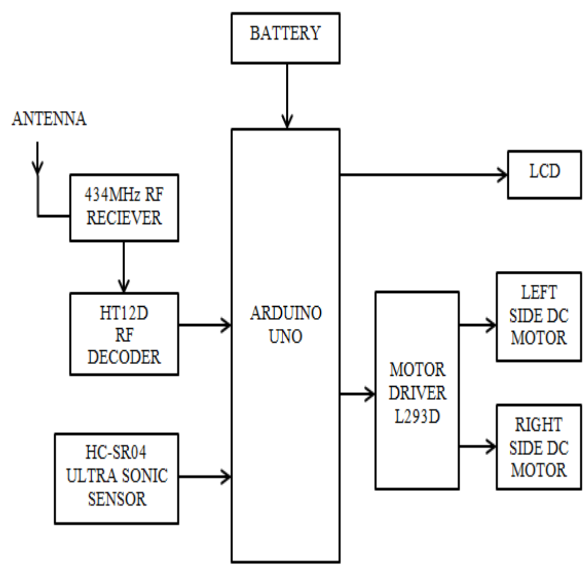


Figure 3. Block diagram of Sensor Controlled Wheelchair.

The block diagram of the developed sensor controlled automatic wheelchair is shown in Figure 3. The MPU6050 based hand gesture of the user is transmitted through 434 MHz RF (Radio-Frequency) transceiver to operate and move the Sensor Controlled Wheelchair in different directions. The Ultrasonic Sensors are employed for automatic obstacle detection to stop the wheelchair during object detection.

### A. E-Speak Speech Synthesis Engine

E-Speak [11] is a compact open source software speech synthesizer for English and other languages, for Linux and Windows, and uses a "formant synthesis" method. E-Speak coverts text into speech signal for the following languages: Afrikaans, Albanian, Aragonese, Armenian, Bulgarian, Cantonese, Catalan, Croatian, Czech, Danish, Dutch, English, Esperanto, Estonian, Farsi, Finnish, French, Georgian, German, Greek, Hindi, Hungarian, Icelandic, Indonesian, Irish, Italian, Kannada, Kurdish, Latvian, Lithuanian, Lojban, Macedonian, Malaysian, Malayalam, Mandarin, Nepalese, Norwegian, Polish, Portuguese, Punjabi, Romanian, Russian, Serbian, Slovak, Spanish, Swahili, Swedish, Tamil, Turkish, Vietnamese, Welsh.

Methods of accessing E-Speak:

- The command line program of Linux and Windows to speak the text from a file or from a standard input.
- On Windows, a shared DLL library of E-Speak.

The features of E-Speak:

- Includes many languages with different voices whose characteristics can be altered.
- It provides flexibility to generate WAV file for Synthesized Speech Output.
- Provides program and data memory of about 2 Mbytes.
- Converts text to phonemes with pitch and length information and can be used as a front-end to MBROLA diphone voices.
- Modifies as a front end for another speech synthesis engine.
- Used with screen-readers and other programs supporting the Windows SAPI5 interface.
- Supports Speech Synthesis Markup Language (SSML) and HTML language and other platforms including Android, Mac OSX and Solaris.

### B. Matrix Laboratory (MATLAB)

MATLAB [12] is a multi-paradigm numerical computing environment and patented programming language developed by MathWorks. It allows matrix manipulations, plotting of functions for data, implementation of algorithms, creation of user interfaces and interfacing with programs written in other languages including C, C++, C#, Java, Fortran and Python.

### C. Flex Sensor

The Flex Sensor, also known as Bend Sensor, measures the amount of bending. The resistance of the sensor element is proportional to the amount of bending; it is used as goniometer and often called flexible potentiometer.

