GESTURE CONTROLLED ROBOTIC WHEELCHAIR

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CERTIFICATE

This is to certify that "**Project/Thesis Report on, Gesture Controlled Robotic Wheelchair"** is submitted in partial fulfillment of the requirement for the degree of Bachelor of Computer Systems Engineering by the following students:

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ABSTRACT

The quest for enhancing the mobility and independence of individuals facing the challenge of physical disabilities or limited independence to mobility has led to the development of innovative assistive technologies. This thesis presents the research, system design and hardware implementation of a Gesture-Controlled Robotic Wheelchair aimed at alleviating the challenges faced by individuals with partial paralysis or weakened muscular control. The project integrates cutting-edge technology, including gyroscope sensors, ultrasonic sensors, infrared sensors, and a GSM module, to create a user-centric and safe mobility solution.

The core objective of designing this prototype is to empower users with the ability to navigate their environment effortlessly, without the constant need for external assistance. The gesture-controlled feature, facilitated by gyroscope sensors, allows users to operate the wheelchair with minimal physical effort. The integration of ultrasonic sensors ensures obstacle detection, enhancing safety and preventing collisions. In addition, infrared sensors (IR), are employed to confirm the presence of the user, allowing the system to respond to user intent and restrict motion when necessary.

The GSM module acts as a reliable communication bridge, ensuring that caregivers and users remain connected in real time. It offers the capability to generate and transmit alerts in case of power losses.

In conclusion, this thesis represents a significant advancement in assistive technology, offering an autonomous wheelchair system that empowers individuals with limited mobility, enhances their quality of life, and provides a pathway to increased independence. The combination of innovative technologies and thorough testing underscores the system's potential to make a meaningful impact in the lives of those it serves.

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List of Abbreviations

BCW	Brain Controlled Wheelchair
EEG	Electroencephalogram
IR	Infrared
SCI	Spinal Cord Injury
MEMS	Micro-Electro-Mechanical Systems
EPW	Electric-Powered Wheelchair
IMU	Inertial Measurement Unit
HMI	Human-Machine Interface

Chapter-1

INTRODUCTION

1.1 BACKGROUND:

The overall population of the world has changed in dramatic ways over the last few centuries [1]. Between 2025 and 2050, the elderly demographic is estimated to increase nearly two fold to reach 1.6 billion on a global scale. In contrast, the entire population is expected to grow by only 34 percent during this timeframe [2]. The United Nations World Population Prospects for 2017 indicate that by 2030, it is expected that the number of older individuals will surpass that of children under the age of 10, as demonstrated in Figure 1.1.

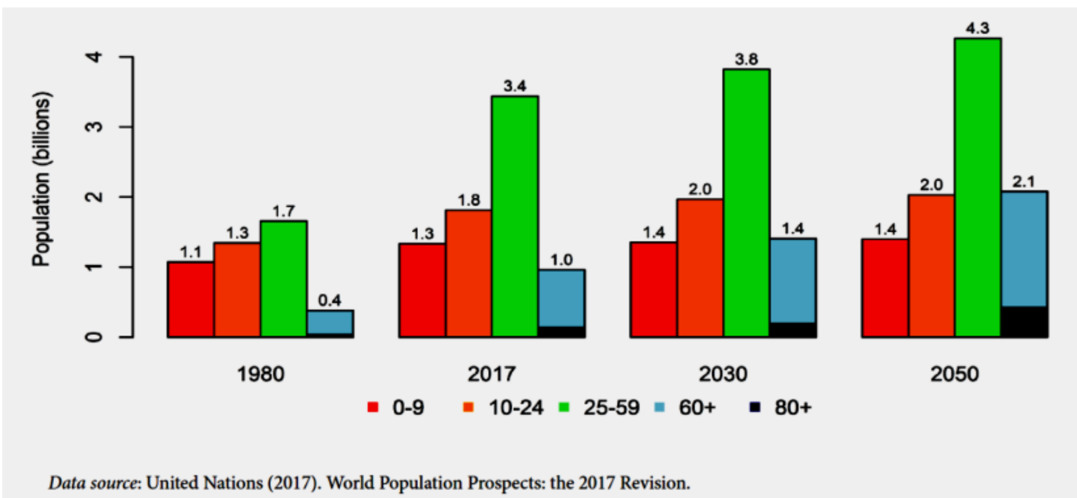

Figure 1.1 Elderly population Prospects [3]

Aging brings many dysfunctions of body parts along with mobility decline. As people grow older, they face challenges like balancing, poor vision, and dementia. About one-third of the group over 65 years often fall every year and get injured. However, only 10% of the falls result in fractures.

This aging population has to encounter age-related diseases and impairments that will limit their functioning as an individual in society. These people would need assistance with their daily trades. Lately robots have made their way in assisting humans. Aged people have robotic friends which take care of them, remind them their medicines and appointments, and supervise their daily routine. Hence assistive robots that help elderly and impaired persons are becoming radically important.

1.2 MOTIVATION:

The ability of an individual to move independently is an underrated blessing intrinsically given to mankind. Human life revolves around continuous movement from one phase to another. Nature has given this immense power to humans to move in their surroundings, explore every inch of this universe, socialize with other human beings, perform their duties, share their resources with others and participate in the society to bring change. We humans are pretty much adaptable to change, be it the situations or surroundings. It has been observed that human nature is unable to remain fixed to a single place for a long period of time. It demands change. This proves that humans are keen to move in their surroundings. This phenomenon of life has led to many fundamental inventions to keep the lives in momentum. Independent mobility gives a feeling of self-reliance and independence.

Ever since motorization has changed the lives of humans, enabling them to move anywhere by means of automobiles, it has also caused major harm due to numerous traffic accidents and fatal injuries. These accidents lead to malfunctioning of various body parts and impacts on the mental health and well-being of an individual. But there are individuals who merely can perform their day-to-day to stuff without depending on other individuals. These are the ones with some disability either by birth or due to any unfortunate incident. Nearly 1.3 billion people worldwide, or 16% of the global population, struggle with significant disabilities, equating to 1 in 6 individuals. Since mobility is an essential part of life, people with their lower limb paralysis suffer being mobile at stages where movement is crucial. They need a human assistance to help them in their jobs.

The world is getting revolutionized by the technology precipitously. Technology has evolved almost every field including medical, education, construction, transportation trade, marketing and many more. Things that seem very difficult to operate manually earlier, can now be easily controlled with this evolution of technology. Humans have demonstrated noteworthy inventions and problem-solving skills, creating tools, technologies, and infrastructure that boost their ability to sail across and act together in their environments. In fact, robots are being introduced in various fields of life to accommodate humans in real-time.

With this growing number of aging population, disabled, and severely injured people, their dependency on other individuals is becoming a concern as it requires a large number of skilled labor to lend them a hand. This gap is being filled with autonomous robots that can provide assistance to them at a very low expense.

One solution for this mobility problem was given in the form of wheelchairs. Traditional manual wheelchairs have been a venerable solution to address mobility challenges but are off suited for the people with a combination of physical and cognitive weakening. For a manual wheelchair to be functional, it is always necessary to have the upper limbs of the patient strong enough to bear the pressure and strength it costs to navigate it.

Meanwhile many automatic wheelchairs have been introduced lately. But people having frail muscles or limited dexterity cannot tolerate operating a manual wheelchair. They cannot even stand with the one that requires their muscle strength to grab the joystick or the remote controller to function the device. This group deals with extensive teething troubles operating a manual wheelchair or even conventional power ones, entailing constant presence of their caretakers to navigate the world around them.

Motorized wheelchairs are the ones which are propelled with the help of electrical power than that of manual maneuver. These smart wheelchairs typically consist of conventional power with other sensors connected with a computer.

In general, a wheelchair is a device containing chair and wheels attached to it for movement. It comes with two basic variations i.e. labor-intensive wheelchair or automatic wheelchair see Figure1.2.

Figure 1.2 Manual and Autonomous Wheelchairs

Manual wheelchair moves when user sits on it and turns the rear wheels with his hands. It has handles at the back of the chair to allow the caretakers to push it. While automatic or electric wheelchairs operate with a push button, a joystick or other techniques embedded on them.

Although electric propulsion wheelchairs are very common and in high demand but 40% of them find it difficult or impossible to maneuver using a joystick [4], often due to tremors, limited range of motion, or spasticity [5]. In addition, the use of power wheelchair use can be physically and cognitively troublesome, even for those able to operate a joystick [6].

