TONGUE DRIVE SYSTEM

by

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Master of Engineering in Mechatronics

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AUTHOR'S DECLARATION

I Mayank Bharti, declare that the research work carried out for this thesis was in accordance with the regulations of the Asian Institute of Technology. The work presented in it are my own and has been generated by me as the result of my own original research, and if external sources were used, such sources have been cited. It is original and has not been submitted to any other institution to obtain another degree or qualification. This is a true copy of the thesis, including final revisions.

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ABSTRACT

The Tongue Drive System (TDS) is a non-obtrusive tongue-operated assistive device that has the potential to give persons with severe impairments effective computer access and environmental management. It detects and classifies users' voluntary tongue movements using a tiny permanent magnet recurred on the tongue and an array of magnetic sensors installed on a headset outside the mouth or an orthodontic brace inside the mouth to convert their intents into control commands.

The magnetic sensors are nothing but hall-effect sensors. A transducer that changes its output voltage in response to a change in a magnetic field is known as a hall-effect sensor. In its most basic form, the sensor is an analog transducer that outputs a voltage. It is possible to calculate the distance between the hall plate and a known magnetic field. A Hall-effect sensor and a microprocessor make up the control system in the proposed tongue drive system. The data from the sensor is collected by the microcontroller.

Fundamentally, this system is a wearable assistive technology in which a magnet is attached to the tongue, which sends signals to drive assistive devices based on tongue movement. Research fact says the tongue drive system provides better results with a full comfort zone as compared to other assistive technologies (*Georgia Institute of Technology*. (2008, June 30), *"Tongue Drive System Lets Persons with Disabilities Operate Powered Wheelchairs, Computers"*). Through this study, various types of assistive technologies are compared, which are available in the market. The study also illustrates the controlling of a mobile result through hall sensors and via Bluetooth connection.

The results obtained as an output following command execution when the hall sensor is in an active condition and via a mobile application. Nowadays, assistive technology is used by a lot of people in various ways and it has immensely helped people who are suffering from severe disabilities as well as those around them. Thus, there is a vital need to look into it and make such systems that can improve the lives of people.

Keywords: TDS- tongue drive system; AT- Assistive Technologies; SCI- Spinal cord injuries

CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

LIST OF ABBREVIATIONS

AT = Assistive Technology

EEG = Electroencephalography

EMG = Electromyography

TDS = Tongue Drive System

PWC = Power Wheel Chair

SCI = Spinal Cord Injury

EOG = Electrooculography

BCI = Brain Computer Interference

KNN = K-Nearest Neighbor

LR = Logistic Regression

EMF = Electromagnetic Field

NdFeB = Neodymium Iron Boron

SPP = Serial Port Protocol

DC = Direct Current

I/O = Input Output

I2C = Inter Integrated Circuit

CHAPTER 1
INTRODUCTION

This study illustrates about a system which is one of the solutions for the people who are suffering from the physically disability. It is magnet-based system, and has two certain control modes; sensor and Bluetooth control mode (via application). Study also explains about the commands which are basic need of a person and make them independent to perform at least their day-to-day essentials.

1.1 Background

As nowadays accidents may lead to severe damage to a person's life, it may result in physical injuries, spinal cord injuries specifically. Some people get injured in their spinal cord and suffer major issues. Also, it can be caused by strokes, which result in paralysis, and individuals with disabilities in limbs. So, to overcome this problem, we can go for some assistive technology that helps these people to improve their daily life problems. There are many assistive technologies (AT) that are being introduced in the market like eye trackers, head arrays, EEG (Electroencephalogram) and EMG (Electromyography) configuration, speech recognition, etc. Speech recognition devices have become popular with computers and smartphones being ubiquitous. Even though these technologies allow people to type effectively, they are not efficient for wheelchair or cursor navigation on a computer. EMG configuration systems may lead to muscle fatigue and can even harm a person. On the contrary, the tongue drive system (TDS) is a non-obtrusive tongue-operated assistive technology that has the ability to provide effective computer access and environmental management to those with severe disabilities. It detects and classifies users' voluntary tongue movements using a tiny permanent magnet recurred on the tongue and an array of magnetic sensors installed on a headset outside the mouth or an orthodontic brace inside the mouth to convert their intents into control commands.

Among ATs, those giving elective control to PC access and wheeled portability are considered the most significant for the present way of life as they can possibly improve users' personal satisfaction by facilitating two significant limitations: successful correspondence (effective communication) and autonomous versatility (independent mobility). Although there are a couple of ATs accessible for either PC access or fueled wheelchair (PWC) control, none can adequately and securely address the two applications.

Hence, users are troubled with figuring out how to utilize different ATs for various undertakings and frequently switching between them with the assistance of a guardian. Sip-n-puff, for example, is an easy and simple to use AT, which permits users to control their PWC by blowing or sucking through a straw. But it has a number of limitations to certain factors such as fewer direct choices, slow input commands, and appearance which can be a result of a serious inability, which is quite awkward to the end-users. It additionally needs incessant cleaning and cannot be utilized by those without stomach pressure.

In the past, some assistive devices have been inspired by and based on different human phenomena. Such assistive technologies include head movement, eye cursor movement, etc. In an AT including head movement, a system usually relies on a device similar to a headband cap. However, these technologies are inaccessible to people who are unable to move their heads. A typical eye cursor movement system is based on the infrared beam. Cursor movement can usually be implemented by tracing the IR beam emitted via transmitter. This leads to limitations in terms of variety and number of operations. Recently, some ATs have been introduced which are based on the concept of facial movement as well to perform various functions, which can be challenging for people who have lost control over their facial muscles. Taking all of these factors into account, research says a system that would be controlled by the tongue is more efficient because the tongue is directly connected to the brain via the cranial nerves of humans. In addition to it, this type of system could help individuals with severe disabilities lead more independent lives. In this area of the field, research is going on to provide better facilities to people who are facing paralytic issues.

1.2 Problem Statement

People who are severely crippled as a result of spinal cord injuries have a difficult time carrying out even day-to-day tasks and chores with limitations to their use of limbs. Their caretakers also have to put in more effort every day. In order to help disabled people in gaining more control of their life, an assistive system, which eases the caretaker's labor as well, will be helpful. Among many, one of the most helpful technologies is the tongue drive system.

1.3 Objectives

As people with disabilities strive to improve their quality of life, they are eager to adapt to and incorporate innovative assistive technologies (AT) in their daily lives. Particularly important to such people are input devices which enable them to access computers, mobile robots, wheelchairs, smartphones, and home/office appliances. In this study, the following is the focus:

- To assess the operation of a Tongue-Drive System using a computer, a smartphone, and a powered mobile robot by people.

- To perform various operations as authorized by the user via commands.

- To compare various assistive technologies which are available today.

1.4 Scope and Limitation

The tongue and the mouth have a lot of sensory and motor cortex in the human brain that rivals the finger and the hand. They are also uniquely able to manage and handle complex motor functions with several degrees of freedom. The tongue is a suitable organ for operating an assistive technology. So, in the future, it will be really helpful for the people. Also, to avoid interference with the users' usual activities like talking and eating an extra feature is added which is activation mode in the future. Also, researchers have likewise begun to create software and to associate the TDS with widely accessible specialized devices, for example, text generators, discourse synthesizers, and lastly readers. Research into the development of ATs by making use of advances in neurosciences, microelectronics, wireless networking, and computer technology has been comprehensive. In this project study, some of the major points are considered such as assessment for TDS, 3 DOF mobile robots, and 6 action patterns to be executed (4 are directional and 2 are customized or authorized by the person holder). It will be really useful for the people who get injured in an accident, and the person is able to notify them with the help of their tongue movements. Tongues each movement in each direction provides certain notifications. In the future, it will be beneficial to the injured people.

Also, it is limited by certain factors such as limited notifications as there are limited tongue movement, depending on the sensor sensitivity, it is limited by the distance also, like where the person is and where the smart device is located. These parameters are dependent upon the sensor sensitivity. Another limitation of a tongue drive system and other devices can be defined as that person's head should always be in the range of the smart device which is connected with the smart devices (laptop, computer, or smartphone) in order to perform the functions.

CHAPTER 2
LITERATURE REVIEW

In this field, there are many pieces of research that are still going on. Earlier there were some researchers which gained some outcomes regarding this topic. In previous studies, we analyzed the speed and accuracy of nondisabled and tetraplegic participants accessing PCs, smartphones, and PWCs using TDS and compared their performances with traditional computer input devices and joysticks.

2.1 Technology Assessment

There are numerous ATs that are available in the market and some of them are most popular with different success rates. These ATs have their different source of controlling parameters, some are based on ears, eyes, brain, etc. For some ATs, assessment is concluded as follows:

2.1.1 Qualitative Assessment of Assistive System

The paper (*J Rehabil Res Dev*, *May 27, 2015)* defines the usage of the tongue drive system in major spinal cord injuries. And using this assistive technology, it was found that people are a bit comfortable using this technology. In this paper, the author has defined the results of a qualitative study on a group of potential TDS end-users with high-level SCI, seeking their opinions about the acceptability of this new AT during and after a 6-week usability study. They applied the qualitative approach method in which a person with a high level of spinal cord damage will be using the magnetic tongue piercing method for 6 weeks trial.

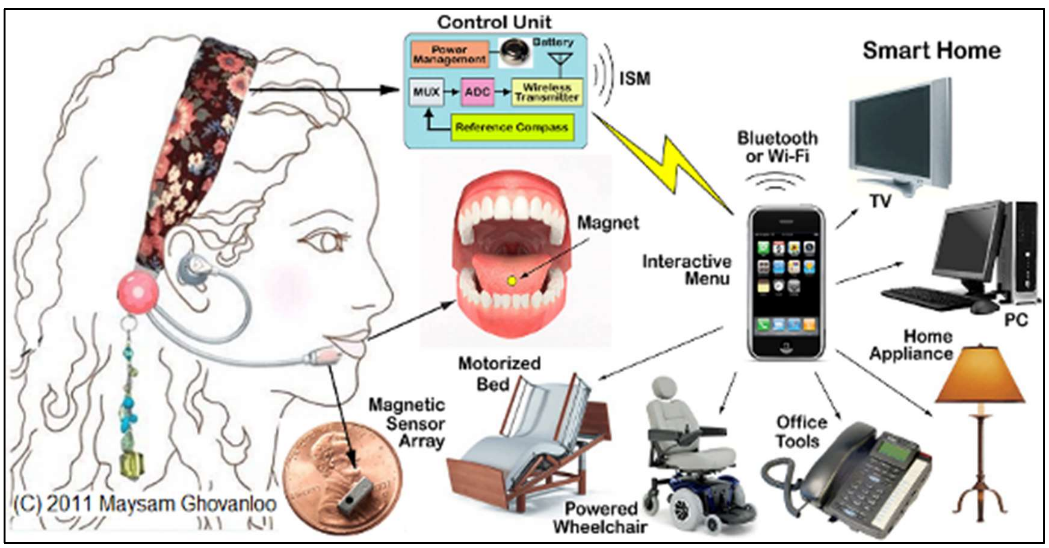
In this paper, they prepared a questionnaire to evaluate their approach method in a practical aspect of the experience for usability and comparing with the users' current ongoing assistive technologies. In the end, they responded, in a positive way by keeping the magnetic tongue-based system with a success rate of 73%. According to the people, they were able to go for more things rather than using their ongoing assistive technologies.

2.1.2 System for High- Level Spinal Cord Injury

In a paper, (*Xuoliang H., Chihwen C., Maysam G., Jun 15, 2015*), created an external device that is tongue-based. In this, they used wireless headphones, a laptop, and a commercial-powered wheelchair for accessing the experiment. This device was evaluated by eight parameters for high-level spinal cord injury. And it is an Atlanta-based project. In this project, they submitted a few commands such as navigation commands (Left, Right, Up, Down) and there were a few commands for the PWC control session (Forward, Backward, Turn Right, and Turn Left). Also, some commands were included in the directional commands for single and double mouse clicks while using a laptop/PC.

Figure 2.1

Maysam Model for Assistive Technology



2.1.3 Development of an Assistive Tongue Drive System for Disabled Individuals

From the paper, (*Kumar R., Sharma K., Assaf M., Sharma B., Naidu S.; 2019*), there are several techniques for helping people who are suffering from paralytic issues. Some of them are defined as sip-n-puff, eye-operated systems, chin control systems, think-a-move systems (ear-based technology), brain-computer interfaces, etc. Under sip-n-puff, this technology is based upon switches that are operated by blowing or sucking through a straw. In the case of the voice recognition system, it is an unacceptable technical system as it cannot be used by spinal cord injury (SCI) patients.

Figure 2.2

Alternative Assistive Technologies

As the study describes another category for helping people is a system in which it is operated by tracking eye movements which can be done by observing corneal reflections and pupil position to be very precise. Electrooculography (EOG) potential measurement, has been used to detect eye movements. There is a disadvantage of using this category of assistive technology is that it affects the users' eyesight as this technology expects an extra amount of eye movements which can affect normal activities such as reading, writing, and watching. There are much more technologies that were based on the Brain-Computer Interfaces (BCI); for example- Brain gate, and Cyber link interferences. Brain gate includes intracardial electrodes as it is an invasive sort of technology but on the contrary cyber link interferences are a non-invasive sort of technology. Here invasive technology refers to in which either cutting or inserting medical devices inside the human body system is operated. These interfaces depend upon two things, one can be called a computer algorithm and signal processing, which can create a delay in the response time of the system; also, it increases the significant cost too.

2.1.4 Sensor Based Wireless Assistive Technology for People with Severe Disabilities

This paper (*G. Krishnamurthy and M. Ghovanlo*) concerns another side of technology, there is another way of admitting to helping the people. Think-a-move inner voice is such an interface technology that is totally based on the ear capabilities. In this, a small earpiece records the change in air pressure in the ear canal; in which pressure is caused by some parameters such as tongue motion, speech, and thoughts. Conversion of these changes in the pressure to device control commands can be done by only signal processing phenomena. Chin control is another technology that is based on a switch system and it also provides a certain limit regarding the degree of freedom with respect to operation to the user. BCI (Brain computer interferences) are based upon electroencephalography (EEG) signals, which are very low in nature but unfortunately, this is limited by its bandwidth. This is expensive technology too as compared to other technologies.

2.1.5 Optimization of Tongue Gesture Processing Considering a System

This paper (Md Nazmus Sahadat, Student Member, IEEE, Nordine Sebkhi, David Anderson, Senior Member, IEEE, and Maysam Ghovanlo, Senior Member, IEEE) discusses a system in which magnetometers are used to operate certain functions. This system is based on a Vector Machine with a Linear Kernel algorithm, and it makes use of additional magnetometers to improve efficiency and accuracy. Because this algorithm produces more accurate results, it can control devices independently. They used tongue movement as their discrete input and head movement as their proportional input in this.