TABLE I. CHARACTERISTICS OF FLEX SENSOR.

| | |
|---|---|
| Range of Resistance | 1.5-40 kΩ depending on sensor type. Flex point claims a 0-250 kΩ resistance range. |
| Range of Temperature | -35 to +80 degrees Celsius |
| Lifetime | Lifetime greater than one million life cycles |
| Hysteresis | Hysteresis 7% |
| Voltage | Voltage 5 to 12 V |
| Size | Approximately 0.28" wide and 1"/3"/5" |

The Flex Sensor contains carbon resistive elements within a thin flexible substrate. The characteristics are described in Table I. The sensor produces a resistance output relative to the bend radius. Practically, the deflection in degrees of 0, 20, 40, 45, 50, 70 and 90 will give 10 kΩ, 14.5 kΩ, 18.8 kΩ, 20 kΩ, 21.1 kΩ, 25.5 kΩ and 30 kΩ of resistances, respectively.

### D. Motor Driver

The Motor Driver L293D is a Dual H-bridge IC; it allows the DC motor to drive in either direction and can control a set of two DC motors simultaneously in any direction. The clockwise and anti-clockwise rotation of the DC motor depends on the polarity of the applied voltage. A 9-volt battery is used to power the motor driver for driving the DC motors.

### E. MPU6050 Sensor Module

The MPU6050 Sensor Module is a 6-axis Motion Tracking Device and combines 3-axis gyroscope, 3-axis accelerometer and Digital Motion Processor in a single package with the additional feature of on-chip Temperature Sensor. It has I2C bus interface to communicate with the microcontrollers and auxiliary I2C bus to communicate with the sensor devices magnetometer, pressure sensor, etc.

### F. Ultrasonic Sensor

The Ultrasonic Sensor measures the distance of the nearest object. HC-SR04 is employed for the automatic obstacle detection and its range is from 2 cm to 3 meters.

$$\text{Distance} = (\text{Echo Pulse Duration} * .0343)/2 \quad (1)$$

The Ultrasonic Sensor detects the nearest object by emitting a short pulse and receiving the reflected echo. The time spent by the pulse signal to reach the object and return is used to determine the relative distance (1).

## IV. SYSTEM IMPLEMENTATION

The working principle of the developed Sign to Speech system is presented in a flowchart, as shown in Figure 4. After the hand glove is powered up, every fingers and hand movement is analyzed each time to detect word or character for its given American Sign Language pattern. The gesture of fingers is obtained by Flex Sensor and hand by MPU6050 Sensor. Depending on the degree of bending, the Flex Sensor values are mapped onto eight different values 0, 1, 2, 3, 4, 5, 6 and 7.

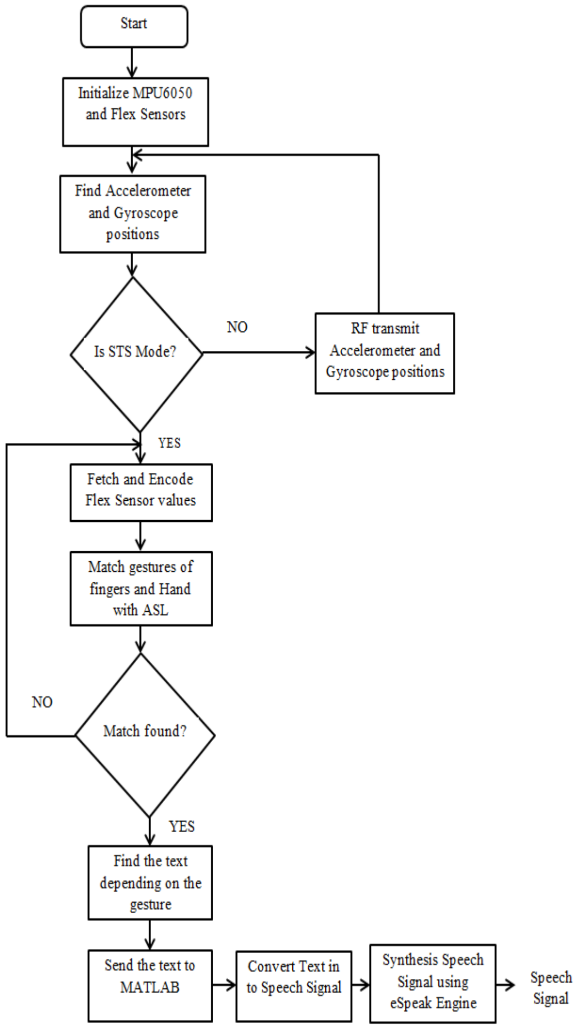


Figure 4. A flowchart of Sign to Speech System.