Therefore, it is necessary to build an autonomous wheelchair that can address these issues and navigate them according to their desires. In most of the cases, various sensors and algorithms are used to navigate wheelchairs in both indoor and outdoor environments. However, these type of wheelchairs are hindered when an impaired person is in the outdoor environment and come across any fault in the system. It would be difficult to inform the caretaker implicitly. Many robotic wheelchairs are also equipped with gyroscopic sensor to steer them but using only gyro has a drawback of continuous motion at times when no movement is required. Thus it is necessary to design a robotic wheelchair that navigates safely, has an intrinsic fault detection system especially for outdoor environments and detects hindrances and apply automatic brakes as response of machine is higher than human response to apply brake.

Through this research study we aim to design a robotic wheelchair that will bring innovation in the field of health and well-being of humans. To grow the infrastructure and industry mainly in health sciences, it is important to draw the feasibility to enhance the functionality of how humans work to train the machines. This way we can install helpers to assist humans in the form of robots. Scientists are constantly working to bring advance life on land. Our motive is no different than this. Therefore, a robotic gesture-controlled wheelchair has got our attention to facilitate impaired and older people.

1.3 PROBLEM STATEMENT

Mobility is an essential part of human life and those having this blessing are the ones who usually take it for granted. A number of elderly people and individuals with mobility issues have more difficulty to steer a manual wheelchair. There are many handicapped people with an addition of neuromuscular syndromes which do not allow the user to drive a one even with a remote controller or a joystick. Existing technologies also include brain controlled wheelchair and head motion sensing wheelchairs but it is observed that it’s difficult for a brain to differentiate numerous thoughts to focus on movement for controlling a brain controlled wheelchair, and head motion ones are not viable for the people with neck injuries.

These challenges demanded a need for a new technological based robotic wheelchair that would eliminate the need of any significant muscle strength and can be operated by a wide range of patients. Therefore a gesture controlled robotic wheelchair with a gyroscope navigation technique is designed to address the issues encountered by such individuals.

1.4 AIM AND OBJECTIVES

The main aim of this project is to develop a cost-effective prototype of an autonomous wheelchair based on wide-ranging research on existing models, fact verdicts and technology used to transform the traditional wheelchairs. The project's goal is to propose a wheelchair to enhance the ability of those facing mobility issues due to severe injuries or old age. To ensure the safety of the patient, implementing other techniques to make the wheelchair reliable and consistent under various conditions.

The primary objectives of this research and design project are as follows:

- To develop a wheelchair prototype that can be controlled using a gyroscope sensor.
- To implement safety features by integrating IR sensors to limit the movement when necessary.
- To incorporate obstacle sensing and avoidance through the use of ultrasonic sensors.
- To ensure real-time communication and safety by integrating a GSM module that can alerts caretakers by auto generating short message in case of power loss.

1.5 SCOPE OF PROJECT:

The primary goal of technology is to alleviate the burden on humanity, with the overarching objective being the reduction of human effort required to accomplish tasks. Robotics, as a field, that encompasses the scientific and technological aspects of designing, producing, and implementing robots. This thesis takes one step in the right direction to fulfill the demand of improved mobility solution by proposing an automated wheelchair integrated with gyroscope sensor. The basic idea behind this innovative initiative is to give people suffering from muscular dystrophy or Spinal Cord Injury (SCI), a kind of control and independence by utilizing small hand movements that do not need much muscle effort. This project using current technology like an Arduino-UNO microcontroller, ultrasonic sensors, infrared sensors and more.

The project does recognize the wide scope of mobility needs, it particularly addresses the need of this target group. This is a practical, user-driven solution that allows users to take back control and improve their lives in general.

1.6 RELATED SDGS:

SDG 3: Good Health and Well-being.

This gesture-controlled wheelchair aims to provide a means of mobility for individuals with severe motor disabilities. By allowing them to control the wheelchair using gestures, the project contributes to improving the quality of life and well-being of these individuals. By creating a wheelchair system that responds to gestures, it may enhance accessibility for individuals who may have difficulty operating traditional wheelchairs with physical controls. This improved accessibility can lead to better health outcomes and an improved quality of life. For individuals with mobility impairments, immobility can lead to various health issues. Our project helps reduce these health risks by providing a means for them to move independently.

SDG 9: Increase Industry, Innovation and Infrastructure

The project represents innovation in the field of assistive technology. It involves the development of a smart wheelchair system that utilizes innovative technology to assist individuals with severe motor disabilities. This aligns with SDG 9's emphasis on promoting innovation and technological advancement. The development contributes to the creation of inclusive infrastructure. It addresses the need for improved mobility and accessibility for individuals with disabilities, supporting SDG 9's goal of building resilient infrastructure that serves everyone, including vulnerable populations. By introducing new assistive technology, our project can escalate industries focused on improving the lives of people with disabilities. It provides universal access to information and communications technology. Our project, by using gesture control technology, contributes to this goal by making it easier for individuals with motor disabilities to interact with and control their wheelchairs, thus enhancing their access to technology.

SDG 10: Reduced Inequalities

By developing a technology that allows individuals with motor disabilities to control their wheelchairs through gestures, we are promoting accessibility and inclusion. This technology helps reduce the inequality faced by people with disabilities, enabling them to participate more actively in society. We aim to provide equal opportunities for individuals with motor disabilities by enhancing their mobility and independence. This, in turn, contributes to reducing the disparities and barriers that often limit their participation in various aspects of life. Also access to assistive technologies can be unequal, with many individuals with disabilities lacking the means to acquire such devices. By working on a cost-effective and innovative solution, our project aims to reduce this technology gap.

Improved mobility and independence can also lead to economic empowerment for individuals with motor disabilities. Our project directly addresses economic inequalities by enhancing their ability to engage in education, employment, and daily activities.

1.7 THESIS LAYOUT

Chapter two delves into an extensive review of existing wheelchair technologies and related assistive devices. It examines the shortcomings of traditional wheelchairs and highlights the potential of gesture control and sensors to address these issues.

Chapter three focuses on the design and system analysis phase, offering an in-depth examination of the chosen components, including gyroscope sensors, infrared sensors, ultrasonic sensors, and a GSM module. The methodology section provides a detailed account of how each hardware component is integrated into the system. It explains the connections, pin configurations, and methodology for gyroscopes, infrared sensors, ultrasonic sensors, and the GSM module

Chapter four rigorously assesses the system's performance, evaluating its ability to meet objectives such as gesture recognition accuracy, user presence detection, obstacle avoidance, communication reliability, and data security. It demonstrates the system's robustness and reliability.

The final chapter concludes the thesis, summarizing the project's achievements and its impact on enhancing mobility and independence for individuals with physical disabilities. It also discusses future developments and the ongoing refinement of the system.

1.8 GANTT CHART

A Gantt chart is a prevalent project management instrument employed for visually depicting a project's timetable. It illustrates the tasks or activities of a project across a timeline, indicating their respective start and end times. Gantt charts serve as valuable tools for project managers, team members, and stakeholders to monitor and oversee a project's advancement, guaranteeing its adherence to the schedule and budget constraints. The Gantt chart for our project timeline is given in Figure 1.3.