2.2 Control Algorithms

There were certain algorithms which were used to in the previous frame work and to assess their performance for comparison purpose.

2.2.1 K- Nearest Neighbor with 9 Distance (KNN -9D) Algorithm

Elnaz Banan Sadeghian, Xueliang Huo, and Maysam Ghovanloo, IEEE, "Command Detection and Classification in Tongue Drive Assistive Technology." The previous version of the tongue drive system used this algorithm, which divides tongue movement into a different set of commands after attenuating EMF (Earth Magnetic Field) interfaces using a projection and subtraction method. We can use this algorithm to designate specific commands, such as left commands, which are responsible for Left, UP, LS, and Resting. For Right, Down, RS, and Resting operations, right commands are curtained.

A feature vector is fed to 9 different linear and non-linear classifiers as EMF is attenuated. The majority voting method is used to determine final results.

2.2.2K- Nearest Neighbor (KNN) Algorithm

From "Optimization of Tongue gesture processing considering a system" by *Md Nazmus Sahadat, Nordine Sebkhi, David Anderson, and Maysam Ghovanlo*. Basically, KNN is a simpler version of the KNN-9 algorithm and has the potential to be implemented in the system. Likewise, the nearest neighbor classifier is used to train tongue command after attenuating the EMF interferences using the projection and subtraction technique. It includes the vector feature after attenuating interferences is fed into the algorithm to train and test the classification performance. As compared to another algorithm, KNN uses only one distance of n-number; thus, does not need any voting schema to find the assigned command.

2.2.3 Logistic Regression (LR) Algorithm

From "A Low Power Wearable Stand-Alone Tongue Drive System for People with Severe Disabilities" by *Ali Jafari, Nathanael Buswell, Maysam Ghovanloo, and Tinoosh Mohsenin, IEEE (2015)*. Under this algorithm, the classifier is used after attenuating the EMF interference using the projection and subtraction method. While one versus other all classifiers category is used to find the assigned tongue command. This algorithm was proposed in the past.

2.2.4 Support Vector Machine Linear Kernel (SVM) Algorithm

Park, Hangue, Kim, Jeonghee, and Maysam Ghovanloo wrote "Development and Preliminary Evaluation of an Intraoral Tongue Drive System" (2012). When discussing this algorithm, it is very useful to determine the effect of adding a reference magnetometer to the control unit in order to attenuate the earth's magnetic field. It only uses four magnetometer data points to detect the user's tongue command. The other two magnetometers, one on each side of the cheek, serve as a reference to capture dynamic EMF interferences.

During training and testing, it projects reference magnetometers onto other sensors and subtracts them to determine the six-dimension input feature. To find the results, the input feature vector is fed into a one Vs one classifier. Same as in the previous algorithm, the voting schema is considered in this algorithm. In this maximum vote win schema is implemented to detect the assigned tongue command from the results.

2.2.5 Support Vector Machine RBF Kernel (SVM- RBF) Algorithm

This algorithm compares the effect of changing the kernel function of a classifier to the performance. Also, it deals with an additional reference magnetometer located in the control unit of the tongue drive system headset to attenuate EMF interference. After attenuating the noise, a 12-D input feature vector is used to train and check the algorithm's performance using a support vector machine with a radial basis function (RBF) kernel.

2.2.6 SVM Linear Kernel (SVM- Linear) Algorithm

Under this algorithm, 12 features are extracted after attenuating EMF using the reference magnetometer in the control unit and this 1 feature are used to analyze, train and test the accuracy of an algorithm. LIKSVM is used to train seven tongue commands using one vs one support vector machines with linear kernel. This algorithm is implemented in the system of mTDS control units using two state machines. Using the first state machine, it transfers the data of 5 magnetometers to the computer for calibration and training purposes. The secondary state machine utilizes the calibration and testing matrices to attenuate interference and generate input features to find the results for classification.

2.3 Hardware Components

2.3.1 Selection Criterion

While selecting the hardware components, there was a wide range of varieties and while selecting among them, have considered the selection criteria. Mentioned below are the details of the components which are being used in TDS.

2.3.2 Hall Sensor – Linear KY-04

As the Hall Effect principle states, when a current-carrying conductor or semiconductor is placed under a magnetic field, then there is a change in the voltage; that voltage can be measured. In this module, a magnetic field is detected by the sensor and will be displayed in the form of an analog value. There is a potentiometer through which we can control the sensitivity of the sensor. Using the analog pin output, the user can measure and check the polarity and relative strength of the magnetic field. It consists of 4 pins, PIN 1- Digital signal; PIN2- Supply voltage; PIN3 – Ground (0 V) and PIN4- Analog Signal. And following are the parameters that define specifically identified phenomena:

Digital out: If a magnetic field is detected by the sensor, a signal will be printed here.

Analog out: Direct measurement of the sensor unit.

LED1: Represents that the sensor is supplied with voltage.

LED2: Represents that the sensor detects a magnetic field.

Figure 2.3

Hall Sensor - Linear KY-024

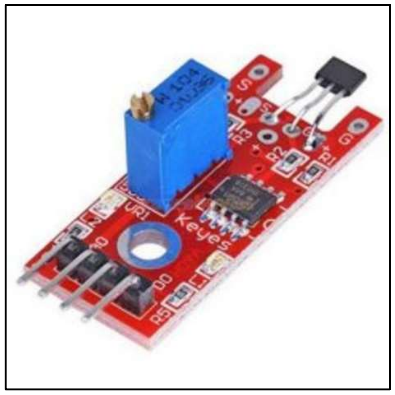


Figure 2.4

Hall Sensor KY-04 Pin Configuration

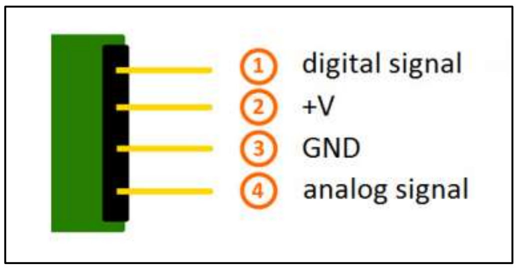
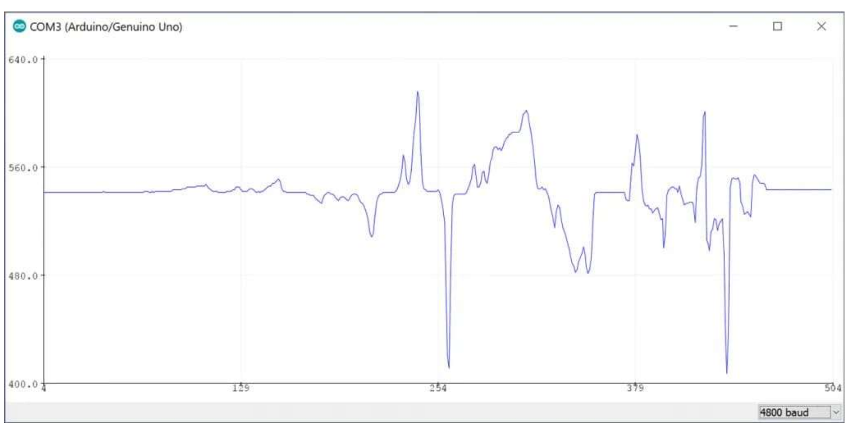


Figure 2.5

Plot Representing the Changes in Intensity and Polarity of the Magnetic Field.



From the plot represented in fig. 2.5, we can see the variations in polarity and intensity of the magnetic field. There are six hall sensors with different actions, placed at the circumference of the denture.

2.3.3 Bluetooth Module – HC- 06

The HC-06 module is a simple Bluetooth SPP (Serial Port Protocol) module that allows for making a transparent wireless serial connection. It has an enhanced data rate, with modulation of 3Mbps and with a complete 2.4 GHz radio transceiver and baseband. The module consists of six pins (KEY, VCC, GND, TX, RX, and STATE).

There are some hardware and software features, a few are mentioned below:

•Typical -80dBm sensitivity

•Operating voltage is 3.5V to 6V

•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

•Auto-connect to the last device on power as default

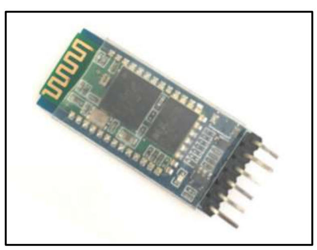
•Permit pairing device to connect as default

•Auto-pairing PIN CODE:"0000" as default

•Auto-reconnect in 30 min when disconnected as a result of beyond the range of connect

Figure 2.6

Bluetooth Module- HC-06



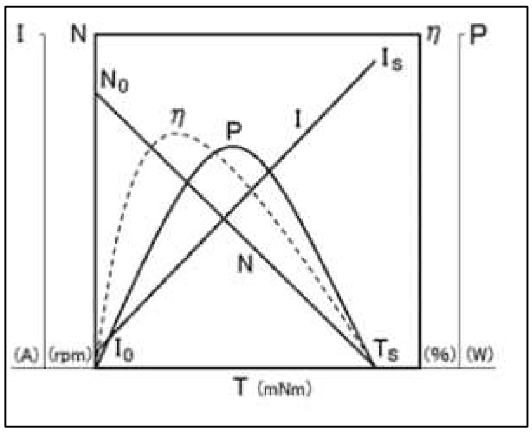
There is one Bluetooth module, used for the system connectivity to an application generated by MIT App Inventor2.

2.3.4 DC Geared Motor

DC refers to Direct Current, and DC motors are the motors that change the direct current of electrical energy to mechanical energy. There are various types of DC motors, which are available in the market; such as brushed motor, brushless motor, stepper motor, servo motor, and geared motor. There are certain factors that are important and taken into consideration while selecting the DC motor (torque, speed, and efficiency).

Figure 2.7

DC Motor: Performance Curve



From the representation in Fig.2.7*,* it can be said the three parameters are important when selecting a motor, based on the user's application.

***Speed/Revolutions (N)* –** shown as a straight line illustrating the relationship between the torque and speed of the gear motor. Depending on the voltage increase or decrease, this line will shift laterally. It is measured in rpm, revolution per minute.

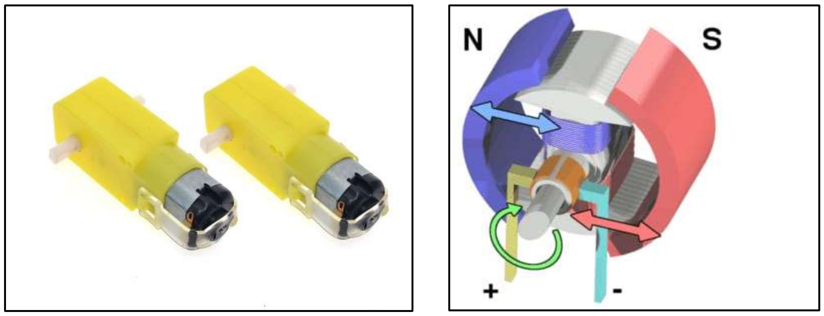
***Efficiency* (η) –**it can be calculated by the input and output variables value, represented by the dashed line in the plot. To realize the full potential of the gear motor, it should be used at or near its maximum efficiency. It is measured in percentage (%).

Torque *(T)* - The load carried by the motor shaft is depicted on the X-axis. It can be measured in N-m.

In common terms, we can say a DC geared motor is nothing but a part of a DC motor. IN DC geared motor, there is an additional gear assembly, which is attached to the motor. And the speed of the motor is measured in terms of rotations of shafts per minute (RPM). In terms of the torque-speed relationship, it helps in increasing the torque and reducing the speed. This study includes two geared motors, which are responsible for the movement of the mobile robot.

Figure 2.8

DC Geared Motor an Inside View



2.3.5 Magnet

When we talk about magnets, there is a very wide range of their different sizes and strengths. As per research, the maximum energy product, which relates to the magnetic flux output per unit volume, is used to grade neodymium magnets. That means, the higher the value, the stronger the magnet is. Though neodymium is a magnetic metal., there are two production approaches that came to light, one is Sintered magnet process or Classical Powder Metallurgy. Another method to produce a magnet is bonded magnet process or the Rapid Solidification process. In the Sintered way of production, Sintered Nd-magnets are made by melting raw materials in a furnace, casting them into a mold, and cooling them to create ingots. Pulverized alloys are processed into powder, which is subsequently fused into compact blocks. After that, the blocks are heat-treated, given desired shape, surface-treated, and magnetized. On the contrary, the Rapid Solidification magnet producing approach can be explained as, a melt spinning a narrow band of the NdFeB alloy forming bonded Nd-magnets. The ribbon is made up of $Nd2Fe14B$ nano-scale grains that are randomly positioned. This ribbon is then crushed into particles, combined with a polymer, and molded into bonded magnets via compression or injection molding.

In a project, there is one 8*2 mm neodymium magnet to control the mobile bot by movement. A large magnet with high strength is not considered because it may affect the other components by magnetic field effect and increases the chance of an error, while the tongue movement.

Figure 2.9

*Neodymium Magnet Size 8*2mm*

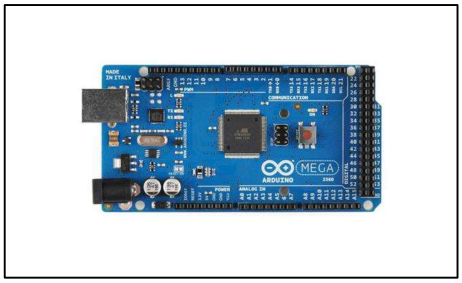
2.3.6 Microcontroller

2.3.6.1 Arduino Mega 2560- Arduino Mega 2560 is a microcontroller based on the ATmega2560 microprocessor. It includes 54 digital I/O pins, out of which 15 can be used for PWM outputs; has 16 analog inputs, 4 UARTS, 16 MHz crystal oscillator, an ICSB header, and a power jack, USB connection, and a reset button. It is operated at 5V and ATmega2560 offers 4kb (4096 bytes) of EEPROM, a memory that is not erased when powered off. We can say that it is similar to Arduino UNO but the only difference is the number of input and outputs. When data is transmitted via the ATmega8U2/ATmega16U2 chip and USB connection to the computer, the RX and TX LEDs on the board will flash (but not for serial communication on pins 0 and 1). Serial communication on any of the Mega2560's digital pins is possible with a Software Serial library.

And there is one Arduino Mega, which is placed in the transmitter circuit. All the hall sensors are connected to this microcontroller including an RF transmitter and Bluetooth Hc-06 module.