The words and characters of the English language are recognized based on values of Flex Sensor and orientation of MPU6050. These are described in Tables II and III.

TABLE II. WORD FORMATION.

| Word | PF | RF | MF | IF | TF | MPU6050 Orientation |
|---|---|---|---|---|---|---|
| FOOD | 2\|3 | 2\|3 | 4\|5 | 4\|5 | 2\|3 | X>5 |
| NEWSPAPER | 1\|2 | 1\|2 | 1\|2 | 1\|2 | 1\|2 | X>5, Y<5 |
| WASHROOM | 4\|5 | 3\|4 | 4\|5 | 3\|4 | 2\|3 | X>5 |
| SICK | 1\|2 | 1\|2 | 3 | 1\|2 | 1\|2 | X>5 |
| MEDICINE | 1\|2 | 1\|2 | 4\|5 | 1\|2 | 1\|2 | X>5 |
| EMERGENCY | 5\|6 | 4\|5 | 4\|5 | 4\|5 | 4\|5 | X>5 |
| WATER | 4\|5 | 1\|2 | 1\|2 | 1\|2 | 4\|5 | X>5 |

The system provides flexibility to convert multiple signs into text depending on the combination of American Sign Language words and characters. However, the obtained text is processed in MATLAB using E-Speak to get a synthesized speech signal in English and other Indian languages. This speech signal is used by a mute patient to communicate with other people to inform or their needs, desires and any other problems.

TABLE III. CHARACTER FORMATION.

| Character | PF | RF | MF | IF | TF | MPU6050 Orientation |
|---|---|---|---|---|---|---|
| A | 5\|6 | 5\|6 | 5\|6 | 5\|6 | 1\|2 | X>5 |
| B | 1\|2 | 1\|2 | 1\|2 | 1\|2 | 4\|5 | X>5 |
| C | 2\|3 | 2\|3 | 2\|3 | 2\|3 | 2\|3 | X>5 |
| D | 3\|4 | 3\|4 | 3\|4 | 1\|2 | 2\|3 | X>5, Y>2 |
| E | 5\|6 | 5\|6 | 5\|6 | 5\|6 | 5\|6 | X>5 |
| F | 1\|2 | 1\|2 | 1\|2 | 4\|5 | 3\|4 | X>5 |
| G | 4\|5 | 4\|5 | 4\|5 | 1\|2 | 1\|2 | X>0, Y>5 |
| H | 4\|5 | 4\|5 | 1\|2 | 1\|2 | 2\|3 | X>0, Y>5 |
| I | 1\|2 | 4\|5 | 4\|5 | 4\|5 | 4\|5 | X>5, Y<5 |
| J | 1\|2 | 4\|5 | 4\|5 | 4\|5 | 4\|5 | X>5, Y>5 |
| K | 4\|5 | 4\|5 | 1\|2 | 1\|2 | 2\|3 | X>5 |
| L | 5\|6 | 4\|5 | 5\|6 | 1\|2 | 1\|2 | X>5 |
| M | 5 | 4 | 4 | 4 | 4 | X>5 |
| N | 5 | 5 | 4 | 4 | 4 | X>5 |
| O | 4 | 4 | 4 | 4 | 3 | X>5 |
| P | 3\|4 | 3\|4 | 3\|4 | 1\|2 | 2\|3 | X<5, Y<5 |
| Q | 4\|5 | 4\|5 | 4\|5 | 2\|3 | 2\|3 | X<5, Y<5 |
| R | 4\|5 | 4\|5 | 1\|2 | 3\|4 | 4\|5 | X>5 |
| S | 4\|5 | 4\|5 | 4\|5 | 4\|5 | 4 | X>5 |
| T | 4\|5 | 4\|5 | 4\|5 | 4\|5 | 3 | X>5 |
| U | 4\|5 | 4\|5 | 2\|3 | 1\|2 | 4\|5 | X>5, Y<2 |
| V | 4\|5 | 4\|5 | 1\|2 | 1\|2 | 4\|5 | X>5, Y>2 |
| W | 4\|5 | 1\|2 | 1\|2 | 1\|2 | 4\|5 | X>5 |
| X | 5\|6 | 4\|5 | 5\|6 | 3\|4 | 4\|5 | X>5 |
| Y | 1\|2 | 5\|6 | 5\|6 | 5\|6 | 1\|2 | X>5 |
| Z | 5\|6 | 4\|5 | 5\|6 | 1\|2 | 2\|3 | X>5, Y<-2 |