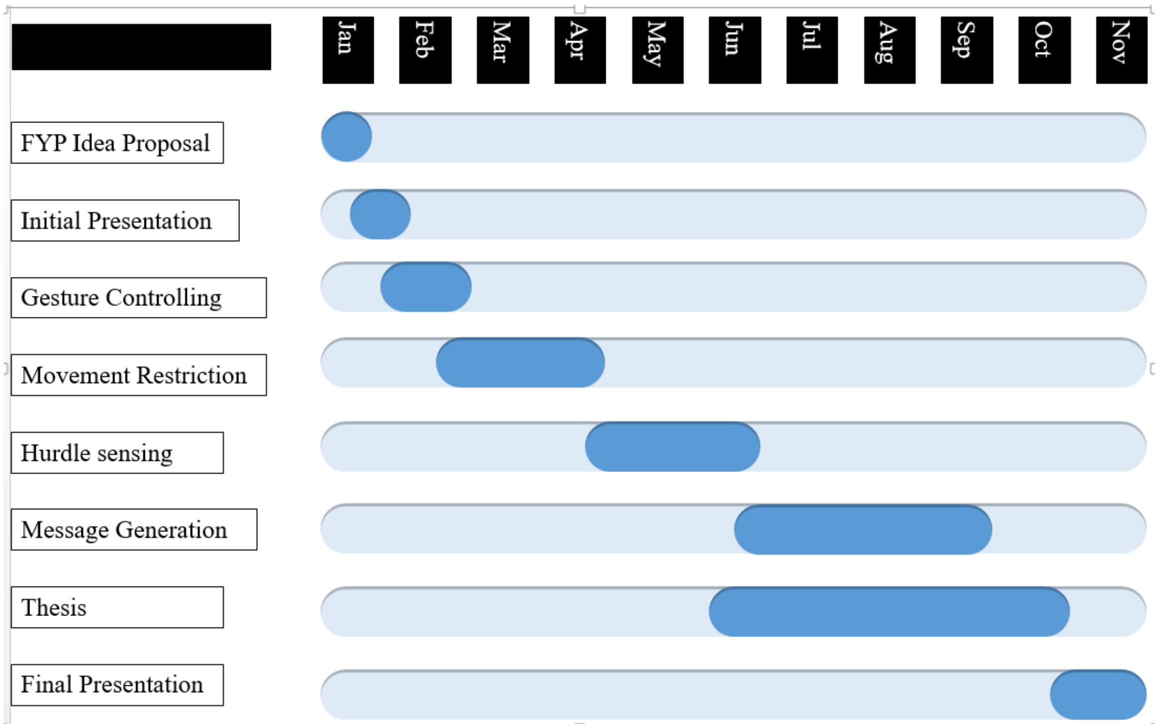

Figure 1.3 Gantt chart of project

Chapter-2

LITERATURE REVIEW

The increasing elderly population and the uptick in accidents, conflicts, and disabilities have driven the development of management methods aimed at assisting individuals with disabilities in their daily lives. Individuals who have experienced spinal cord injuries, frequently face limitations in moving their upper and lower limbs. However, they can still utilize head movements. Those at the C4 neurological stage may require support but can generally make head and neck movements.

In response to these challenges, an electric-powered wheelchair (EPW) has been designed to interpret various input methods to maneuver the chair in desired directions. This technology is tailored for individuals who cannot operate a conventional wheelchair or joystick due to physical constraints, necessitating an intelligent control system.

Many existing EPWs rely on joystick control, limiting accessibility for disabled individuals and the elderly, who may lack the necessary physical strength. Smart EPWs have emerged as a natural alternative to traditional wheelchairs, providing invaluable assistance to seniors and people with mobility challenges. The demand for EPWs with intelligent commands became evident.

Research in this field explores various techniques for operating wheelchairs without the need for physical exertion. Numerous sophisticated devices and HMI, including methods based on vision, voice commands, hand gestures, head control, eye-tracking systems and biological signal-based systems have been introduced lately.

Some authors have proposed EPWs with head motion capabilities, employing Inertial Measurement Units (IMUs) for gesture identification obtained from user’s head to control the movement of the EPW. This advancement signifies a significant step toward enhancing the mobility and independence of individuals with mobility challenges. Following are the further explanations of certain research publications.

2.1 WHEELCHAIR CONTROL SYSTEM BASED ON GYROSCOPE OF WEARABLE TOOL FOR THE DISABLED.

The research paper in [7] stands out from previous works by incorporating various types of motions and speed behaviors, along with the calculation of wheel rotation radius, which is essential for determining corridor and door dimensions. The system boasts six unique motor speed settings and four different wheel rotation radius options, offering a high degree of flexibility. Notably, it does not requires for a user to maintain a specific posture while operating the (HMI).

The system is based on an EMOTIV sensor based headset that can be worn by the user to capture head gestures data, which is transmitted to a computer for analysis. An Arduino Nano microcontroller is employed to process this data, managing speed and direction instructions. A DC motor driver is utilized to convey these instructions to control the wheelchair's motor, facilitating precise user-driven movement.

The selection of the EMOTIV Insight headset, as detailed in [14], is based on its swift response speed, wireless technology, user-friendly design, and the convenience it offers in terms of headwear and control. Once a command is executed, there is no need for the user to maintain a specific head posture.

CRITICAL ANALYSIS:

However, a critical analysis suggests some limitations. The system may not be suitable for patients who cannot keep their head in the same direction for extended periods. Additionally, it lacks a method for obstacle avoidance and wheelchair orientation, which are crucial for ensuring user safety and navigation in complex environments.

2.2 A LASER-VISION-BASED OBSTACLE DETECTION AND DISTANCE ESTIMATION FOR SMART WHEELCHAIR NAVIGATION.

This study in [10] focuses on introducing a system for estimating hindrance distances plus facilitating movement for autonomous wheelchair system. The proposed system consists of a laser coordinating with a camera for obstacle avoidance while navigating.

A technique for identifying patterns of detected obstacles is implemented using a blob detection approach on the line laser image. Both modules are securely positioned in fixed locations to maintain a constant correlation between spaces in the blobs and the distance from obstacles to the wheelchair.

This paper presents a smart system, employing machine vision technology to enhance the mobility of individuals. The wheelchair features a DC motor as its driving mechanism and is designed for detecting obstacles and make informed decisions regarding further actions. In the realm of obstacle detection research, simplifying image analysis and reducing processing time is essential. To achieve this, a combination of a camera and a line laser is employed, using active imaging principles. The line laser emits additional light onto objects, streamlining mathematical calculations and enhancing pathway condition detection accuracy. The system effectively estimates the distance between hindrances and wheelchair, providing detailed information about obstacle locations in relation to the wheelchair's position.

CRITICAL ANALYSIS:

The research introduces a novel approach to obstacle detection and navigation for smart wheelchairs, leveraging computer vision and the integration of a line laser and camera. This approach aims to enhance the mobility of quadriplegic individuals. The combination of image processing technologies, such as Raspberry Pi 2 and OpenCV, demonstrates a practical implementation for real-world applications.

However, certain limitations should be considered. The paper discusses obstacle recognition but lacks a comprehensive evaluation of the proposed system's performance in real-world scenarios. Furthermore, while the combination of a line laser and camera is explored, the paper would gain from a more comprehensive examination of the technical obstacles and constraints associated with this method, as well as possible enhancements or alternative strategies. The paper successfully presents an innovative concept for obstacle detection and navigation, yet further research and experimentation are needed to validate its practicality and effectiveness in assisting individuals with disabilities.

2.3 AUTONOMOUS CAMERA BASED EYE CONTROLLED WHEELCHAIR SYSTEM USING RASPBERRY-PI.

The core principle underlying the system in [11] is the detection of eye pupils and eye tracking, facilitated by computer vision technology. A novel algorithm has been introduced for accurately detecting the location of the eye pupil through image processing. This innovative technique forms the basis for an independent and cost-effective system. The primary objective of this eye-controlled electric wheelchair system is to provide disabled individuals with a newfound sense of independence, reducing their reliance on external assistance. The system allows users to navigate the wheelchair without the need for external help.

The system operates by monitoring and detecting the eye pupil's location through image processing methods. A camera is positioned at the front to draw images of either left or right eye, based on which the wheelchair's motor is directed to move in the desired direction—left, right, or forward. For safety purpose, an ultrasonic sensor is mounted at the front of the designed system to recognize obstacles and automatically stop the motion when obstacles are detected. The design also includes a Raspberry Pi board, allowing system access without a display unit to keep costs down.

The real-time image capture and analysis are carried out with minimal delay, utilizing Face, Eye, and Eye Pupil detection based on the OpenCV (Open Computer Vision). Numerous computer vision techniques, such as object detection, movement detection, edge detection, and pattern matching, are employed. The Raspberry Pi microcontroller processes the output signals of digital image processing and sends control signals towards the driver controller, dictating motor operations.

Each wheel of the wheelchair is equipped with an individual motor. The system operates autonomously, and its modules function independently. Adequate and standardized power supplies are essential for the design, such as the Raspberry Pi, camera, motors, and sensor. The Raspberry Pi board serves as the system's central processing unit, connecting components like the monitor, camera, power circuit, and Wi-Fi module. The Raspberry Pi board can be accessed remotely over the internet, enabling emergency control and monitoring.

Challenges lie in the exact identification of the location of eye pupil. A new image processing technique has been developed for detecting and tracking the eye pupil, primarily relying on the OpenCV of Python. The system architecture allows accurate connection to a desktop using Putty software, with coding predominantly in Python. Overall, this system represents a significant advancement in assistive technology, providing greater independence and mobility to individuals with disabilities.

CRITICAL ANALYSIS:

The system's innovative approach to electric wheelchair control through eye movements and image processing is commendable. It offers a valuable solution for individuals with disabilities, enhancing their independence and mobility. The combination of eye tracking and obstacle detection provides a comprehensive solution to facilitate autonomous navigation.