Figure 2.10

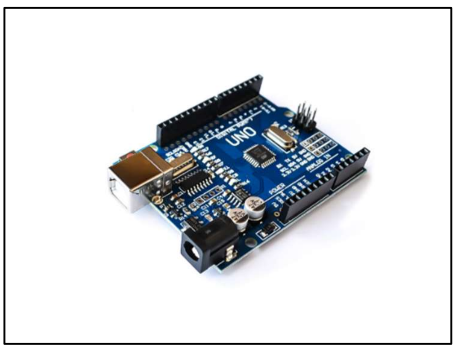
Microcontroller: Arduino-Mega2560



2.3.6.1 Arduino UNO: Arduino UNO is an open-source microcontroller that is widely available across the globe. It has an ATmega328P chip as a microcontroller. It has 14 digital input-output (I/O) pins out of which 6 can provide PWM output (pin no.- 3,5,6,9,10 and 11); 6 analog input pins; 1 UART, i2c, SPI pins each. It is operated at 5V and with a flash memory of 32KB, EEPROM - 1KB. It has a clock speed of 16 MHz. It can be used for various applications, especially for prototyping purposes. Via Arduino-IDE software, the board can be programmed as per the user's requirements. There are two Arduino UNO, which is used in the receiver circuit.

Figure 2.11

Microcontroller: Arduino UNO

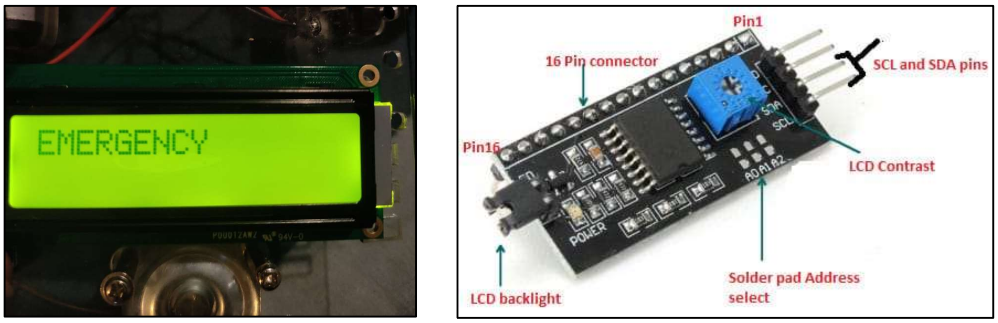


2.3.7 I2C LCD Screen:

LCD stands for Liquid Crystal Display, used to define and display following certain information. The one which is considered is a 16*2 alphanumeric LCD which contains 16 columns and 2 rows. It has a 16-pin configuration. I2C makes it easier to use, by using the I2C LCD module reduces from 16 pins configuration to 2 pins i.e., only 2 pins will be occupied in the board (use i2c interface - SCL and SDA pins). It is compatible with multiple communication logic levels, also it is an Arduino library supported module, which reduces the difficulty. It supports 64-level screen contrast adjustment. Moreover, it can integrate 7 sizes of ASCII font and 5 graphic functions. In total there are 4 pins (VCC, GND, SCL and SDA) which are coming from the LCD and connecting to the Arduino board.

Figure 2.12

*(a) Alphanumeric 16*2 i2C LCD and (b) I2C Pin Configuration*



(a) (b)

There is only one module of i2c LCD, which is used in the study. With the help of LCD, some emergency notifications will be displayed.

2.3.8 Denture and Toy Tongue

A denture is a prototype used by the dentist and medical industry to illustrate the cavities and other issues that may cause inside the mouth. Toy tongue is usually used by the professors to explain the tongue movement details in medical institutions (dentistry) and is also used by the magicians to play a trick. For this study, the denture is used to illustrate the position of the Hall sensor and with the help of a toy tongue, a magnet on its tip is placed to define the theme of the project. At the periphery of the denture, six hall sensors are placed in an omnidirectional manner. The sensor’s angular position is decided as per the user's comfort, where there is an ease of tongue movement.

Figure 2.13

Denture with a Toy Tongue

2.3.9 Breadboard and Jumper Wires

A breadboard is a baseboard on which we can connect multiple connections, and can share the VCC and ground from it. It is used for the construction of prototyping electronics. It didn't require any soldering and is reusable. Jumper wires are used to give the connection from one module to another.

Figure 2.14

Breadboard and Jumper Wires

2.3.10 Speaker

Speaker is a device that converts an electrical audio signal into an audible sound. Depending on the design goals, the size and kind of magnet, as well as the characteristics of the magnetic circuit, change. Sensitivity is usually expressed as a number of decibels measured at 1 meter (unless for headphones) at a single frequency. Typically, 2.83 VRMS is utilized, which is 1 watt into an 8Ω (nominal) speaker impedance (approximately true for many speaker systems). Measurements taken with this reference are given in decibels (dB) at 2.83 volts per meter. This project includes a speaker with a nominal impedance of 8Ω and is attached to Arduino Uno and DF mini play to play audio as part of command actions that are set by the user.

Figure 2.15

Speaker; for Recreational Feature

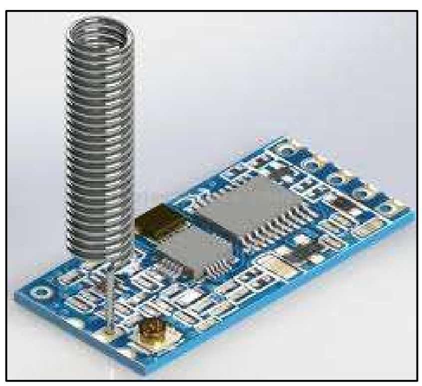
2.3.11 HC 12 Transceiver Module

Basically, RF stands for radio frequency, and RF transmitter/receiver is a module that transmits or receives (depending upon the module type) the signals from one device to another. Both the modules are used for communication. The transmitter module will transmit the signal from one end to the receiver’s end. And on the other hand, the receiver module will receive the signal, also only simple communication is possible. That means, the transmitter can only transmit and the receiver will only receive the signal. In easy words, we can term it one-way communication. The performance of an RF module, like that of any other RF device, is determined by a variety of parameters. A longer communication distance can be accomplished, for example, by increasing the transmitter power.

But there is a transceiver module which can perform both functions, transmitter as well as receiver. Modules that are used in the project, have a radio frequency band of 433MHz. HC-12 is such a module which can perform the function and has certain feature: it is a long-distance wireless transmission (1000 in open baud rate, 5000 bps in an open air); works on a frequency range of 433.4-473.0MHz, up to 100 communication channels; it has three working modes, concerning to the different application situations, has built –in MCU; number of bytes transmission can be unlimited to one time and performing communication with external device can be through serial port. It is 11 pin modules, out of which PIN 1-6 have two bonding bases respectively as per the outer half is used for welding purpose. On pin, a spring antenna can be welded. One pine defines the TXD pin used to send the command signal and other pin defines RXD pin which is used to receive the command signal. HC-12 module has three serial port (transmission modes) and can be represented with FU1, FU2 and FU3 respectively. Using all three modes; they are responsible for receiving and sensing serial port data rather than wireless transmission.

Figure 2.16

HC-12 Transceiver Module



Considering from the project point of view, there are two receivers and one transmitter which are used in the overall circuit.

Table 2.1

Pin Connection - HC-12 Transceiver

Module Pin No.	Pin Function
VCC	Input Power Supply (3.2V – 5.5V DC)
GND	Common Ground
RXD	UART Serial I/P – Receiving Signal
TXD	UART Serial O/P – Transmitting Signal
SET	Parameter Setting Control Pin
ANT	433 MHz Antenna Pin
GND	Common Ground
GND	Common Ground
ANT1	Antenna Socket (IPEX 20279-001E-03)
ANT2	433 MHz Spring Solder eye

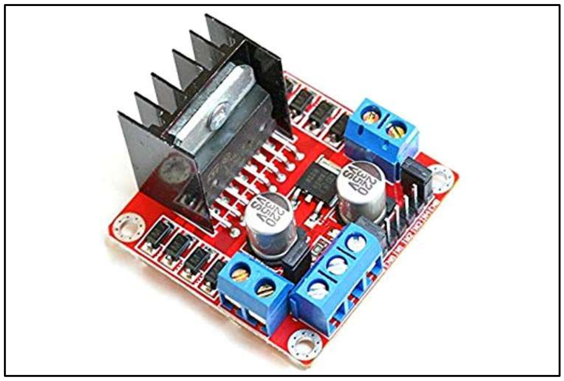
2.3.12 L298N Motor Driver

The L298N is a 15-lead multi-watt and PowerSO20 design with an integrated single unified circuit. It's a high-voltage, high-current dual full-bridge driver that can drive inductive loads including relays, solenoids, DC motors, and stepping motors. The device may be enabled or disabled using two enable inputs that are independent of the input signals. Each bridge's subordinate transistors' emitters are coupled together, and an external sensing resistor can be connected to the matching external terminal. To allow the logic to operate at a lower voltage, an extra Supply input is supplied. This module consists of an L298N motor driver integrated circuit (IC) and a 78M05 5V regulator. It is a high-power motor driver module for driving DC and Stepper motors. It can be used to control up to 4 DC motors or 2 DC motors with directional and speed control.

In this module, there are four input pins and four output pins; adding one pin for Enable A, one pin for Enable B, one pin for supply voltage, 2 pins for current sensing 1&2, 1 pin for logic supply voltage, and one ground pin. Since the module uses the dual h-bridge technology, therefore both the motors can run simultaneously.

Figure 2.17

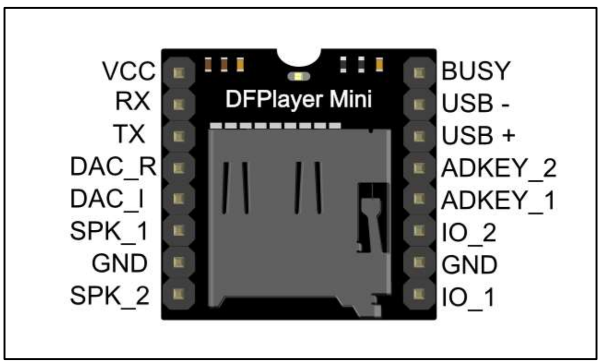
L298N Motor Driver



2.3.13 DF mini-Player

Figure 2.18

DF Mini Player Pin Diagram



The DF-Player Mini MP3 player for Arduino is a compact, low-cost MP3 player with a simple output that goes straight to the speaker. The module may be used as a stand-alone module with a built-in battery, speaker, and push buttons, or it can be used in conjunction with an Arduino UNO or other RX/TX capable device.

It uses a micro-SD card to store the memory and play the casted audio. As per the protocols of DF mini-Player, the file stored which needs to be played on activation should be in .mp3 format. Number of songs, audio books can be stored and can be played on the player accordingly.

Table 2.2

DF Mini Player Pin Configuration Parameters

Pin	Description	Note
VCC	Input Voltage	DC 3.2-5.0V; Type: DC 4.2V
RX	UART Serial Input	Receiving Signal
TX	UART Serial Output	Transmitting Signal
DAC_R	Audio Output Right Channel	Drive earphone and amplifier
DAC_L	Audio Output Left Channel	Drive earphone and amplifier
SPK2	Speaker -	Drive Speaker less than 3W
GND	Ground	Power Ground
SPK1	Speaker+	Drive Speaker less than 3W
IO1	Trigger Port 1	Short Press to Play Next (long press to decrease volume)
GND	Ground	Power Ground
IO2	Trigger Port 2	Short Press to Play Next (long press to increase volume)
ADKEY1	AD Port 1	Trigger Play with First Segment
ADKEY2	AD Port 2	Trigger Play with Fifth Segment
USB+	USB+ DP	USB Port
USB-	USB- DM	USB Port
BUSY	Playing States	Low Means Playing \ High means no

2.3.14 Buzzer

Figure 2.19

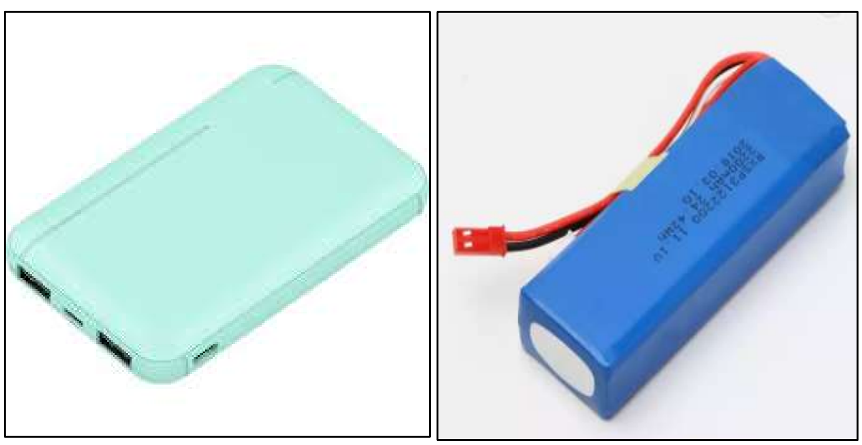
Buzzer, Used for LCD Notification

A buzzer, often known as a beeper, is a mechanical, electromechanical, or piezoelectric audio signaling device (piezo for short). Alarm clocks, timers, trains, and confirmation of human input such as a mouse click or keyboard are all common uses for buzzers and beepers. Piezoelectric buzzers are often referred to as piezo buzzers. There is one such piezo buzzer used in the circuit in order to make a sound to alert the caretaker of a paralytic person.

2.3.15 Power Bank and LiPo Batteries

Figure 2.20

Power Bank and LiPo Battery, Source for Power Supply



It is a gadget that uses an electric current to store energy in a battery. The charging methodology is determined by the size and kind of battery being charged. Some battery types have a high tolerance for overcharging (continued charging after the battery has been completely charged) and, depending on the battery type, can be recharged by connecting to a constant voltage or constant current source. Power banks are nowadays very common to use for charging the mobile phone, as nowadays mobile batteries drain really fast. It produces 5V as an output. A lithium polymer battery is a rechargeable battery that uses a lithium-ion technology and a polymer electrolyte. It can be specifically known as lithium – ion polymer battery. These power banks are also being utilized in small-scale project prototypes as power backups. LiPo battery is used as supply source for the motor driver (+12VDC) and Arduino (+5VDC).

2.4 Software Used

For this study, the following software was used to fulfill the requirements and to obtain desired output

2.4.1 Solid Works

Initially, before implementation and starting the circuitry section, any prototype needs a proper design, through which we can have an idea about the project. As nowadays there are too many software and tools which are available in the market for designing purposes, computer aided design and for design modeling purposes.