Note: PF=Pinky Finger, RF=Ring Finger, MF=Middle Finger, IF=Index Finger, TF=Thumb Finger, | = Logical – OR

The movement of the Sensor Controlled Wheelchair is dependent on the orientation of the MPU6050 dictated in Table IV. A single MPU6050 is shared between the nodes in the Medical Sensor Network.

TABLE IV. WORKING STATUS OF SENSOR CONTROLLED WHEELCHAIR.

| MPU6050 Orientation | RF Bits | Movement of Wheelchair |
|---|---|---|
| X<0 | 1000 | FORWARD |
| X>0 | 0001 | BACKWARD |
| Y>0 | 0100 | RIGHT |
| Y<0 | 0010 | LEFT |
| X=0 & Y=0 | 0000 | STOP |

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The Sensor Controlled Wheelchair has five types of motions, namely, moving forward, moving backward, moving to the left, moving to the right and stop motion. The Ultrasonic Sensors have been included to stop the wheelchair during obstacle detection.

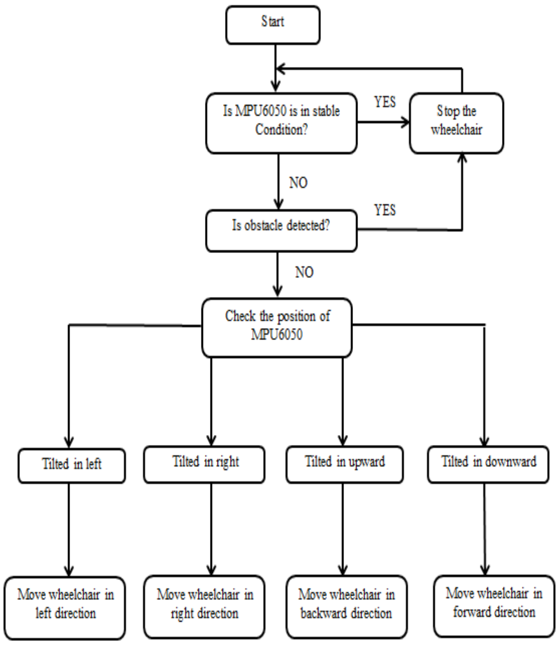


Figure 5. A flowchart of Sensor Controlled Wheelchair.

The working principle of the developed Sensor Controlled Wheelchair is presented in a flowchart, as shown in Figure 5. The orientation of MPU6050 is transmitted to the Sensor Controlled Wheelchair through RF wireless communication includes RF Encoder and Decoder to encrypt the data and remove noise. The Motor Driver L293D controls the rotation of the DC motors in clock and anti-clock wise direction so that the required movement of the wheelchair is achieved.

## V. Result Evaluation

The implementation of Medical Sensor Networks for differently-abled persons has shown good results in encouraging the patients during recovery transition.

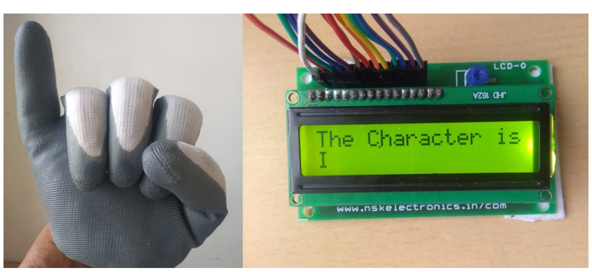


Figure 6. Sign for the English Alphabet 'I'

Figure 6 shows the sign for English Alphabet letter 'I' based on American Sign Language, getting converted into the corresponding text on the right-hand side by processing the obtained values of Flex and MPU6050 Sensors.