However, implementation and testing of the system in real-world scenarios could be discussed more briefly in this paper. Performance metrics, user experiences, and potential challenges or limitations need to be explored to assess the system's effectiveness. Additionally, security and safety aspects, especially regarding remote access over the internet, should be elaborated upon. The integration of the Raspberry Pi board and the use of the OpenCV library for image processing demonstrate a technically sound approach. Yet, further research and development are necessary to refine the system and make it accessible to a broader user base.

2.4 BRAIN-CONTROLLED WHEELCHAIR REVIEW: FROM WET ELECTRODE TO DRY ELECTRODE, FROM SINGLE MODAL TO HYBRID MODAL, FROM SYNCHRONOUS TO ASYNCHRONOUS.

Study in [12] is an output-independent model of human-computer interaction. Over the last three decades, scientists have become so interested in it that it has finally become a research center. As a typical BCI application, a brain-controlled wheelchair (BCW) could provide a new channel of communication with the external environment for people with physical disabilities. In this review, its examined BCW from several perspectives, including the type of signal acquisition, the command pattern of the control system, and the operating system of the control system. In addition, based on previous research, it’s summarized the development trend of BCW, and it is mainly shown in three aspects: from wet electrode to dry electrode, from single-mode to multi-mode, and from synchronous control to asynchronous control. With the continuous development of BCW, new features have been added to BCW that increase its stability and durability. It is believed that BCW will make its way from the laboratory to real life and will be widely used in rehabilitation in the future. In amyotrophic lateral sclerosis (ALS), degenerated motor neurons contribute to the slow decline of muscle motor function. Thus, the brain gradually loses all voluntary functions and control functions. Central nervous system exhibits structural and functional plasticity after injury, but that plasticity depends on functional compensation of the central nervous system. Functional compensation does not happen automatically, but requires special learning and training.

A BCI can replace, enhance, improve, mediate and improve the normal output of the central nervous system by sensing the activity of the central nervous system and converting it into artificial output. Thus, BCIs can realize a direct connection between the brain and the outside world and contribute to the recovery of motor and cognitive functions of patients. This article is mainly about discussing the applications of BCI in the field of EW and the development process of BCW. This article aims to explore the origins, development and future of BCW. More specifically, summarizing the development trend of BCW, which is mainly manifested in three aspects: from wet electrode to dry electrode, from single-mode to multi-mode, and from synchronous control to asynchronous control. Thus, it can provide technical information to researchers and popular science information to the public. The actual BCW mainly consists of three parts: EEG search system, control module and EW. The EEG acquisition system captures the EEG signals of the patient's mental readiness and then sends the collected signal to the control module [15]. The control module extracts the necessary data that is used to control the EW engine. The motor then performs a predetermined action according to the electrical level of the signal, such as rotating or moving the EW in a certain direction.

CRITICAL ANALYSIS:

An EEG sensor is used but challenge is that how to decode a multi-degree of freedom control instruction from EEG as soon as possible. The biggest limitation is accuracy in reading the signals. There are billions of neurons in the human body that are firing various signals at any given time.

Also, it is generally difficult to read electrical signals derived from our brains, since they have a very low voltage. Furthermore, there are a lot of noisy signals generated in our surroundings that have a higher voltage and may interfere with the detection of the precise signals of our brain.

2.5 A NOVEL STRATEGY FOR CONTROLLING THE MOVEMENT OF A SMART WHEELCHAIR USING INTERNET OF THINGS.

The research described in [18] revolves around the development and features of a smart wheelchair that offers diverse control options and can be accessed remotely via the internet. It introduces several unique aspects, such as modular control modules and the utilization of a Raspberry Pi for master control. The research aims to create a cost-effective, user-friendly, expandable, and reliable electric wheelchair tailored to quadriplegics and paraplegics. One of the distinctive features of the research is the flexibility it offers to users and caregivers. They can select specific control modules to integrate into the wheelchair, reducing costs and tailoring the chair to individual needs. Additionally, the control system is designed to easily accommodate future modules.

The research demonstrates an innovative approach through a prototype that employs a Raspberry Pi for controlling the wheelchair via the internet, making it accessible from anywhere globally.

CRITICAL ANALYSIS:

One potential limitation is the cost associated with integrating various control modules and using a Raspberry Pi for master control. While the system aims to be economical, the cumulative expenses of multiple modules and hardware components may still pose financial challenges for some users.

The inclusion of multiple control modules and the Raspberry Pi system may increase the complexity of the wheelchair. This complexity can be a limitation for users who may find it challenging to understand and operate the different control options effectively. With the integration of various components and control modules, the maintenance and troubleshooting of technical issues could become more intricate. This may require specialized technical knowledge or support, which could be a limitation for some users or caregivers.

2.6 DESIGN AND DEVELOPMENT OF SMART WHEELCHAIR SYSTEM USING HAND GESTURE CONTROL

This research in [19] introduces a semi-automated smart wheelchair system designed for control through a multi-input user interface based on hand gestures. It leverages an accelerometer sensor, as detailed in [16], and relies on an Android application in conjunction with a Bluetooth module for communication. Users have the capability to issue control commands, which are then processed by a microcontroller to govern the operation of the wheelchair. The primary responsibility of the user is to guide the wheelchair in their desired directions, making it a valuable mobility solution for individuals with significant motor disabilities.

The key components of the system includes motion sensor, a Bluetooth, a relay, electric motors, dc power supply, and a microcontroller. It allows the use to directly interact with the system using two distinct interfaces that are hand gestures and single-touch commands through the accelerometer sensor and mobile application respectively. The Arduino UNO was chosen for its efficiency and compatibility with the system. A MEMS sensor is employed to measure hand orientation and interpret hand movements, thus enabling users to control the wheelchair's direction. This accelerometer sensor boasts high sensitivity and can detect factors like inclination, acceleration, and vibration along the x-, y-, and z-axes concurrently, measuring changes to calculate acceleration. The alignment of the user's hand is a pivotal factor in ascertaining the user's desired wheelchair direction. The system is meticulously programmed to respond to accelerometer sensor values within predefined minimum and maximum ranges for each directional motion.

CRITICAL ANALYSIS:

The system's sensitivity to hand movements might lead to unintended commands, resulting in issues with precise control, especially in situations where users may experience involuntary hand motions or tremors.

The smartphone control aspect via the Bluetooth module is subject to the limited range of Bluetooth connectivity. Users may face connectivity issues if they move out of range, potentially limiting the wheelchair's operability. The system's dependence on a mobile application for control might pose limitations for users who are not proficient with or lack access to smartphones. It may not be suitable for those who require a more intuitive and direct means of control.

2.7 EFFECTUAL GESTURE CONTROLLED SMART WHEELCHAIR FOR THE INCAPACITATED.

The primary research's objective in [21] is to develop an advanced wheelchair control system that offers accessibility to individuals with various disabilities, such as deaf and dumb, paralyzed individuals, and the blind. The main purpose of this study is to design a system that is capable of autonomous movement in all directions. This system aims to provide newfound mobility freedom for those with limited mobility through the use of electric wheelchairs equipped with acceleration sensors, obstacle sensors, and computer-based controls.

The smart wheelchair operates by tilting the acceleration sensor, enabling it to move in any of the four primary directions. It incorporates obstacle sensors to assist users, especially those who are still in the learning phase, in maintaining control over their mobility devices. Users and their caregivers can determine the level of control the wheelchair assumes. If an obstruction is detected, the wheelchair halts immediately.

Individuals unable to use their hands can operate the wheelchair and other attached devices solely through head movements. The system can cater to users who maintain control over their head movements, making it an effective method of interaction. The project's handicap wheelchair relies on a two-axis accelerometer sensor, with the wheelchair's movement direction determined by the sensor's output. The acceleration sensor forms the core of this project for handicapped wheelchairs, offering various sensors and controls to facilitate user interaction. Another goal is to help patients reduce pain by customizing the wheelchair to their unique needs.

This wheelchair control system is developed using hybrid technology, integrating both MEMS accelerometer sensors and flex sensors. The accelerometer sensor is implanted into the user's cranium to facilitate directional control. The chair moves according to the user's head orientation. If the user tilts their head forward more than 20 degrees, the chair moves forward; tilting the head back results in a turn, while left and right head tilts make the chair shift in those respective directions. The system also includes a voice announcement unit for non-verbal users who operate the wheelchair using flex sensors. The flex sensor allows users to convey their feelings by moving their fingers in various directions, which are then converted to voice messages. For visually impaired users, a specialized keypad with four buttons assists in navigation.