Figure 2.21

Software: SolidWorks

Solid Works is one of the software tools which is used for the solid modeling computer aided design (CAD). This software is written on the Para solid kernel. Building a design model in solid works initiates with the 2-dimensional, and later it can be drawn to 3-dimensional ways as well. It is a very easy and user-friendly software tool for designing purposes. There are too many features which makes the work easy, such as "*Smart*

Dimension" it works as per the design changes and gives the measured dimension of the product geometry.

2.4.2 Fritzing

In terms of designing, there is a wide range of tools available in the market, which are used to design the electrical components and circuits accordingly. Fritizing is an open-source software, used to design the hardware components for the prototype building. This software is developed suited to processing programming language and Arduino microcontroller. There are few features which makes it more useful for the prototype models such as it provides an Arduino suited hardware components library into it, and also making the schematic diagrams for the circuits is very easy.

Figure2.22

Software: Fritzing

2.4.3 Arduino IDE

For making the prototype work as per the demand, the microcontroller board is supposed to be controlled and programmed accordingly. Arduino IDE is an open-source software which makes writing a code and uploading it to the board in a simple and easy way. Any Arduino board may be used with this software. It also serves as editor and compiler to the serial board.

Figure 2.23

Software – Arduino IDE

2.4.4 MIT App Inventor 2

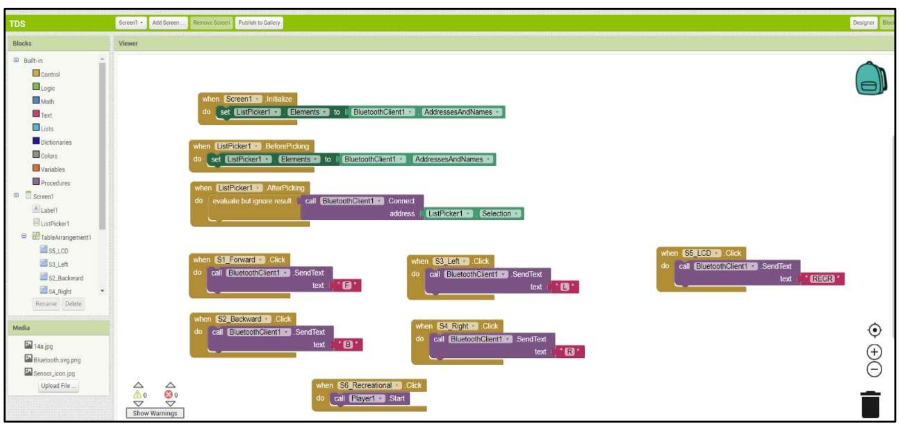
There are a wide range of tools and app generators which are available in the market, one of them is MIT Inventor App 2. MIT App Inventor 2 is an open-source platform for designing applications as per your convenience. In MIT App Inventor 2, there is one screen which includes various information and features regarding the connectivity and controls. In MIT inventor, there are various tools through which users can generate the desired feature application, which can make the requirements matched. It is divided into two sections: Designer and Blocks, referred to fig.2.25. Under the Designer part, components which are being utilized are visible in the components slot, with media used and properties respectively. Different kinds of app can be generated using this too.

Figure 2.24

Software: MIT App Inventor2

Figure 2.25

Block design – MIT App Inventor 2



There are various features which were taken into consideration while designing the application, some of them are discussed as below:

2.4.4.1 Screen: It is a home screen and only screen which is available in using application, multiple screens can be added depending upon the users' requirements. There are various properties which can be updated and changed by making the necessary changes in the tool side section. There is a feature to add multiple screens and palettes which includes various collections of tools with respect to each domain respectively. Some of them are user interface, layout, media, drawing & animation, sensors, connectivity, storage, etc. So, concluding it as a screen is a parameter of MIT App inventor which is an overview of tools in designing an application.

2.4.4.2 Label: This parameter is used to put the name to the respective tag- title which is desired for the user application.

2.4.4.3 List Picker: By using this feature, it provides the list of tags (devices) with respect to the control unit and connectivity unit. Here, in this study it is being used to display – show all the available devices from the Bluetooth connectivity point of view.

2.4.4.4 Table Arrangement: Through this tool from the user interface pallet, users can arrange the screen with the divisions with respect to columns and rows. In other words, this feature helps the user to decide the layout of their application.

2.4.4.5 Buttons: Button is a command feature through which users can control and view their user product by clicking on the desired buttons. There are seven buttons used in the TDS mobile application (show Bluetooth devices, four directional two special purpose command buttons).

2.4.4.6 Bluetooth Client: Through this feature from the connectivity pallet, users can connect their device to other devices using Bluetooth. This component uses the serial port profile (SPP) for communication.

2.4.4.7 Player: It comes under a media pallet that plays audio and controls phone vibration. This component is relevant and best for sound files such as songs, while the sound component is more efficient for short files such as sound effects. Through the property section, volume and other controlling parameters can be changed accordingly.
Finally, after the app is decided with all parameters and inputs, it can be downloaded in .apk format or. abb format. Applications can be downloaded on the mobile phone and computer respectively.

2.5 Bio Compatibility for the System Module:

There are certain studies which explains about the tongue implantation for assistive technology. From the study by Mimche, S., Ahn, D., Kiani, M., Elahi, H., Murray, K., Easley, K., Sokoloff, A., & Ghovanloo, M. (2016), "*Tongue implant for AT: Test migration, tissue reactivity and impact on the tongue function*" TDS application, however, is restricted with the aid of using restricted facts on organic outcomes and protection of tool implantation onto the tongue module body. Despite of having certain advantages and features which are unique to the tongue biology, it might give a negative impact on the safety and reactivity of implantation of device on the anterior tongue system. Complex changes in tongue tension-tension pattern during oral motor behaviors as well as tonic and energetic activation of tongue muscles during maintenance behaviors (breathing, swallowing) can influence the formation of a capsule of sequestering implant. Tongue muscles are densely capillarized, and the presence of large ventral lingual arteries and branches increases the risk of embolization if a tiny device is not properly incorporated into the surrounding tissue.

We implant migration, tongue lick function, tongue lick function, and tongue histology to assess the safety and reactivity of implantation of a tiny, unanchored device in the anterior tongue. Water intake (weight change of water in bottle in grams) was measured on most days but was occasionally exposed as an average of 2-4 days of consumption. Actual or average daily water intake was linked to lick behavior measurements taken during the consuming period. The placement of a spherical magnet implant on the front tongue had no effect on the animal's weight, water consumption, or lick habit. The presence of implant encapsulation and the absence of implant migration indicate that the implant was quickly integrated into tongue tissue, reducing the danger of embolization into the vast ventral lingual arteries. The factors discussed characterize the safety and biocompatibility of human anterior tongue implantation of tiny biomedical devices.

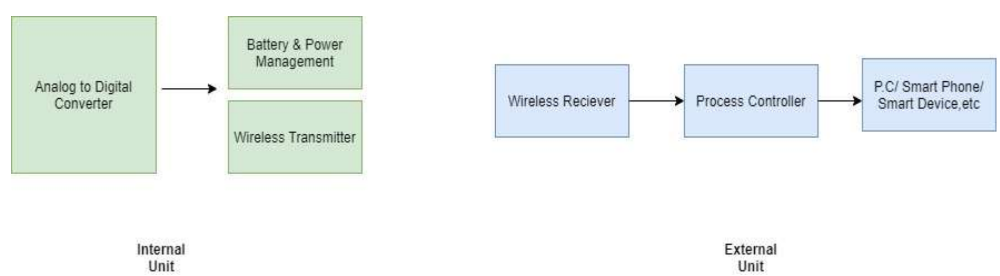
CHAPTER 3
METHODOLOGY

3.1 Brief Overview

As we know that tongue possesses an extensive zone of the motor cortex in people and accordingly, is naturally equipped for complex control assignments. The tongue is innervated through the hypoglossal cranial nerve, which for the most part gets away from harm even in serious spinal cord injuries. One similarity about heart and tongue is they have muscles. Tongue is very simply moved inside the mouth.

Figure 3.1

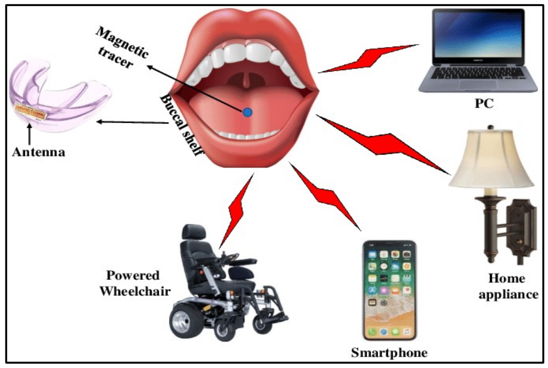
Brief Block Structure of Model



As we know tongue drive system is an assistive technology, consist of small magnet size which will be attached to the tongue with the help of adhesive tissues and gum. Magnetic relay will be used to sense the tongue movement to perform various operation. It is sort of sensor which will be used for transmitting the tongue movement signal (magnetic sensor data) from the receiver side with the help of wireless connection between transmitter and receiver. (Here receiver could be anything like computer, laptop or smartphone.) And using this data we can command to perform various operations.

Figure 3.2

TDS Overview



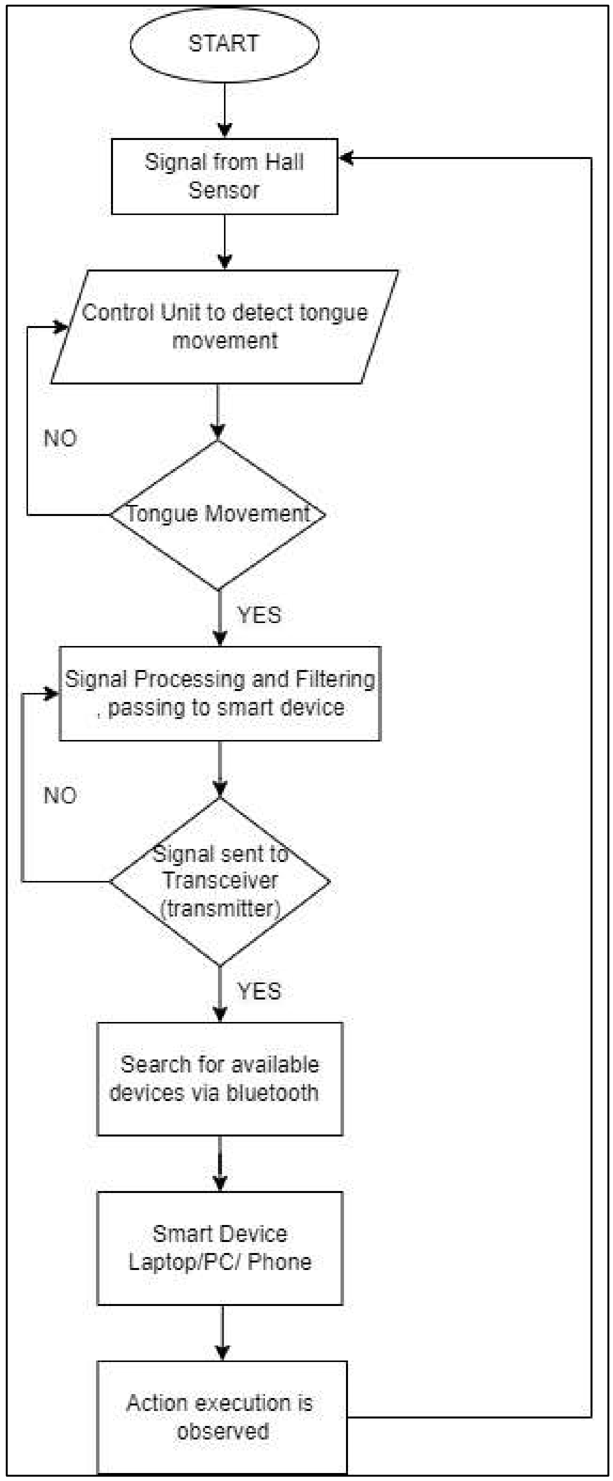
3.1.1 Overall Working Flow-chart Diagram

Every system works in a sequence and in a certain way. In this study, referring to fig.3.3, there is a system dealing with hall sensors and a toy tongue with a magnet at its end. When system is powered ON, control unit detects whether there is any tongue movement or not. If there is a tongue movement, then on the basis of direction, hall sensor comes in active state, and signals are being filtered and sent to transmitter in order to transmit the signals at the receiver end. Then the transmitter sends the signal to receiver, to execute the require action. Foe the mobile and computer application, it sends a signal to search for the available devices, if gets connected to a device then the action execution is observed otherwise, it keeps on searching till the time it gets connected.

This flowchart is described as an input – output functionality chart. There are two charts, one describes about the sensor mode (when bot is controlled via hall sensors) and another chart explains about the Bluetooth functionality mode, in which robot is controlled through an application.