Figure 7. Sign for The English Word 'NEED'

Figure 7 shows the sign for the English word 'NEED' based on the American Sign Language getting converted into the corresponding text on the right-hand side.

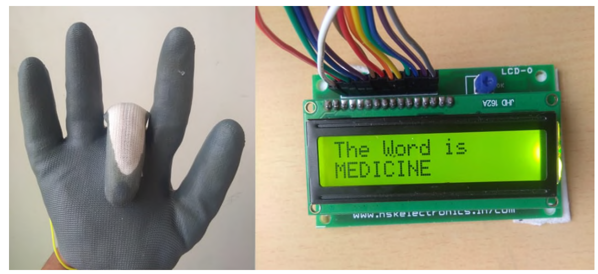


Figure 8. Sign for The English Word 'MEDICINE'

Figure 8 shows the sign for the English word 'MEDICINE' based on American Sign Language, getting converted into the corresponding text on the right-hand side.

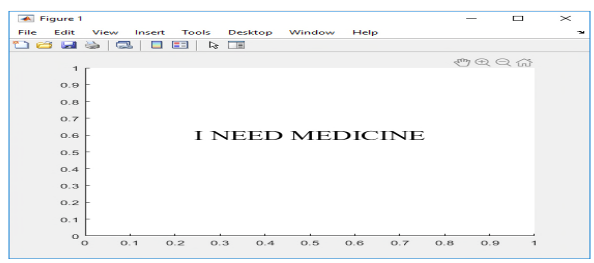


Figure 9. Signs to Speech Conversion in the English Language

Based on the words and characters of American Sign Language, the obtained text is synthesized in MATLAB using Speech API to generate a Speech Signal in the English language, as shown in Figure 9.

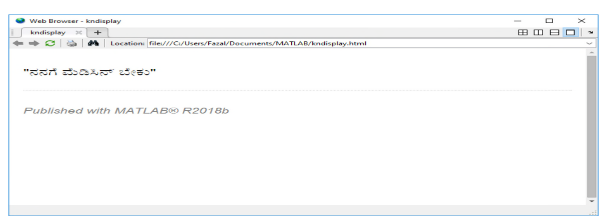


Figure 10. Signs to Speech Conversion in the Kannada Language

The obtained text in the English language is converted into the Kannada language and then synthesized using E-Speak to generate a Speech Signal in the Kannada language, as shown in Figure 10.

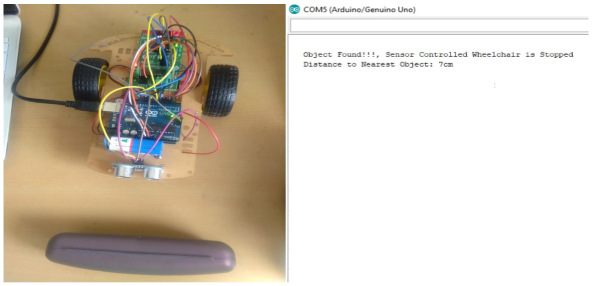


Figure 11. Object Detection in Sensor Controlled Wheelchair

The Sensor Controlled Wheelchair gets stopped automatically as it finds any object in the path it moves using the Ultrasonic Sensors and displays the corresponding message on the right side, as shown in Figure 11.

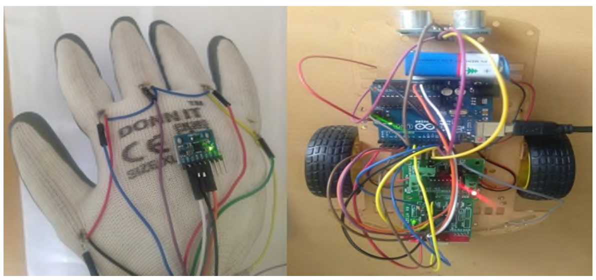

Figure 12. Moving Sensor Controlled Wheelchair in Forward Direction

The Sensor Controlled Wheelchair moving in forward direction as the horizontal orientation of MPU6050 is less than zero makes the RF bits equal to 1000, as shown in Figure 12.