To meet the needs of individuals with various physical abilities, this technology integrates voice playback capabilities and a user-friendly interface for creating voice sequences. The proposed system utilizes Proteus software for simulations, employing a hybrid technology that combines MEMS accelerometer sensors and flex sensors. The integration of these sensors allows the wheelchair to move in different directions based on user input.

CRITICAL ANALYSIS:

The requirement for implanting an accelerometer sensor in the user's cranium is an invasive procedure that may not be suitable for all individuals, and it involves inherent risks. Operating the wheelchair through head movements and flex sensors can be complex, potentially requiring a significant learning curve and limiting usability for some users.

The system's effectiveness heavily relies on the accurate and consistent performance of the implanted sensor, and any sensor malfunctions could disrupt the wheelchair's functionality.

While the system aims to assist visually impaired users, the keypad's four-button navigation may still present complexities for some users. Also the system does not detail external control or emergency override mechanisms, which are essential for safety and caretaker intervention.

2.8 AUTOMATIC WHEELCHAIR USING GESTURE RECOGNITION.

This project in [22] centers around the creation of a wheelchair system designed to assist individuals with physical disabilities. The primary objective is to create a versatile system that allows robust interaction with the wheelchair, offering different levels of control and sensing. The project revolves around an automatic wheelchair that operates based on the principles of acceleration. It incorporates a single acceleration sensor with two axes, where the sensor's output varies in response to applied acceleration. A simple formula is applied to calculate the degree of tilt, and this tilt output determines the direction of movement.

Obstacle sensors are an integral part of the wheelchair, with four sensors installed to detect obstacles or walls in the all four directions. The project's objective is to create a wheelchair control system that can interpret and act upon NLP commands, enabling movements in forward, backward, left, and right directions. The wheelchair, equipped with acceleration and obstacle sensors, offers a degree of independence to users with limited mobility.

By tilting the acceleration sensor, the wheelchair can be moved in four primary directions. The obstacle sensors provide assistance in steering and obstacle avoidance until the user becomes proficient in handling the chair. The level of user control versus automated assistance can be adjusted according to the user's preferences and their caregiver's discretion. The system also integrates with head movements and computer interfaces, allowing users to operate the wheelchair and other assistive devices using the same controls. This feature is particularly beneficial for individuals who cannot use their hands.

The project's preliminary work focuses on developing a wheelchair system that responds to head movements for direction control. Users can influence the wheelchair's direction of movement through head tilting while receiving obstacle detection capabilities to avoid collisions. This makes the wheelchair suitable for use in environments with narrow ramps and doorways. The proposed system aims to facilitate automatic movement in forward, backward, left, and right directions through head gesture motion, enhancing the mobility of individuals with physical disabilities.

CRITICAL ANALYSIS:

Utilizing head movements and managing the interaction between various sensors may present a steep learning curve for users and caregivers. Incorporating seamless head movements and sensor interactions into the system may pose integration challenges that need to be addressed. The system's reliance on head tilting, especially at specific angles, may not be suitable for all users, potentially excluding those with limited head mobility.

Users may require time to adapt to the system, especially if they are not accustomed to using head movements for control.

2.9 SMART WHEEL CHAIR USING TOUCH SCREEN WITH OBSTACLE DETECTION.

The fast-paced advancements in technology have opened up opportunities to develop smart wheelchair systems for patients dealing with cognitive disabilities and impairments. These modern systems incorporate touch-screen interfaces, offering an advantage over traditional self-propelled wheelchairs by reducing the physical effort required for navigation. Notably, they come equipped with obstacle avoidance capabilities, enhancing safety in both unfamiliar and dynamic environments.

The primary objective of this project in [24] is to design and create a smart wheelchair system that empowers users to interact through a touch screen, providing various levels of control and integrating obstacle detection and collision avoidance mechanisms. These features enable efficient risk management, ultimately enhancing user safety. The wheelchair's safety features include obstacle detection to prevent collisions and hollow detection to identify potential hazards.

The central feature of the system entails the creation of a touch screen-controlled wheelchair, with user inputs facilitated through this interface. An ultrasonic sensor is used for obstacle detection in the wheelchair's pathway. Upon detecting an obstacle, the sensor transmits a signal to the Atmega microcontroller, which subsequently regulates the DC motor's operation, causing it to stop. The touch screen in the current prototype features keys as the primary input method. Additionally, the user can directly control the wheelchair by engaging the input mode.

Moreover, the wheelchair can be GSM-based, enabling the patient to access additional features. In cases where the patient experiences discomfort or requires assistance, they can send messages to their relatives or friends, signaling the need for help. The wheelchair is equipped with both a receiver and transmitter side, with the transmitter side comprising an ATMEGA328 microcontroller (Arduino UNO), touch screen, and ultrasonic sensor. A DC motor facilitates movement in various directions, and an L293D motor drive module governs the motor's direction based on signals from the touch screen inputs. Ultrasonic sensors, positioned in front, right, and left directions, employ infrared signals to detect obstacles. When any sensor detects an obstacle, the wheelchair automatically changes direction to avoid it.

The inclusion of GSM technology further enhances communication capabilities, allowing the patient to send text messages, make voice calls, and share their location with a designated caregiver. The materials used in this project encompass Arduino UNO, GSM Module, DC Motor, Ultrasonic Sensor, L293D Motor Driver, Temperature Sensor, and Flex Sensor.

The designed smart wheelchair offers users the flexibility to move the chair in any desired direction (forward, backward, right, and left) through a user-friendly touch-screen interface mounted on the armrest. The touch screen is designed to be portable, enhancing its usability. The wheelchair's robust safety features include obstacle detection, obstacle avoidance, an LED for providing illumination in dark surroundings, and a buzzer to signal emergencies and alert caregivers or nearby individuals.

CRITICAL ANALYSIS:

The effectiveness of obstacle detection and avoidance relies on the precision and reliability of the ultrasonic sensors, which may be influenced by environmental conditions. The incorporation of advanced technology may require specialized maintenance and repair services, potentially leading to increased costs. The integrated features, while beneficial, add complexity to the system, which may be overwhelming for some users.

2.10 DEVELOPMENT OF SMART WHEELCHAIR SYSTEM FOR A USER WITH SEVERE MOTOR IMPAIRMENT.

This paper in [25] presents a framework designed to assist individuals with severe motor impairments, particularly in situations where they face challenges operating a conventional joystick-based wheelchair, such as tight spaces or obstacle avoidance. The suggested framework embraces a semi-autonomous control approach, providing a smart wheelchair solution designed to cater to the requirements of individuals with profound motor disabilities. Users have the flexibility to switch between the two modes offered by this system using manual controls. The introduction of a safety map plays a pivotal role in both modes by enabling collision avoidance, thus alleviating the continuous burden on users to monitor their surroundings while maneuvering. Real-world operation experiments have validated the system's efficiency and its ability to navigate cluttered environments without collisions.

Additionally, the paper presents a semi-autonomous control system for wheelchairs with a multi-input interface to improve the mobility of individuals with severe motor impairments. Given that users may issue only few control commands in such a less time frame, the computer system takes on the responsibility of navigation and threat avoidance, allowing users to focus primarily on directing the wheelchair. This arrangement effectively addresses critical and potentially hazardous situations while preserving the user's sense of control.

The choice of input medium for issuing commands leans toward simplicity, aiming to reduce the user's cognitive load, particularly when navigating in confined spaces. A specially designed switch button is employed to issue commands, offering a straightforward user interaction method. The sensor suite, including the laser and Kinect, plays a pivotal role in detecting obstacles and potential threats within the wheelchair's vicinity. The IMU sensor contributes to correcting the wheelchair's heading orientation, improving the overall control accuracy.

In the system's operation, the primary role of human-computer interaction (HCI) inputs is to steer the wheelchair in the direction the user intends, particularly in the manual mode. During this stage, the computer system assumes responsibility for navigation and low-level control, significantly minimizing the user's involvement and increasing overall comfort. If the user desires to halt or change the predetermined path, they can issue a "stop" or "manual" command using the switch.

Notably, gaze direction is employed for commanding "left" and "right" movements, mirroring natural human behavior during direction changes while walking or driving. User safety is a top priority in all operating modes, with a safety map ensuring collision-free motion.