Figure 3.3

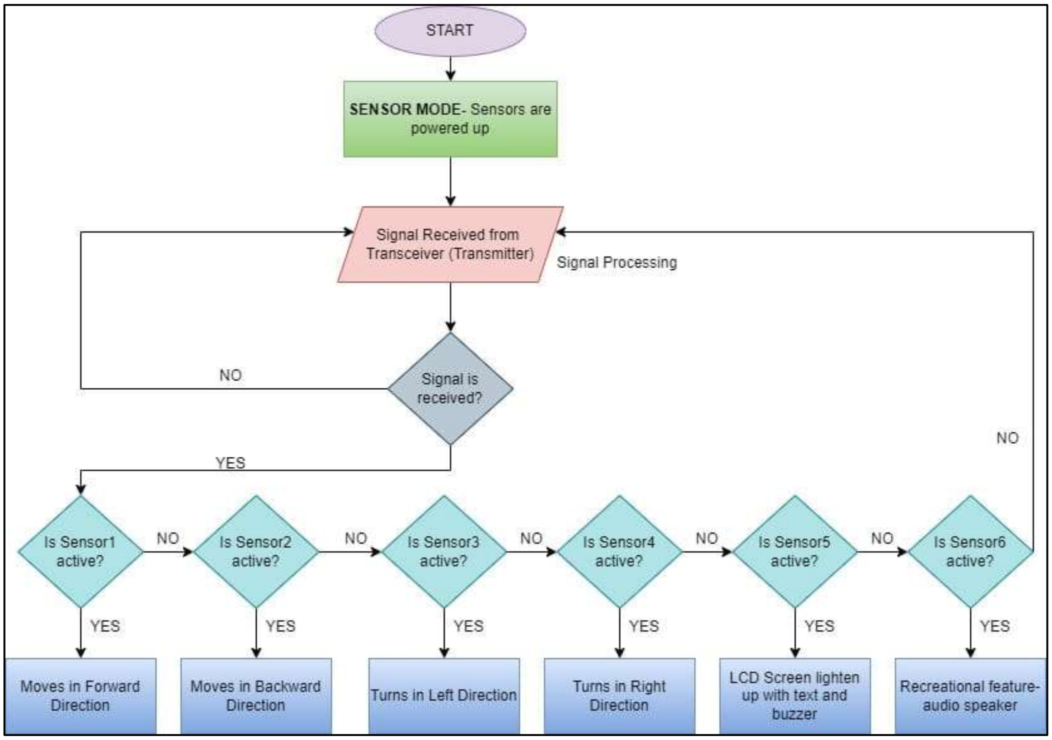
Overall Working Flowchart



3.1.2 Working Flowchart – Sensor Mode

Figure 3.4

Sensor Mode - Working Flowchart



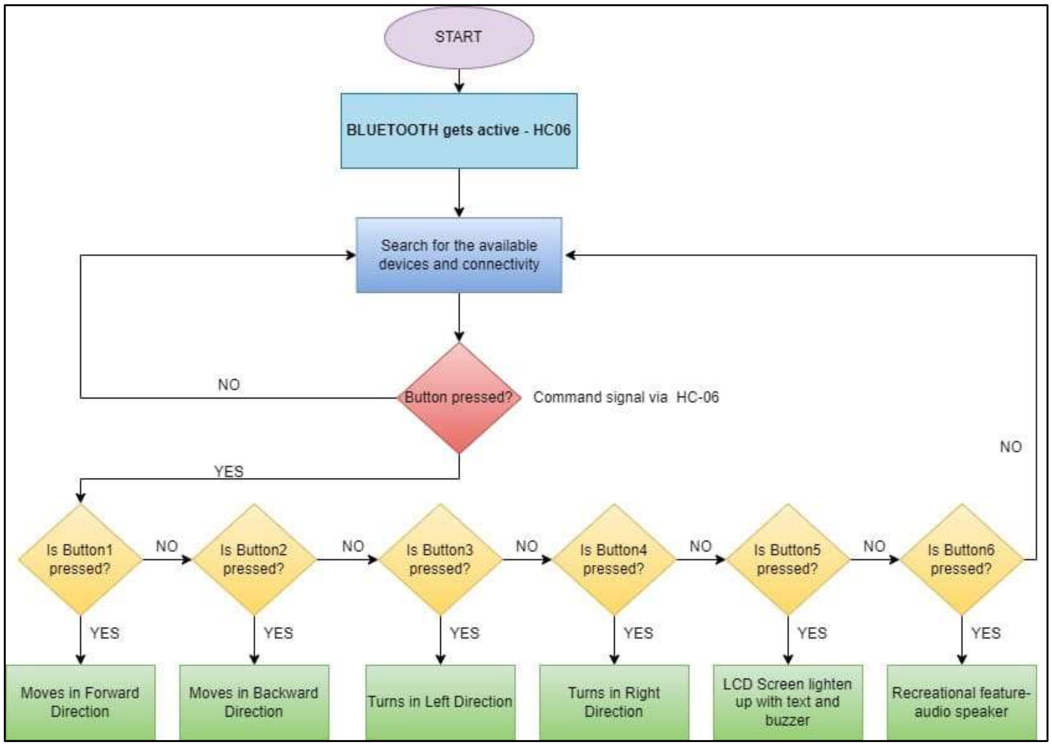
Referring to *fig.3.4*, it defines the input-output functionality in a sequential and well-defined way. On the basis of tongue movement, hall sensors send the signals through RF transmitter to the receiver end of mobile robot. When the signals are received and RF receiver module's DATA state is HIGH, it makes the relevant action pin for which hall sensor is high.

When data is received from the transmitter end, it checks which sensor is active, if sensor1 is active, then robot moves forward, if not then it move to check the sensor2. If sensor2 is active, then robot moves backward, if not then it moves further to check sensor3. If sensor 3 is active, then robot turns right, if not then it moves to check the sensor4. If sensor4 is active, then robot turns left, if not then it moves to check the sensor5. If sensor5 is active, then LCD with buzzer is ON to display a text EMERGENCY, if not then moves towards the sensor6. If sensor 6 is active, then using DF mini player, an audio is played as a part of recreational feature, if not then again as loop it goes back to receive the signal from the transmitter.

3.1.3 Working Flowchart: Bluetooth mode

Figure 3.5

Bluetooth Mode - Working Flowchart



Referring to *fig 3.5,* it clearly explains about the input output functionality based on Bluetooth connectivity or we can say Bluetooth mode. In this chat, HC-06 Bluetooth module is used as the communication medium between the robot and mobile app. Bluetooth module is placed in the transmitter circuit, from where it sends the signals on pressing the buttons of mobile app. So, when the module is active, then it searches for the available Bluetooth devices which can be connected.

After checking the availability and connectivity, when it gets connected to particular Mobile / computer app device, there are six buttons responsible for the action features of robot. If button1 is pressed, then robot moves forward, if not then it move to check the button2. If button2 is pressed, then robot moves backward, if not then it moves further to check button3. If button 3 is pressed, then robot turns right, if not then it moves to check the button4. If button4 is pressed, then robot turns left, if not then it moves to check the button5. If button5 is pressed, then LCD with buzzer is ON to display a text EMERGENCY, if not then moves towards the button6. If button 6 is pressed, then using DF mini player, an audio is played as a part of recreational feature, if not then again as loop it goes back to search the available devices and check the connectivity of module and the device.

3.2 Working

3.2.1 Commands for Operation

In this study, there are six commands out of which, four are the normal directional initiative commands and the remaining two commands are used to perform special purpose operation as commanded by the user.

Command 1: used to move in forward direction

Command 2: used to move in backward direction.

Command 3: used to turn right.

Command 4: used to turn right.

Command 5: used to display an emergency notification on the LCD display.

Command 6: used to perform recreational feature, plays a music/audiobook, etc.

But all these commands are based on the movement of the tongue too.

Basically, in TDS tongue motion can be observed using hall sensors, which will be used to identify the magnetic field that is generated by the small magnets which we will used (placed inside the mouth). There will be two units in this system, one unit will be placed inside the mouth and the other unit will be placed outside the mouth for the connectivity. Hall sensors (magnetic read relay) will be placed outside the teeth in order to measure generated magnetic field to view an output. When the signals will receive by an external unit, these signals will be demodulated to get an exact output response. Small batteries will be used to power the inside unit of the mouth.

Figure 3.6

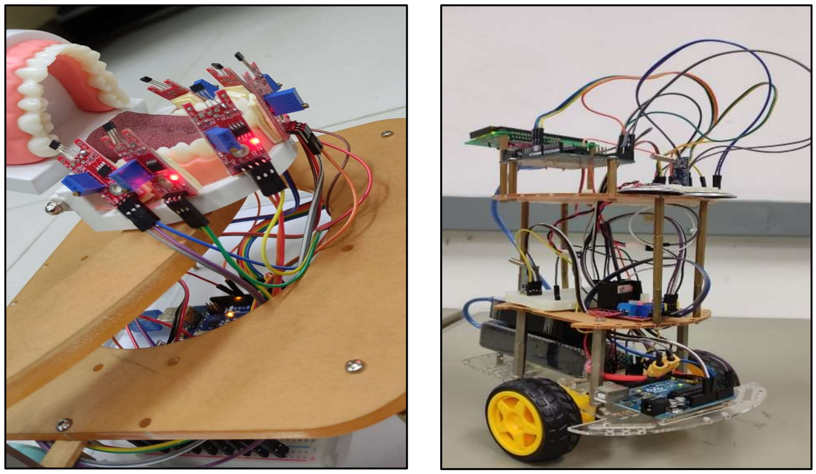
TDS Working Method

Processing an output response can be observed by the actual action inside the mouth (as per the movement of tongue, command will be processed and come in action according to it) by assigning the same command to the action as scheduled by the user in the software. And these commands are responsible for the action of the system. As these commands are used operate various function/actions which may include wheelchair, mobile robot, computer functions, bed movements and etc.

Furthermore, tongue is chosen to make this system because tongue is very simple to move inside the mouth. It is consisting of sensory and motor cortex that ae connected to brain, and on the other side brain also has cranial nerves which has a potential of removing any injury of spinal cord. Tongue provides a privacy kind of thing as it is inside the mouth; therefore, there is no possibility for any kind of disorder. There is a fact that tongue do not move as per the body movement but it moves as per the user comfort.

Figure 3.7

TDS Working Model



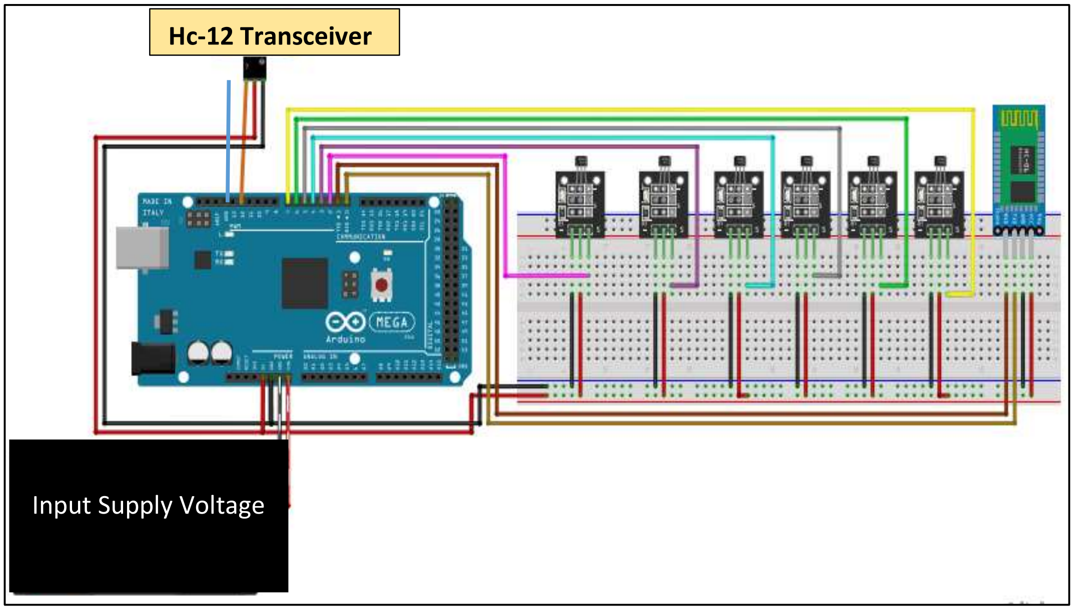
In other words, we can say that magnetic hall sensor is mounted upon the braces (dental retainer) and attached on to the outside of the teeth to measure the magnetic field from different angles and provide real continuous analog output. Later on, these signals will be received by the external unit which are demodulated or de-multiplexed to get certain output. Based on this output, tongue motion inside the mouth can be observed. By designating each function with respect to the tongue movement inside the mouth.

And using software such commands can be done and later on these commands can be customized as per the users' comfort. These commands will be used to operate a variety of devices (such devices may be smartphone, computer, mobile robot and powered wheelchair). Basically, we can say this technology makes by tracking the movement of permanent magnet, served on the tongue and a set of hall sensor. Overall circuit implementation is represented in fig3.7.

3.2.2 Working: Transmitter Circuit

Figure 3.8

Circuit Diagram for Transmitter



In the transmitter circuit, it consists of a denture inside which a toy tongue is present with a magnet at the end on top of it. There are six hall sensors that are placed in an omnidirectional pattern. All the sensors are placed at an equal distance from the user for comfort and to avoid any errors. Each sensor has a separate and different actuation. Whenever a magnet is touched or nearby, a dedicated action is executed with respect to that sensor. And for sending the sensor signals from the transmitter circuit to the receiving circuit (a mobile robot), they are transmitted by the RF transceiver, which is connected to the transmitter circuit, which works at the frequency of 433MHz. And by using Bluetooth module HC-06, a mobile robot is controlled using an application based on Bluetooth connectivity.

So, wherever the tongue with a magnet is moving, based on the intensity/strength of the magnetic field, each sensor will perform its action.

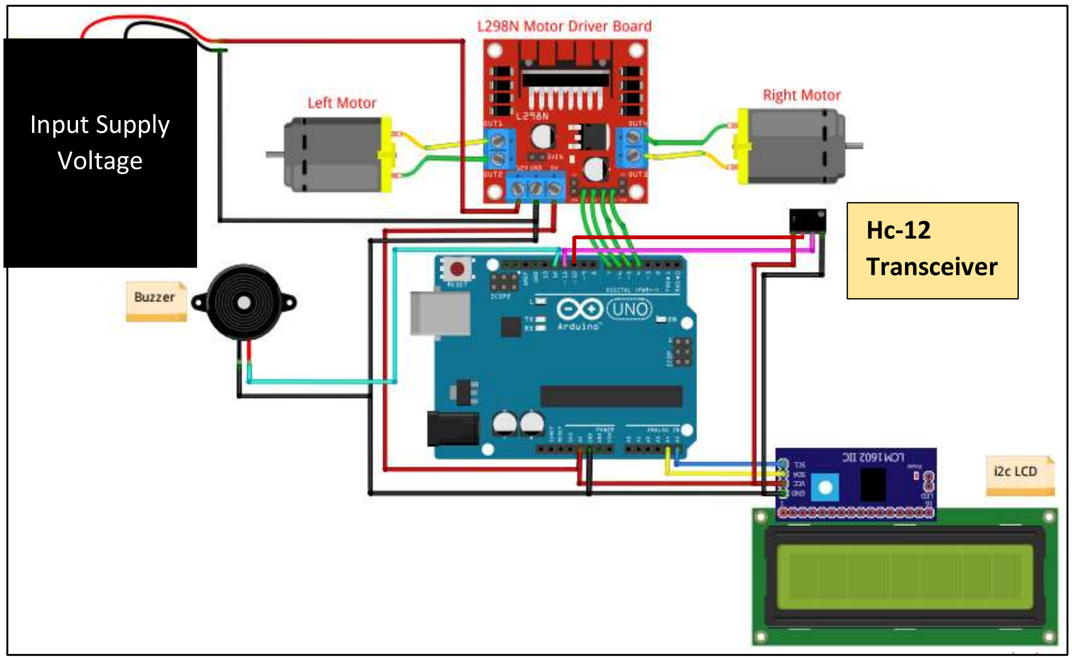
After connecting all the connections as per the circuit diagram, fig 3.8; on actuation of each sensor (by putting magnet near to sensor) an output is generated. Using serial monitor it can be clearly seen, what and when signal is being sent from one transceiver end to another receiver end. When any of the sensor is active, the bot is in stationary position. While using application, same functions can be controlled. Application is based on

Bluetooth based technology. Using device Bluetooth should be connected to the HC-06 Bluetooth module. Once it is connected via application controlling robot can be controlled. Application comprises of 8 buttons which are forward, backward, left, right, LCD, Recreational, stop and show device button.