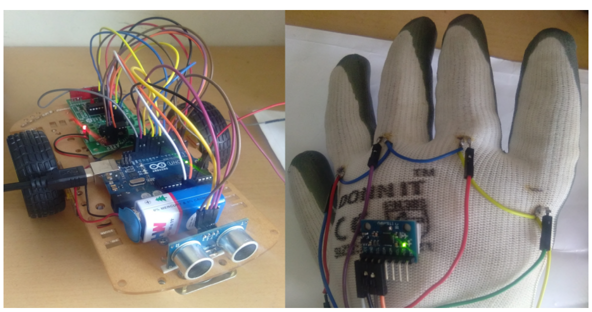

Figure 13. Moving Sensor Controlled Wheelchair in Left Direction.

The Sensor Controlled Wheelchair moving towards left as the vertical orientation of MPU6050 is less than zero makes RF bits equal to 0010, as shown in Figure 13.

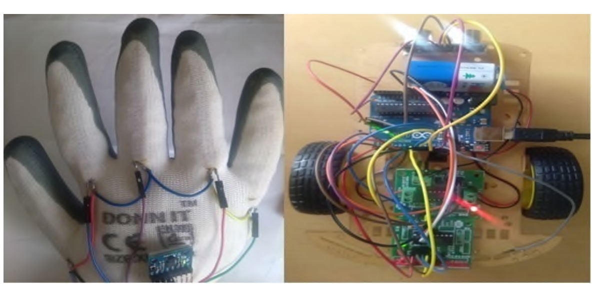

Figure 14. Moving Sensor Controlled Wheelchair in Backward Direction

The Sensor Controlled Wheelchair moving in the backward direction as the horizontal orientation of MPU6050 is greater than zero makes RF bits equal to 0001, as shown in Figure 14.

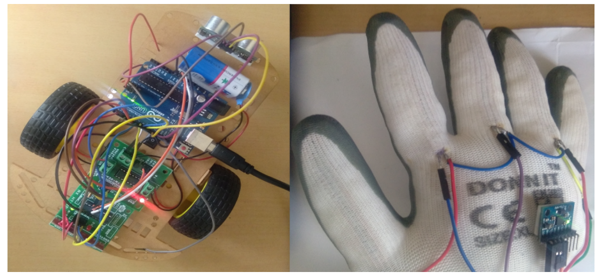

Figure 15. Moving Sensor Controlled Wheelchair in Right Direction

The Sensor Controlled Wheelchair moving towards the right as the vertical orientation of MPU6050 is greater than zero makes RF bits equal to 0100, as shown in Figure 15.


Figure 16. Sensor Controlled Wheelchair is Stopped

The Sensor Controlled Wheelchair gets stopped as the vertical and horizontal orientation of MPU6050 is equal to zero makes RF bits equal to 0000 and displays the corresponding message on the right side, as shown in Figure 16.

## VI. CONCLUSION

Our proposed system uses Sign to Speech, which converts American Sign Language into a Speech Signal useful for speech impaired elderly patients to fill the communication gap between patients, doctors and relatives. The output speech can be in English or other Indian languages for the mute patient to express their needs by using gestures.

The Sensor Controlled Wheelchair operated by the gestures of hand provides the opportunity for the old age patients with mobility impairment to move through indoor and outdoor environments. The automatic obstacle detection is implemented in the system to stop the movement of the wheelchair automatically, providing easy access for elderly people and automatic protection from obstacle collision.

## VII. FUTURE SCOPE

The Flex Sensors based hand glove can be replaced by an E-Textile make hand glove that is light weight and less wiring is required; however, it can be very expensive.

The K-Nearest Neighbors Algorithm can be adopted as the graphical view of the characters, words and sensor values change with different persons.

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