CRITICAL ANALYSIS:

Implementing the proposed system may require sophisticated sensor and computing hardware, potentially increasing system complexity and cost. Users may need time to adapt to the system's control modes and interactions, and some users may find the switch-based control method challenging. Accurate calibration of sensors and user-specific adjustments may be necessary, potentially leading to a learning curve. Technical malfunctions or software issues could affect the system's reliability and user experience.

While the system aims to improve user comfort, individual preferences and ease of use may vary. Efforts to address these limitations are vital to ensure the system's accessibility and usability for individuals with severe motor impairments.

2.11 AUTONOMOUSLY CONTROLLED INTELLIGENT WHEELCHAIR SYSTEM FOR INDOOR AREAS.

This study in [26] presents a system that is created for intelligent wheelchairs, specifically designed for indoor navigation. A smart and an autonomous wheelchair that is intelligent also, refers to an electric-powered system with the ability to autonomously reach designated destinations without the need for user intervention. Path finding in outdoor environments can be facilitated using global positioning systems (GPS), but for indoor spaces, interior mapping and path planning algorithms are essential. The interface leverages building floor plans and path finding algorithms to chart a course to the selected destination. Fuzzy logic is employed to autonomously control the electric-powered wheelchair based upon the predetermined location. As the hardware implementation is concerned, the system is equipped with a depth camera, a single-board computer, microcontrollers, speed sensors, lighting systems, and a motor driver. These components work in coordination, enabling obstacle detection and synchronous path adjustments, which can be simulated using software.

The development of software have already facilitated the execution of intelligent controlling algorithms and the processing of statistics obtained through sensors. User-provided location information, entered via a touch screen projected onto the software interface, is used to determine the wheelchair's position. The software on a single-handed computer board, computes the most efficient route using this location data. Images from a depth-sensor camera are analyzed, and the responsible movement instructions are sent to the wheelchair's motion controller for driver circuit. Collision avoidance features and controlling commands are integrated to find and recognize hindrances and mitigate risks. The intelligent wheelchair features a front-facing depth-sensing camera to detect and identify elements in the environment. A single-board computer is employed to enhance the system's capabilities, including indoor map-based positioning, path finding, and motor control via movement commands. The depth camera is integrated to allow the system to avoid obstacles coming in the way of wheelchair. If the system find any unexpected hindrance in its way, it goes through the alternative path to reach its destination location. To optimize processing power and responsiveness, four microcontrollers are incorporated into the system. The intelligent wheelchair's movement is managed using a dual-channel DC motor driver card. Speed sensors are integrated to precisely measure the distance covered by the motors. The study also utilizes CoppeliaSim software, chosen for its offering features equivalent to the high end other software applications that can be used for this purpose.

CRITICAL ANALYSIS:

Implementing the hardware and software components described can be complex and potentially costly, posing challenges for practical deployment and affordability. Users may require training to operate the system effectively, as it introduces new technology and interfaces that may be unfamiliar. The reliability of sensor-based obstacle detection and avoidance is critical, and any malfunctions or inaccuracies could pose safety risks.

The system may require regular maintenance and updates to ensure proper functionality, which could be a burden for some users. Users may experience sensory overload due to the multitude of sensors and feedback mechanisms integrated into the system. Addressing these limitations is essential to ensure that the autonomously controlled intelligent wheelchair system can be a viable and effective solution for users with mobility challenges in indoor environments.

RELATED WORK TABLE:

Table 2-1: references, years related work along with limitations

Ref	Year	Related Work	Limitations
[21]	2022	Effectual Gesture Controlled Smart Wheelchair for the Incapacitated.	Building a control system can become prohibitively expensive. Additionally, performing soldering on flex sensors can be a challenging task
[19]	2022	Design and Development of Smart Wheelchair System Using Hand Gesture Control.	An accelerometer is designed to detect changes in velocity, not constant velocity. It's incapable of measuring rotation around its own axis. Its operation relies on external power. Additionally, accelerometers cannot

			differentiate between sitting and standing still.
[26]	2021	Autonomously Controlled Intelligent Wheelchair System for Indoor Areas.	When using your power wheelchair outdoors, it's important to proceed with caution and at a reduced speed when handling different types of terrain. Failing to do so can result in a loss of control, potential chair entrapment, or damage to the wheelchair itself
[12]	2021	Brain-controlled wheelchair review: From wet electrode to dry electrode, from single modal to hybrid modal, from synchronous to asynchronous.	An EEG sensor is employed, but the challenge lies in quickly deciphering multi-degree of freedom control commands from EEG signals. The most significant limitation is the accuracy of interpreting these signals. Furthermore, reading electrical brain signals can be inherently difficult due to their extremely low voltage.
[24]	2020	Smart wheel chair using touch screen with obstacle detection.	The sensor may not be activated by hard objects like pens or fingernails. Water can sometimes cause false triggers. The presence of materials on the screen can lead to unresponsive areas until they are removed.
[7]	2020	Wheelchair control system based on gyroscope of wearable tool for the disabled.	The design lacks practicality for patients, as it doesn't account for the need to change the direction of head movement. Additionally, it doesn't incorporate a method for steering the wheelchair around obstacles
[10]	2016	A laser-vision based obstacle detection and distance estimation for smart wheelchair navigation.	The paper utilizes a camera for its operations, but relying solely on a camera for pathway condition detection proves to be challenging and time-

			consuming due to the processing required.
[11]	2015	Autonomous camera-based eye-controlled wheelchair system using raspberry-pi.	Tracking the eye pupil in low-light conditions can be challenging. The primary drawbacks include complexity, reduced accuracy, and increased expenses.
[18]	2014	A novel strategy for controlling the movement of a smart wheelchair using internet of things.	A joystick control system is in use, but it can be quite challenging for individuals with complete paralysis, as it may be very difficult for them to operate such systems.
[22]	2013	Automatic wheelchair using gesture recognition	While power wheelchairs may come with certain drawbacks, it's worth noting that many of these disadvantages can be mitigated or even transformed into advantages through the investment of additional funds or the incorporation of extra features.
[25]	2012	Development of Smart Wheelchair System for a User with Severe Motor Impairment.	The paper does not put forth a comprehensive assessment of the overall system's reliability. Additionally, there is no measurement provided for cognitive complexity..

Chapter-3

DESIGN AND METHODOLOGY

This section outlines the blueprint for the entire system's construction and operation. This section serves as the cornerstone for implementing the project's objectives, offering a comprehensive explanation of how the proposed system or methodology will function. It encompasses the technical infrastructure, procedures, tools and components that will be employed to achieve the project's goals. In this section, we delve into the intricacies of system design and methodology, providing a clear roadmap for readers to understand how the project will be executed and what techniques will be employed to achieve our aim.

3.1 SYSTEM DESIGN COMPONENTS

3.1.1 HARDWARE COMPONENTS:

Hardware components used in this project are Ultrasonic sensor hc.sr04, Arduino UNO, GSM sim800l, touch sensor TTP223B, Motor Driver l298n , IR proximity sensor, lithium ion battery, Gyro mpu6050, DC Motors,

3.1.1.1 ARDUINO UNO

The Arduino UNO is a widely utilized microcontroller board within the Arduino platform, designed for open-source electronics projects. It features the Atmega328P microcontroller, offering multiple digital and analog input/output pins that enable the connection of sensors, actuators, and other components for diverse project development. Known for its user-friendly and straightforward operation, the Arduino UNO is particularly suitable for beginners in electronics and programming. It facilitates programming through the Arduino Integrated Development Environment (IDE), which utilizes the C/C++ programming language. This IDE enables code creation, uploading to the Arduino board, and interaction with a variety of sensors and devices.

Figure 3.1 Arduino UNO

Arduino UNO boards find applications in a range of fields, including robotics, home automation, data logging, and prototyping. They serve as a versatile platform for electronics experimentation and project development, making them an essential tool for many enthusiasts and innovators. Figure 3.1 shows the arduino UNO component.

3.1.1.2 ULTRASONIC SENSOR

An ultrasonic sensor, sometimes known as an ultrasonic distance sensor or ultrasonic transducer, is a specialized tool employed in various scenarios, particularly for tasks related to gauging distances and detecting objects. It operates based on a fundamental principle: it emits high-frequency sound waves, typically beyond the range of human hearing, and subsequently detects the returning echoes generated when these sound waves encounter an object or obstruction. This sensor comprises a transceiver capable of both sending and receiving ultrasonic signals. To determine distances or identify objects, the sensor emits a brief burst of ultrasonic waves in a specific direction. These waves travel through the air at a consistent speed. Upon encountering an object, a portion of these sound waves rebounds towards the sensor.