3.2.3 Working: Receiver Circuit

Figure 3.9

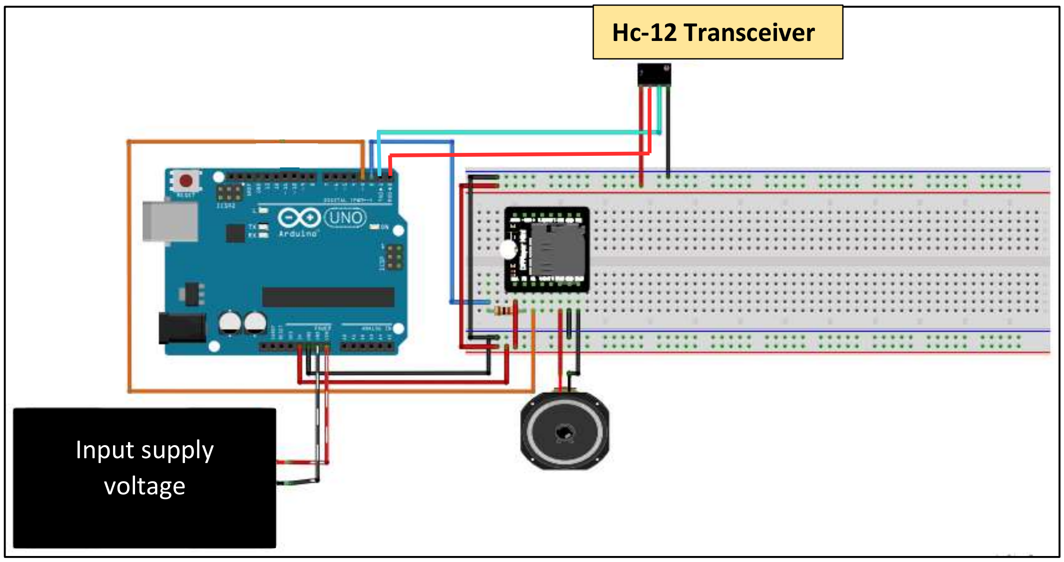
Circuit Diagram for Receiver for the Robot



In order to avoid lagging or any errors because of the RF receiver module, the whole receiver circuit is divided into two parts; one describes the bot's working phenomena and the other one is for the DF mini player. In the receiver end circuit for mobile robots (*fig.3.9*), while considering the sensor mode, there are various components which work on the sensor's signals being transmitted by the transmitter end. When sensor1 is active, the robot moves in a forward direction; when sensor2 is active, the robot moves in a backward direction; when sensor3 is in an active state, the robot turns in the right direction; when sensor4 is in an active state, the robot turns in the left direction; when sensor5 gets active, an LCD gets ON with a text display saying "EMERGENCY". A buzzer will be active as well for the same span of time as the LCD. Furthermore, referring to fig. 3.10, receiver end circuit for the DF mini player, at the time when the sensor6 gets active, a recreational feature is actuated, i.e., it plays an audio file using the DF mini player module as an entertainment purpose for the user. In this case, the RF receiver receives the signal and makes the pin HIGH for the mini player to perform its function.

Figure 3.10

Receiver End Circuit for the Mini Player



While mobile and computer application mode is active, it works on Bluetooth connectivity. An app is generated using MIT Inventor App 2, in which there are 6 buttons which are used to control the robot with the same 6 control command functions. Likewise, there is the same app for the computer, which is used to control the robot with the same functions.

3.2.4 Mobile and Computer Application

Now, coming to another section of the MIT Inventor App 2 that is Blocks designing section(*fig2.25*); it is a back-end controlling and coding section, this coding is block based in which blocks can be dragged and dropped with respect to the element component used in the designing the application. There are built blocks which includes control, logic, math, text, variables, procedure, etc. and there are blocks related to the components which are used in the designing section (player, Bluetooth client, table arrangements, etc.).

To initiate, project is created within the MIT application portal. There are few properties for the application, selecting the required components and the screen size (Monitor, tablet, phone) for the application. Select the text alignment as either Horizontal or vertical alignment (H: Center 3 and V: Center 2). Insert the name of the application in the property section, and also put the background image in order to look better. Select the title, theme, screen orientation. In screen1 component, insert label and list picker tag from the user interface column. Put the designated text in the label tag (Text: Available Devices) and select the properties with its accordance (Font Size, Text Color, Font Type, text alignment, height and width of the label). Under Screen1, there is another more tab i.e., list picker. Insert the list picker feature from the user interface column. Similarly, insert the respective text to it and select the properties with regards to the list picker tag.

Moving Further, while designing a layout of an app, there are some parameters such as rows and columns are considered as dependent upon the user requirement. Using table arrangement feature tab, from user interface column, this parameter consideration can be done, just by putting no. of rows (4) and no. of columns (3) in the properties section of table arrangement. In these rows and columns, buttons are placed; referring to dedicated function.

Button names and specifications are as follow:

BUTTON 1: S1 FORWARD: Bot moves in forward direction

BUTTON 2: S2 BACKWARD: Bot moves in backward direction

BUTTON 3: S3 LEFT: Bot turns in left direction

BUTTON 4: S4 RIGHT: Bot turns in right direction

BUTTON 5: S5 EMERGENCY: LCD turns ON with buzzer, displays text EMERGENCY

BUTTON 6: S6 RECREATIONAL: Plays an audio and music.

6 buttons are as same as the sensor control mode. In addition to, two buttons are included. 'Show device' button helps the user to connect the device's Bluetooth to TDS system Bluetooth module. It helps to display the available Bluetooth device, which are available within the range. And 'Stop Button', is specifically included in order to control the bot by the care taker person; safety purpose. It helps to hault the running operation and is included in the application only so that care taker user can control the wheel chair functions as per the requirement.

Then similarly, like mobile application; all the used components of the application are coded by block designing approach in the back-end screen (Block Design). It also includes non-visible tools which are being used in the mobile application such as Bluetooth client;

which help in the connectivity purpose. After coding part is completed, then “.apk” file can be downloaded on android phone / tablet/laptop. For operating the same operations/features via PC/laptop, an emulator is used to run the same application. Emulator is used to run the same application. Emulator runs the application which is in .apk format. Application for the PC/laptop has same number of buttons and control features.

From TDS point of view, various blocks are used to set – arranged in such a way that it gives a desired output which matches user’s requirements.

3.3 Advantages of TDS

- Unobtrusive
- Low cost
- Flexible
- Non-Invasive technology
- Easy to handle
- No effect of temporal parameters

As there is limited space for tongue motion, therefore; a smaller number of sensors will be required. This will make a system and this technology a smoother, faster and more natural controls as user will not face any sort of issues related to the switches for multiple times. Unlike, other technologies it does not have any other additional input devices. Permanent magnet (which is used to produce magnetic field) is small, passive and inherent wireless component. Also, it helps in saving power for the system. Therefore, tongue drive system (TDS) is required to be more robust against interference, noise and automatic movement as compared to other AT.

CHAPTER 4
RESULT AND DISCUSIION

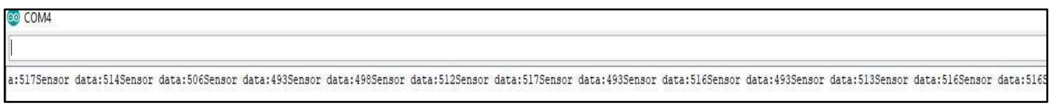
4.1 Output Data Analysis:

As mentioned, the overall system is divided into two circuit sections. One defines the transmitter section, which transmits the hall sensor signal to the receiver end. Another circuit is referred to as the receiver section, in which signals are being received and actions will be executed accordingly. Moreover, this section of study also includes the inputs from the mobile and computer application, which are used to control the receiver end via Bluetooth signals. Here, HC-05 is being used as the communication medium between the system and application.

4.1.1 Pre-testing Stage: Sensor Data Output

Figure 4.1

Pre-Testing Stage: Sensor Data Output



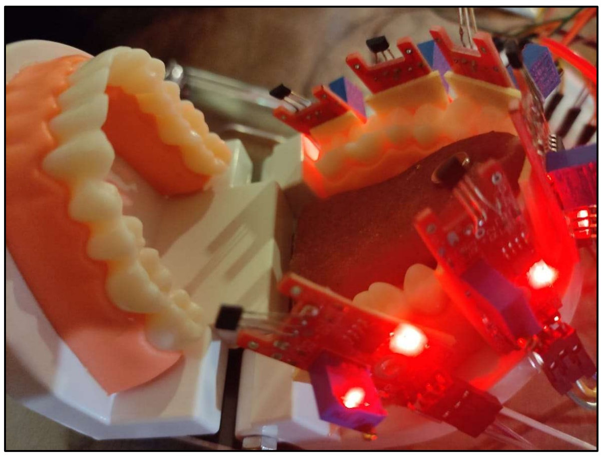
For TDS, the magnetic hall sensors (Linear KY-024) are being used in order to control the mobile robot, respectively. In the initial phase of the circuit implementation, it is really important to check and verify whether the suggestive sensor or component will give the desired output, which will meet the user's requirements or not. So, from Fig. 4.1, we can identify that that sensor is giving some values as an output (when it is connected to the analog pin of the sensor). These values are recorded while testing the hall sensor, with the range of values varying from 500 -550 Tesla (T); it is a case when the sensor is not in contact with the magnet. On the other hand, when a magnet is placed near the hall sensor, these values change in a decreasing manner. It is reduced to less than 500 T and goes up to 430 T. When it is connected to the digital pin of the sensor, it gives the results as HIGH or LOW with respect to the placement of the magnet on the sensor. In this way, it can be identified that when the magnet is near the sensor it becomes active (HIGH). Conversely, when a magnet is away, the hall sensor is off (LOW). It also gives a logic to create and stimulate the system in such a way that sensor's sensitivity can be considered with respect to the magnet. Moreover, it gives a direction to put if – else condition on the basis of the range of values that the sensor will give as an output.

4.1.2 Transmitter Output

A whole transmitter circuit works around the denture and tongue with a magnet on its end. In the transmitter circuit section, it consists of components that include different components such as magnetic hall sensor, RF transceiver, microcontroller- Arduino MEGA, Bluetooth module-HC-06, and an input power source (power bank). In terms of pin connection, each hall sensor has four pins, which are: A0 (Analog pin); ground voltage, GND (0V); supply voltage, VCC (+5V) and D0 (Digital pin). There are six hall sensors that are being used in the transmitter circuit.

Figure 4.2

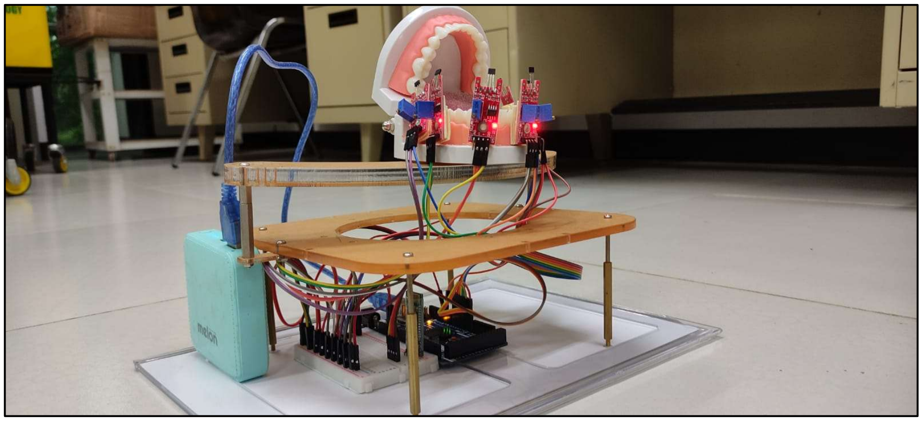
Placement of Hall Sensor, Peripheral Area of Denture



In the transmitter module, there are three pins, which are VCC, GND, and a data pin. And the remaining Arduino board is the main controlling board of the transmitter section. All the sensors, and other modules that are part of the transmitter circuit are connected to this microcontroller. From the supply source point of view, there will be a power bank connected to the microcontroller. The Bluetooth module, HC-06, has 6 pins in total, but 4 pins (VCC, GND, TXD, and RXD) are taken into consideration while implementing the circuit.

Figure 4.3

Overall Transmitter Circuit



Pin connection from each component to the Arduino board is as follows:

Table 4.1

Pin Connection from Each Component to the Arduino Board

Module Name	Module Pin No.	Pin Function	Arduino Pin No.
Hall Sensor 1	D0	Digital Pin	01
	GND	Ground	GND
	VCC	Supply Voltage	+5V
Hall Sensor 2	D0	Digital Pin	02
	GND	Ground	GND
	VCC	Supply Voltage	+5V
Hall Sensor 3	D0	Digital Pin	03
	GND	Ground	GND
	VCC	Supply Voltage	+5V
Hall Sensor 4	D0	Digital Pin	04
	GND	Ground	GND
	VCC	Supply Voltage	+5V

Module Name	Module Pin No.	Pin Function	Arduino Pin No.
Hall Sensor 5	D0	Digital Pin	05
	GND	Ground	GND
	VCC	Supply Voltage	+5V
Hall Sensor 6	D0	Digital Pin	06
	GND	Ground	GND
	VCC	Supply Voltage	+5V
Transceiver Module HC-12	RXD	Receiving Pin	12
	TXD	Transmitting Pin	11
	GND	Ground	GND
	VCC	Supply Voltage	+5V
Bluetooth Module HC-06	VCC	Supply Voltage	+5V
	GND	Ground	GND
	TXD	Transmitter	RXD
	RXD	Receiver	TXD

All the supplies (+5V) and ground pin are commonly connected to the bread board. Using breadboard as a medium to connect Arduino to all modules. Although the function of the transmitter circuit is to transmit all the signals that are being produced by the sensors irrespective of the sensor's working state status (HIGH/LOW).