The sensor's internal electronics precisely measure the time it takes for the emitted sound waves to return as echoes. By taking into account the speed of sound in the medium, which is typically air, and the duration for the echoes to come back, the sensor can compute the distance between itself and the object that reflected the sound waves. This distance calculation is vital for a broad array of applications, such as robotics, parking assistance systems, and industrial automation.

In essence, ultrasonic sensors are adaptable instruments that exploit high-frequency sound waves to assess distances and spot objects, relying on the precise measurement of echo arrival times to provide valuable data for a wide range of uses. Figure 3.2 shows the Ultrasonic sensor.

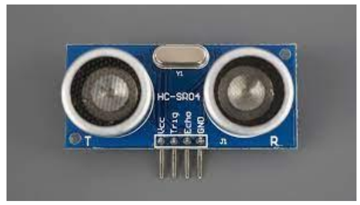

Figure 3.2 Ultrasonic sensor

3.1.1.3 DC MOTOR

A DC (Direct Current) motor is a mechanical device engineered to transform electrical energy, typically supplied by a DC power source, into physical movement. DC motors are prevalent due to their precise control and efficient functionality. They come in various sizes and types, including brushed and brushless DC motors, each tailored to specific applications. Brushed DC motors employ brushes and a commutator, while brushless DC motors depend on electronic controllers for commutation, enhancing their reliability and reducing maintenance requirements. When a voltage is applied to the brushes, an electric current flows through the armature coil. This current interacts with the magnetic field generated by the stator, resulting in a twisting force (torque) that induces the rotation of the armature. The commutator ensures that the armature keeps spinning by altering the current direction as it rotates.

The speed and direction of the DC motor's rotation can be regulated by modifying the supplied voltage. Adjusting the voltage allows for speed control, while changing the polarity (inverting the voltage) facilitates direction alteration. All in all, DC motors are a versatile choice for converting electrical energy into mechanical motion across a broad spectrum of devices and systems. Figure 3.3 represents the DC motor component.

Figure 3.3 DC motor

3.1.1.4 GYRO MPU-6050

The MPU-6050, often referred to as a gyro and acceleration module or sensor, is a compact and versatile electronic component utilized for the measurement and detection of angular movement and acceleration. This module integrates both a gyro and an accelerometer within a single integrated circuit, making it highly adaptable in various applications like robotics, drones, motion tracking, and gaming controllers. The gyroscope component within the MPU-6050 measures angular velocity, representing the speed of rotation or changes in orientation. It has the capability to detect rotational movements along its three axes: X, Y, and Z. On the other hand, the accelerometer measures linear acceleration. It is capable of sensing sudden movements, vibrations, or changes in speed along its three axes. This information is essential for comprehending the sensor's linear movement, whether it is stationary or undergoing acceleration. The MPU-6050 provides precise data on both rotational motion and linear acceleration. This information can be sent to a microcontroller or computer, which can subsequently analyze and utilize it for various applications, such as device stability, motion tracking, and enabling gesture control. Figure 3.4 is the representation of gyroscope sensor.

Figure 3.4 Gyroscope sensor

3.1.1.5 LITHIUM-ION BATTERY

A Lithium-ion battery, commonly shortened to Li-ion battery, is a type of rechargeable battery that operates by facilitating the movement of lithium ions between its positive and negative electrodes to produce electrical power. These batteries find widespread use in a variety of devices such as mobile phones, laptops, electric cars, and numerous portable electronic devices. They are valued for their high energy density, lightweight construction, and the capacity to be recharged multiple times, making them a preferred option for situations that require both portability and reusability. Below in Figure 3.5 is the illustration of lithium-ion battery.

Figure 3.5 Lithium-ion Battery

3.1.1.6 IR SENSOR

An IR sensor, short for Infrared sensor, is a device created to identify and react to infrared radiation. Infrared radiation, a form of electromagnetic radiation that is imperceptible to the human eye but can be sensed as heat, is the target of IR sensors. These sensors have the capability to notice the presence of objects or alterations in temperature and are widely utilized in a range of applications, including motion detection, temperature assessment, and technologies like remote controls that rely on communication via infrared signals. Their functionality is rooted in the capture and assessment of the infrared radiation given off or reflected by objects, with the collected data serving diverse purposes according to the sensor's construction and its intended use. Figure 3.6 shows IR sensor.

Figure 3.6 IR sensor

3.1.1.7 MOTOR DRIVER L298N

The L298N is a dual H-bridge motor driver integrated circuit that plays a crucial role in controlling the speed and direction of electric motors. It accepts input signals from a microcontroller or other control sources, allowing you to precisely manage motor operations, making it ideal for robotics, automated machinery, and various electromechanical systems. Figure 3.7 is the representation of Motor Driver component.

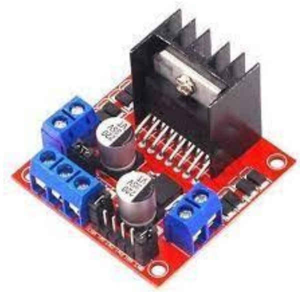

Figure 3.7 Motor Driver

3.1.1.8 TOUCH SENSOR

The TTP223B is a capacitive touch sensor module designed to detect touch or proximity without physical contact. It operates by sensing changes in capacitance when a conductive object, like a human finger, comes into close proximity. This versatile component is frequently used in touch-sensitive applications such as lamps, touch-sensitive screens, and control interfaces. Figure 3.1 shows the arduino UNO component. Figure 3.8 shows the touch sensor.

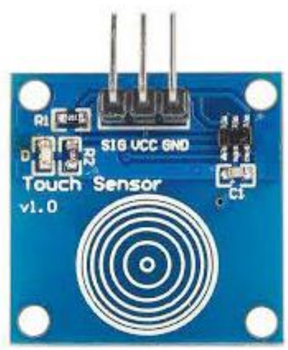

Figure 3.8 Touch sensor

3.1.1.9 GSM SIM800L

A GSM module is a compact electronic device that enables mobile communication through the GSM network. It includes key components such as a cellular modem, SIM card interface, and communication ports to support functions like SMS messaging, voice calls, and internet connectivity. These modules find applications in diverse fields, including IoT devices, vehicle tracking systems, remote monitoring, and other solutions requiring cellular communication. They can be programmed and controlled to perform specific functions by connecting them to microcontrollers or other devices. Figure 3.9 shows the GSM module.

Figure 3.9 GSM module

3.1.1.10 BATTERY CHARGING BOARD

A battery charging board is an electronic module with dedicated functions for the effective recharging and maintenance of rechargeable batteries. It incorporates features like voltage regulation, overcharge protection, and current management to guarantee the secure and efficient charging of batteries. This module finds widespread application in portable devices like mobile phones, laptops, and power banks, as well as in renewable energy systems and electric vehicles, ensuring that batteries are charged safely and optimized for performance. Figure 3.10 shows the Battery charging board.

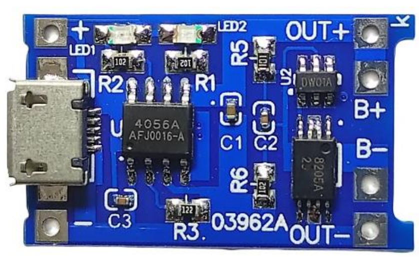

Figure 3.10 Battery charging board

3.1.2 SOFTWARE COMPONENTS

3.1.2.1 ARDUINO IDE

The Arduino IDE is a software platform created for the purpose of coding and crafting applications for Arduino microcontroller boards. It offers a unified environment that combines code writing, compilation, and code uploading for devices based on Arduino. The Arduino IDE boasts a user-friendly interface and employs a simplified programming language, ensuring that it caters to both novices and seasoned developers. It is compatible with a variety of Arduino boards and shields, making it a versatile tool suitable for crafting an extensive array of projects, ranging from basic LED blink programs to intricate embedded systems. Furthermore, the Arduino IDE is equipped with a rich library of resources and sample projects, simplifying the development process, and earning it a prominent position in the realm of electronics and IoT ventures.