4.1.3 Receiver Output

Figure 4.4

Serial Monitor Output when Receiver is Waiting for Signal

Figure 4.5

Sensor 1: Moving Forward

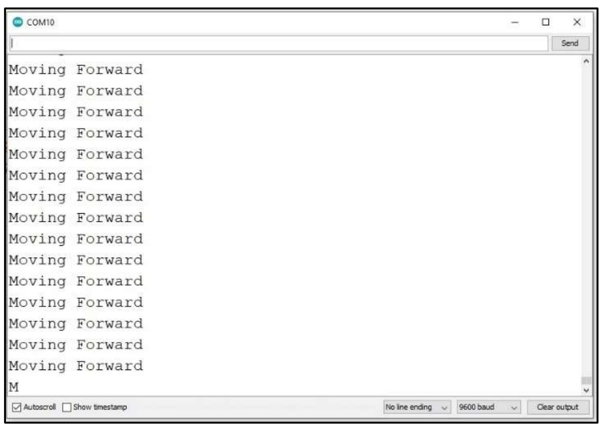


Figure 4.6

Sensor 2: Moving Backward

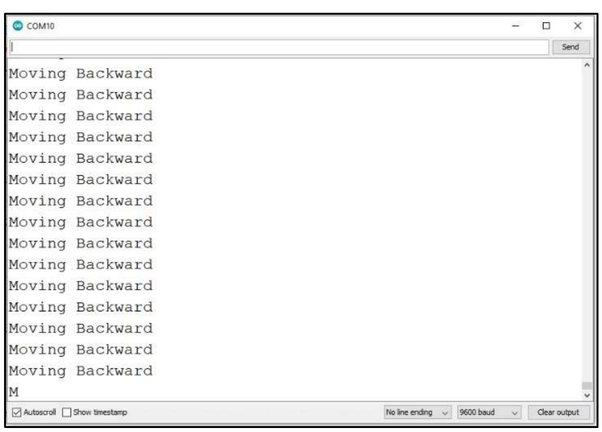


Figure 4.7

Sensor 3: Turn Left

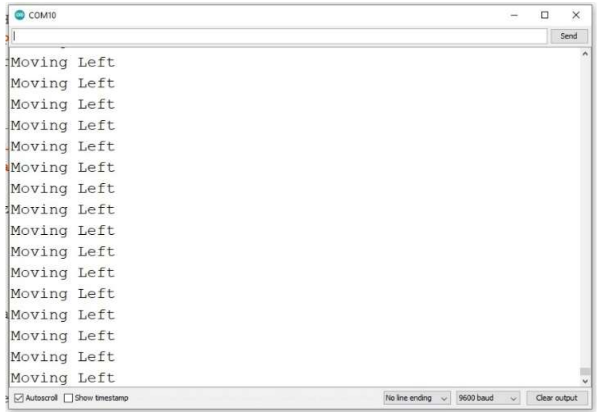


Figure 4.8

Sensor4: Turn Right

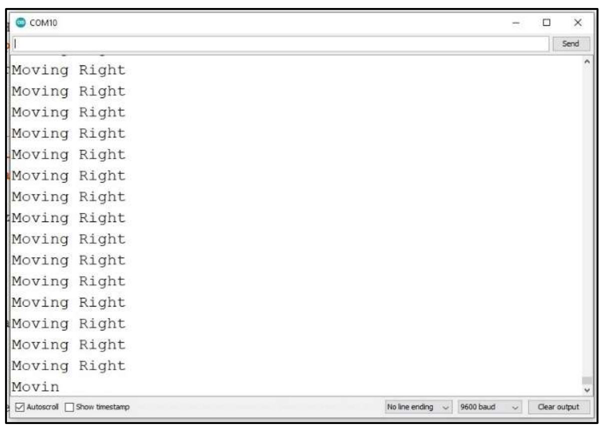
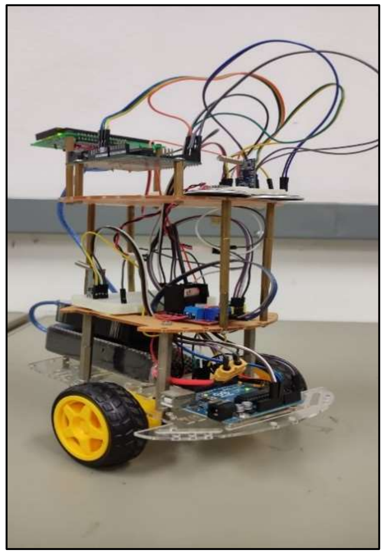


Figure 4.9

Overall: Receiver Circuit Bot



In this receiver circuit, the basic function of the transceiver is to receive the signals from another transceiver (transmitter circuit). An RF transceiver module is placed on the mobile robot, which receives the hall sensor signals and the mobile robot will perform the desired action as set by the user with respect to each sensor module. Using Arduino IDE software, output is obtained at receiver end can be seen using Serial monitor, referred to fig. no. 4.4 to fig. no. 4.8. Component modules which are part of the receiver circuit are: DC motors, Motor Driver, i2c LCD screen (16x2), 12 V battery, buzzer, RF transceiver, DF mini player, microcontroller-Arduino UNO (2), and a power source for the circuit, power bank (+5V). Each component has its own importance. Both the DC motors are connected to the motor driver (L298n), which has four output states, four input states, VCC-12 V, GND, and a +5V pin. DC motors are connected to the output state pins, and four input pins (IN1, IN2, IN3, and IN4) are connected to the digital pins of the board, respectively. With regards to TDS, there is one i2c LCD screen (16x2), which is being utilized in the project to give the desired text as an output (Emergency). There are 16 pins through which it is connected to the i2c module, which has only 4 pins and SCL and SDA pins are connected to two analog pins, A4 and A5. Each pin has its own importance and feature. As the LCD is ON, there will be a buzzer that will be ON simultaneously for the same duration of time as the LCD.

Figure 4.10

Sensor5: LCD Screen Displaying a Text "EMERGENCY"for Care Taker Person

4.1.4 Application Output

Bluetooth communication is used while the mobile and PC application mode is active. MIT Inventor App 2 is used to create an app with six buttons that are used to operate the robot using the same six control command functions. Similarly, there is a computer app that does the same activity. In the MIT inventor App, it executes each command by pressing the respective command. Application is named "*TDS". When the app is accessed, it comes with a home screen titled as *Tongue Drive System,* and there are 7 buttons including search/pairing for Bluetooth devices. Referring to fig 4.10, by clicking on the show device button, it displays the available devices within the range. There are different devices on which app is installed and can be used to control the robot.

Figure 4.11

Application Operating Panel Screen and Available Bluetooth Devices are Shown: Mobile View

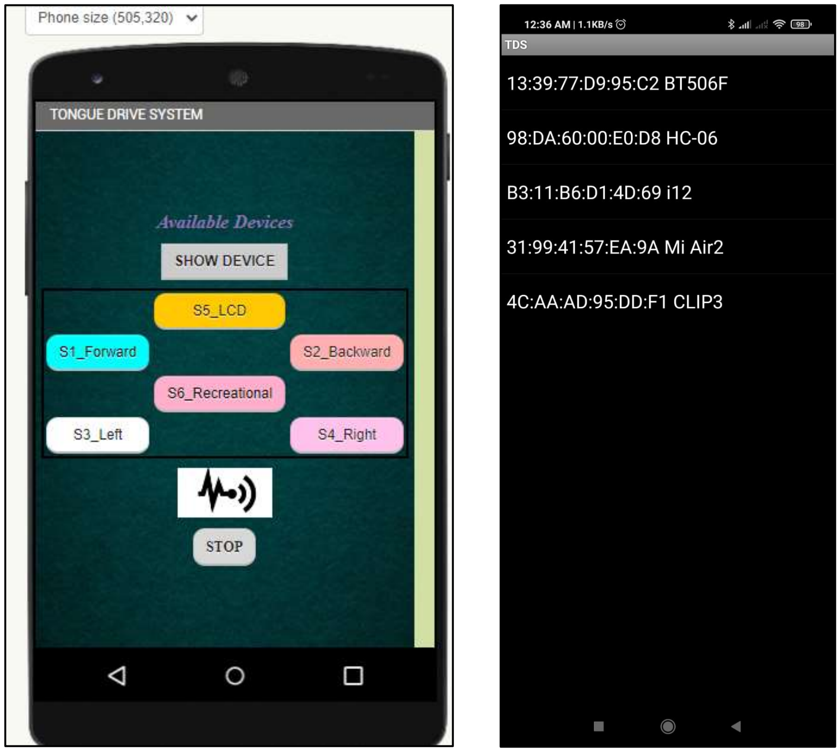
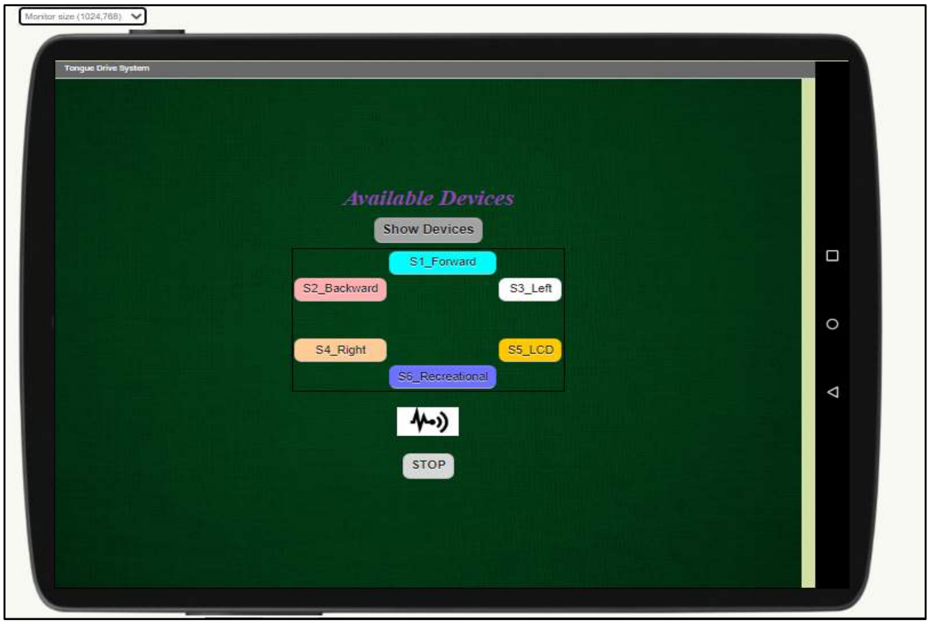


Figure 4.12

Application Operating Panel Screen and Available Bluetooth Devices are Shown: Tablet View

Figure 4.13

Application Operating Panel Screen and Available Bluetooth Devices are Shown: Laptop View



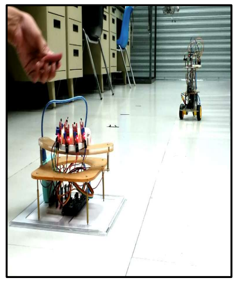
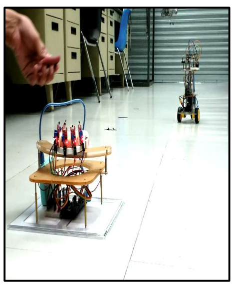
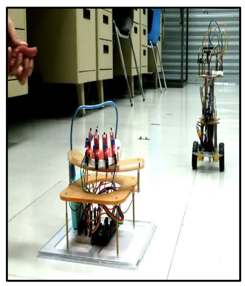
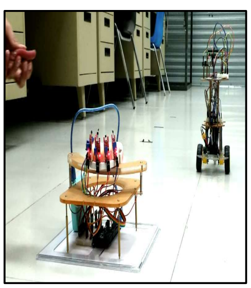
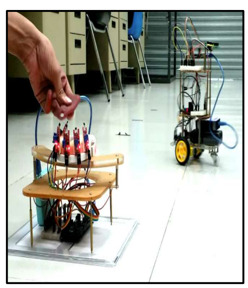
4.2 Results

While going thoroughly regarding the TDS, various studies were taken into consideration while designing all the parameters. Various assistive technologies are being compared which are available in the market such as the eye operated system, system based on brain computer interference, sip n puff, etc. TDS is more comfortable, preferable as it is simple in construction, cost effective, invasive in nature and do not any require any extra or external effort, it is fully controlled by the movement of tongue. TDS has an advantage of having no. of inputs and user comfort, also functionality features can be increased more by putting the sensors on the dental braces inside the mouth. Furthermore, this tongue drive system is useful and helpful to people who are suffering from limbs disability. These people can control their power wheelchair by controlling the moving tongue.

Although results are observed while performing the operations and executing each command. Commands which were discussed leads to move the robot in different directions and specifically customized ones. Mobile application option came out as useful, for instance person unintentionally touches any sensor, so care taker can take an immediate action accordingly. Result outcomes for both the modes, sensor mode as well as Bluetooth mode are described on next page.

Table 4.2

Sensor Mode: Result Outcomes on Actuation of the Command Signals

Initial Stage: Sensor Mode	Final Action	Description
		This is first command signal which is configured in the system, through which a bot moves in forward direction. It can be seen, that when the Sensor1 is active (by placing a tongue with magnet near to hall sensor) bot moves in forward direction.
		Moving to second configured command of the system, in which a bot moves in backward direction. It can be seen that when the Sensor2 is active (by placing a tongue with magnet near to hall sensor) bot moves in backward direction.
		Next moving to third configured command of the system, in which a bot turns in left direction. It can be seen that when the Sensor3 is active (by placing a tongue with magnet near to hall sensor) bot turns in left direction.

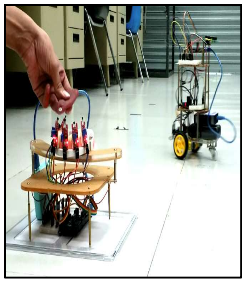
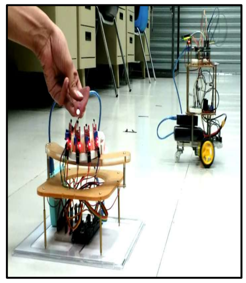
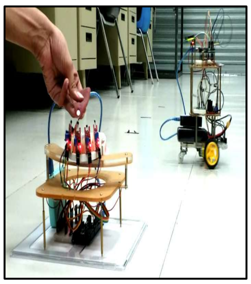
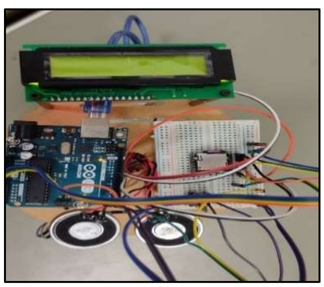
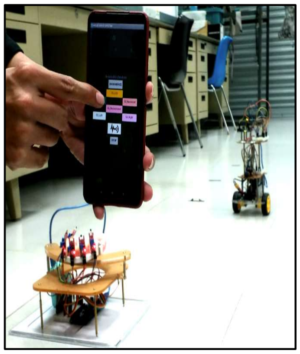
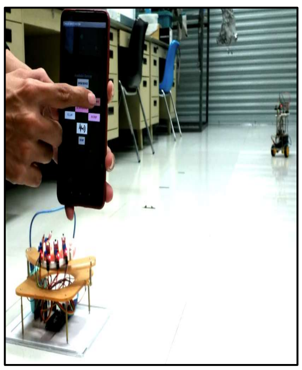
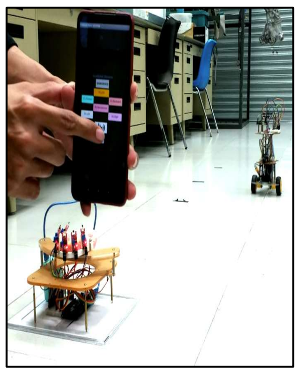
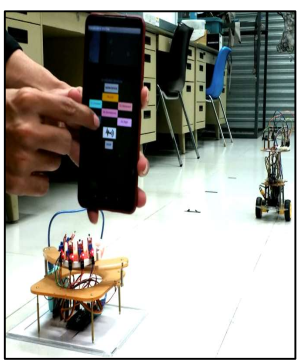
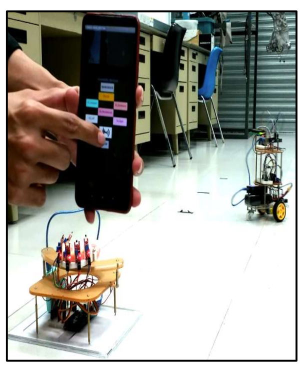
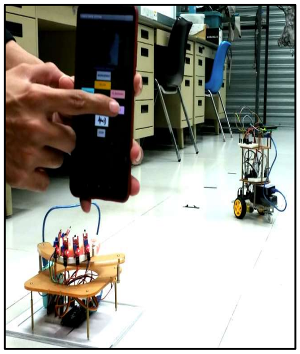
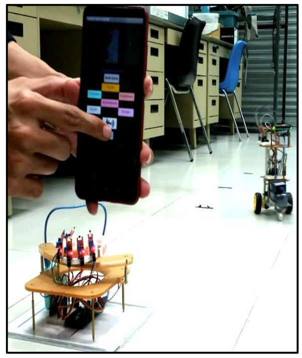
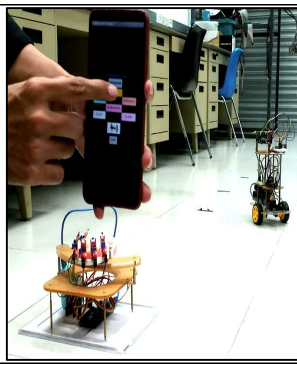
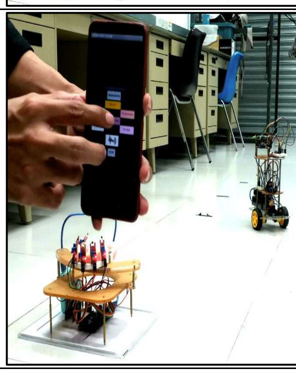
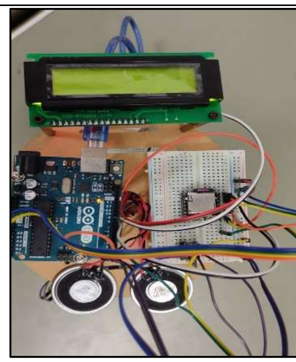
Initial Stage: Sensor Mode	Final Action	Description
		On the contrary, in fourth configured command of the system, a bot turns in right direction. It can be seen that when the Sensor4 is active (by placing a tongue with magnet near to hall sensor) bot turns in right direction
		Moreover, fifth command of the system, it can be seen that when the Sensor5 is active (by placing a tongue with magnet near to hall sensor), LCD turns ON displaying a text "EMERGENCY" along with a buzzer.
		Lastly, sixth command of the system, it can be seen that when the Sensor6 is active (by placing a tongue with magnet near to hall sensor) it activates the mini player, and plays a casted audio.

Table 4.3

Bluetooth Mode: Result Outcomes on Actuation of the Command Signals

Initial Stage: Bluetooth Mode	Final Action	Description
		This is first command signal which is configured in the system, through which a bot moves in forward direction. It can be seen in Bluetooth mode that in application when the S1 Forward button is pressed, bot moves in forward direction.
		Moving to second configured command of the system, in which a bot moves in forward direction. It can be seen in Bluetooth mode that in application when S2 Backward button is pressed, bot moves in backward direction.
		Next moving to third configured command of the system, in which a bot turns in left direction. It can be seen Bluetooth mode that when in application S3 Left button is pressed, bot turns in left direction.

Initial Stage: Bluetooth Mode	Final Action	Description
		On the contrary, in fourth configured command of the system, a bot turns in right direction. It can be seen Bluetooth mode that when in application S4 Right button is pressed, bot turns in right direction.
		Moreover, fifth command of the system, it can be seen Bluetooth mode that when in application S5 LCD button is pressed, LCD turns ON displaying a text “EMERGENCY” along with a buzzer.
		Lastly, sixth command of the system, it can be seen Bluetooth mode that when in application S6 Recreation button is pressed, it activates the mini player, and plays a casted audio.

To start the Bluetooth mode, user connects the system Bluetooth module (HC-06) with the device Bluetooth to initiate the communication. By clicking the Available device, user can see the devices which are accessible in that range.
STOP button is specifically added to the mobile application for the care taker person to control and avoid the unwanted accidents, safety precautions.

As per the objectives which were discussed in the starting of it, are fully obtained. Now a system is controllable by hall sensors and via Bluetooth connectivity a well using an application.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

We noticed and established several means through this system to make the TDS product user independent to a large part and to give them with handy ways of communicating with those who care for them. Following conclusions were made after completing the objectives respectively:

There are many assistive technologies which are available, some are non- invasive and some comes under the invasive category. As TDS is invasive technology, which makes the user not to trouble much. From practical point of view, TDS is also applicable to those people who are suffering for physical disability or as such limb disability. It helps them to relive their live independently.

This system did not harm any person, as these hall sensors are operated at very low level and while comparing this system to the existing systems, this system extends the scope and field of applications not just from the movement of wheelchair but it also provide an emergency alert to the care taker person. It also provides an audio play cast as an entertainment purpose to the user. In the study, this feature is referred as recreational feature.

Also, for security purpose with regards to the user, there will be a remote controllability as well, via mobile/computer applications which are based on Bluetooth technology.

5.2 Future Recommendations

When it comes to the improvement of this system or else, we can say, how can it be more feasible and helpful to the user in an easy and simple way. So, following recommendations should be considered for future study:

Inclusion of a greater number of sensors leads to a greater number of functions, which can be used to enable the home automation feature for the user, in a feasible manner. It can range from controlling the switches to the security systems.

Different operating modes can be created, by using voice recognition system software.

By integrating this headsets and voice recognition system, user can, not control their wheelchair motion but also can perform few tasks on various applications and computer.

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APPENDICES

APPENDIX A
CODE FOR TRANSMITTER

```
#include <SoftwareSerial.h>


SoftwareSerial HC12(10, 11);
int forward =2;
int backward =3;
int right = 4;
int left = 5;
int emergency = 6;
int music = 7;
char Data='Z';
int buttonState1;
int buttonState2;
int buttonState3;
int buttonState4;
int buttonState5;
int buttonState6;
bool Start=false;
void setup()
{

   Serial.begin(9600);
   HC12.begin(9600);
   pinMode(forward, INPUT_PULLUP);
   pinMode(backward, INPUT_PULLUP);
   pinMode(right, INPUT_PULLUP);
   pinMode(left, INPUT_PULLUP);
   pinMode(emergency, INPUT_PULLUP);
   pinMode(music, INPUT_PULLUP);
}
```

```
void loop()
{
 // buttonState1 = digitalRead(forward);
  buttonState2 = digitalRead(backward);
  buttonState3 = digitalRead(right);
  buttonState4 = digitalRead(left);
  buttonState5 = digitalRead(emergency);
  buttonState6 = digitalRead(music);

  if(Serial.available() > 0){ // Checks whether data is comming from the serial
port
    Data = Serial.read(); // Reads the data from the serial port
    Serial.print(Data);
    }



//------------------------------------------------------------FORWARD------------------
-------------------------------------

  if (digitalRead(forward) == HIGH || Data == 'A') {

    Serial.println("Button is pressed");
    Serial.println("MSG is Sending ROBOT moving FORWARD");
   HC12.write('A');
    delay(1000);
     //}
  }

//------------------------------------------------------------BACKWARD----------------
--------------------------------------

  if (digitalRead(backward) == HIGH || Data == 'B') {

    Serial.println("Button is pressed");
    Serial.println("MSG is Sending ROBOT moving BACKWARD");
    HC12.write('B');
    delay(1000);

  }

//------------------------------------------------------------RIGHT-----------------------
------------------------------

   if (digitalRead(right) == HIGH || Data == 'C') {

    Serial.println("Button is pressed");
    Serial.println("MSG is Sending ROBOT moving RIGHT");
    HC12.write('C');
```

```
    delay(1000);

  }

//--------------------------------------------------------------LEFT--------------------------
----------------------------

   if (digitalRead(left) == HIGH || Data == 'D') {

    Serial.println("Button is pressed");
    Serial.println("MSG is Sending ROBOT moving LEFT");
    HC12.write('D');
    delay(1000);

  }

//--------------------------------------------------------------EMERGENCY--------------
----------------------------------------

   if (digitalRead(emergency) == HIGH || Data == 'E') {

    Serial.println("Button is pressed");
    Serial.println("MSG is Sending for EMERGENCY");
    HC12.write('E');
    delay(1000);

  }

//----------------------------------------------------------------MUSIC---------------------
----------------------------------

   if (digitalRead(music) == HIGH || Data == 'F') {

    Serial.println("Button is pressed");
    Serial.println("MSG is Sending for play MUSIC");
    HC12.write('F');
    delay(1000);

  }

  if(digitalRead(forward) == LOW && digitalRead(backward) == LOW &&
digitalRead(right) == LOW && digitalRead(left) == LOW &&
digitalRead(emergency) == LOW && digitalRead(music) == LOW  && Data==
'Z')
   {

    Serial.println("Button is NOT pressed");
    Serial.println(" ");
    HC12.write('Z');
    delay(1000);
```

```
    }
}
```

APPENDIX B

CODE FOR RECEIVER _ ROBOT

```
#include <SoftwareSerial.h>
SoftwareSerial HC12(10, 11); // HC-12 TX Pin, HC-12 RX Pin

#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x27, 16, 2);

#define buzzer 12
#define IN1 4
#define IN2 5
#define IN3 6
#define IN4 7
char last_data,data;
char ch='Z';

void setup()
{

  Serial.begin(9600);
  HC12.begin(9600);

  lcd.begin();
  lcd.backlight();
  lcd.clear();


  pinMode(buzzer,OUTPUT);
  pinMode(IN1,OUTPUT);
  pinMode(IN2,OUTPUT);
  pinMode(IN3,OUTPUT);
  pinMode(IN4,OUTPUT);
```

```
}

void loop()
{
   uint8_t buf[1];
   uint8_t buflen = sizeof(buf);


   if (HC12.available())
   { buf[0] = HC12.read();
     ch = buf[0];
     Serial.print("Message Received: ");
     Serial.println(ch);    }


  if (buf[0]!=last_data)
  {  data = buf[0];
   last_data = data;
   }



  if (ch=='A')
   { forward ();
    }
   if (ch=='B')
   {
    backward ();
    }
   if (ch=='C')
   {
    right ();
   }
   if (ch=='D')
   {
    left ();
   }
   if (ch=='E')
   {
    Emergency ();
   }
   if (ch=='Z')
   {
    Serial.print("Waiting for Commands   ");
    noTone(buzzer);
    lcd.clear();
    stop ();
   }
```

```
}

void Emergency ()
    { ch = 'O';
      Serial.println((String)"ch = "+ch+"   Inside Emergency Function");
    digitalWrite(IN1, LOW);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, LOW);
    digitalWrite(IN4, LOW);
    tone(buzzer,784);
     lcd.setCursor(0,0);
     lcd.print("Emergency");
//     delay(5000);
//     noTone(buzzer);
//     lcd.clear();



    }

void forward()
  {Serial.println("Moving Forward");
    digitalWrite(IN1, LOW);
    digitalWrite(IN2, HIGH);
    digitalWrite(IN3, LOW);
    digitalWrite(IN4, HIGH);
    }

void backward()
     {Serial.println("Moving Backward");
    digitalWrite(IN1, HIGH);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, HIGH);
    digitalWrite(IN4, LOW);
    }

void right()

   {Serial.println("Moving Right");
    digitalWrite(IN1, HIGH);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, LOW);
    digitalWrite(IN4, HIGH);
    }


void left ()

    {Serial.println("Moving Left");
```

```
    digitalWrite(IN1, LOW);
    digitalWrite(IN2, HIGH);
    digitalWrite(IN3, HIGH);
    digitalWrite(IN4, LOW);
    }

void stop ()
   {Serial.println("Stop");
    digitalWrite(IN1, LOW);
    digitalWrite(IN2, LOW);
    digitalWrite(IN3, LOW);
    digitalWrite(IN4, LOW);
    }
```

APPENDIX C

CODE FOR DF MINI PLAYER

```
#include "Arduino.h"
#include "SoftwareSerial.h"
#include "DFRobotDFPlayerMini.h"

//SoftwareSerial HC12(10, 11);
SoftwareSerial mySoftwareSerial(2, 3); // RX, TX
DFRobotDFPlayerMini myDFPlayer;
 bool start = true;
 char last_data,data;
 char ch='Z';
void setup()
{
    // Initialize ASK Object

    // Setup Serial Monitor
    Serial.begin(9600);
    mySoftwareSerial.begin(9600);
    //HC12.begin(9600);

  Serial.println();
  Serial.println(F("DFRobot DFPlayer Mini Demo"));
  Serial.println(F("Initializing DFPlayer ... (May take 3~5 seconds)"));

   if (!myDFPlayer.begin(mySoftwareSerial)) {  //Use softwareSerial to
communicate with mp3.
    Serial.println(F("Unable to begin:"));
    Serial.println(F("1.Please recheck the connection!"));
    Serial.println(F("2.Please insert the SD card!"));
```

```
    while(true){
      delay(0); // Code to compatible with ESP8266 watch dog.
    }
  }
  Serial.println(F("DFPlayer Mini online."));
}
void loop()
{
    uint8_t buf[1];
    uint8_t buflen = sizeof(buf);


    if (Serial.available())
    { buf[0] = Serial.read();
      ch = buf[0];
      Serial.print("Message Received: ");
      Serial.println(ch);
      start=true;}


  if (buf[0]!=last_data)
  {  data = buf[0];
   last_data = data;
   }




 if(ch=='F'&&start==true){
  start=false;
  myDFPlayer.volume(30);  //Set volume value. From 0 to 30
  myDFPlayer.play(1);  //Play the first mp3
 }
 if (ch=='Z'&&start==false)
 {start=true;
 myDFPlayer.pause();
 myDFPlayer.volume(0);
 }

}
```