3.1.2.2 TINKER CAD

Tinkercad is an online application for computer-aided design (CAD) that focuses on 3D modeling and electronic circuit design and simulation. It provides an easy-to-use and accessible platform suitable for both novices and experienced users to produce 3D models and electronic circuits, even if they lack significant technical expertise. Tinkercad is particularly valuable for educational purposes, serving as a virtual environment where students and enthusiasts can grasp concepts related to 3D design, electronics, and programming. It delivers a comprehensive set of tools and components to craft and simulate electronic circuits, making it well-suited for prototyping, especially in projects related to the Internet of Things (IoT) and embedded systems. Tinkercad's user-friendly interface and cloud-based accessibility have established its popularity among educators, hobbyists, and creators seeking to develop and experiment with inventive concepts.

3.1.2.3 VISUAL PARADIGM

Visual Paradigm is a versatile and comprehensive software application used for visual modeling, system design, and business process management. It's a powerful tool that serves software developers, system architects, and business analysts by allowing them to create visual representations of software systems, databases, and business processes. Visual Paradigm supports multiple modeling notations, such as Unified Modeling Language (UML), Business Process Model and Notation (BPMN), Entity-Relationship Diagrams (ERD), and more. Users can generate diagrams and models to plan, design, and document software systems, making it a crucial tool throughout the software development process. This software enhances collaboration and communication among project stakeholders, ensuring that the final product aligns with the initial design and requirements. It's an invaluable resource for organizations and professionals engaged in software and system development.

3.2 HARDWARE INTEGRATION

This section roots into the practical aspects of bringing our project into life. In this chapter we proceed to describe the integration of strategic hardware components, their physical assembly, working, and the configuration required to establish a unified system. The successful integration of these components forms the foundation for the seamless operation of the gesture-controlled wheelchair.

3.2.1 INTEGRATION OF GYROSCOPE SENSOR

Gyroscope sensor is a pivotal component of our project that stems for its compatibility with our system. For this, we have chosen GY-521 gyroscope sensor also recognized as MPU-6050, to track user’s gestures through hand movements and translate them into digital commands for the wheelchair. It is a triple-axes sensing MEMS component that computes angular velocity of all three axes (X, Y and Z) to provide comprehensive motion data.

Integration of gyroscope sensor begins with the process of physical connections of the sensor with the microcontroller. Seamless communication is ensured between Arduino and Gyro through I2C protocol. Inter Integrated Circuit (I2C) is a widely used protocol that allows serial communication between multiple devices using only two wires i.e. SDA and SCL. I2C provides a unique address to each component to remove ambiguity. GY-521 is also assigned a unique address to address the conflicts of ambiguity to identify the sensor. Connecting gyro with Arduino involves appropriate connections of corresponding pins of both modules. These pins configuration is given in the following Table 3.1:

Table 3-1: Pins configuration of Gyroscope

GY-521	Arduino UNO
VCC	5V
GND	GND
SCL	A5
SDA	A4

Gyroscope sensor operates at a supply voltage of 5V. The 5V power supply is readily provided through the Arduino board to ensure the stable maneuver of the sensor. The accelerometer and gyro readings are adjusted accordingly as to provide precise and reliable data for accurate motion analysis and control in the project. Sensor calibration was also ensured to obtain meticulous measurements. We fixed built-in sensor errors by making offset adjustments, which helped remove any unwanted fluctuations and interference from the data stream. The sensor's sensitivity is also adjusted to match the project's needs, to achieve accurate hand movement tracking.

3.2.2 INTEGRATION OF IR SENSORS

The Infrared (IR) sensors, applied to our system, serve as the eyes of the system as they play the key role to prevent unintentional movement in real-time and enhance the safety feature of the wheelchair. IR sensor consists of IR emitter and IR receiver as it works on the principle of emitting and receiving infrared radiations for precise proximity detection. Our system includes the reflective IR sensor that aims to detect user's hand within a predefined range or limit to activate the gyro. If no any object is detected within the range, the system will automatically understand that user is not actively operating the wheelchair hence it is at rest. Using the I2C protocol, IR sensors are connected to the Arduino using the following pins connection in table 3.2.

Table 3-2: Pins configuration of IR sensor

IR Sensor	Arduino UNO
VCC (5V)	5V
GND	GND
OUT	Digital Pin 2

The integration of IR sensors in our project's sensor array, involves three key pins for each sensor: VCC (5V) and GND for power supply and ground connection, respectively, and the Signal (OUT) pin for transmitting sensor data. The data typically consists of binary values, indicating whether the user's hand is detected within the sensor's range or not. The signal values then processed by Arduino to determine the range. If the hand is sensed in the predefined range, it indicates that the person needs to move the wheelchair.

3.2.3 INTEGRATION OF TOUCH SENSOR

In addition of the IR sensors, another vital safety feature is added to our system by the inclusion of touch sensor. Touch sensor serves as an extra layer of confidence and security. The aim is to provide individuals with mobility challenges, a means to navigate their environment with dignity, precision, and minimal effort. It assures the identification of human touch and recognizes the actions or gestures only then, in order to activate the wheelchair. Gyro will only respond to intended actions of the user once the touch sensor recognizes the human touch preventing the unintentional movement. The technical details of interfacing touch sensor with Arduino are discussed in this section. Consider the pin configuration of touch sensor integrated with Arduino, as shown in table 3.3.

Table 3-3: Pins configuration of touch sensor

Touch Sensor	Arduino UNO
VCC (5V)	5V
GND	GND
OUT	Digital Pin 3

When the touch sensor registers the presence of a human hand, it sends a signal to the system, indicating user intent. This signal becomes a crucial condition in the decision-making process for enabling or disabling wheelchair movement, working in harmony with the IR sensors. Touch sensor introduces a level of interaction beyond traditional control interfaces and technologies. It distinguishes and responds to the genuine human touch to activate the wheelchair. It eradicates the need for complex control interfaces, giving our system an enhanced user-centric perspective. the touch sensor's output is integrated into the control logic of the system so that it responds promptly and accurately to the touches and gestures of the user.

3.2.4 INTEGRATION OF ULTRASONIC SENSORS

The integration of ultrasonic sensors stands as a cornerstone in our project's sensor suite, playing a decisive role in enhancing the safety and responsiveness of the proposed system. With the integration of ultrasonic into our system, we empower the wheelchair to actively sense and observe its environment, thereby preventing collisions and ensuring user safety.

Table 3-4: Pins configuration of ultrasonic sensor

Ultrasonic Sensor	Arduino UNO
VCC (5V)	5V
GND	GND
Trigger	Digital Pin

Echo	Digital Pin

Ultrasonic sensors are impeccably connected to the microcontroller to create a real-time feedback loop that constantly inspects the environment. The integration involves three significant pins VCC, GND, Trigger and Echo pins. VCC and GND pins are for the 5V power supply and ground connections of the sensor respectively. Whereas trigger and echo pins are connected with the digital pins of Arduino. Arduino sends a pulse to trigger pin to initiate distance measurements. This trigger pulse causes the sensor to emit a burst of ultrasonic waves. These ultrasonic waves propagate through the surroundings and reflect to nearby objects and received by echo pin of the sensor. Arduino calculates the time taken by waves to return by applying the speed of sound in the space and computes the distance to the object. If the distance matches to the predefined range of the sensor, the system stops moving.

3.2.5 INTEGRATION OF GSM MODULE

The inclusion of Global System for Mobile Communications (GSM), elevates our aim to bring the real-time communication capabilities, enabling it to transmit essential information to designated recipients and enhance safety for users in outdoor environments.

The GSM module is seamlessly integrated with the Arduino, forming a robust communication link that serves multiple purposes within our project.

Table 3-5: Pins configuration of GSM module

SIM800L Pin	Arduino UNO
VCC (5V)	5V
GND	GND
TX (Transmit)	Digital Pin
RX (Receive)	Digital Pin
SIM Card Slot	SIM Card Inserted
Antenna	GSM Antenna Attached

Looking closer into the integration process, the connections include power and ground connectivity, serial communication channel and control logic. The 5V power supply and ground connection is given to the GSM through VCC and GND pins of Arduino. Communication between GSM and Arduino is specifically carried through TX and RX pins of GSM connected serially to the digital pins of Arduino. These pins are responsible to carry a communication link allowing data to be transmitted from the Arduino to the GSM module (TX) and received from the GSM module by the Arduino (RX). This bidirectional communication channel facilitates command exchange and data transfer between the two components. GSM is logically integrated to in our system to respond to predefined triggers and conditions when power loss of the system occurs.

3.3 CHASSIS DESIGN

The design of our robotic wheelchair chassis is discussed in this section. It has been observed that chassis is usually designed using acrylic sheets serving as the base of any project. Based on this observance, we chose acrylic sheet as the base of our prototype design. Connected to the base, are the 4 wheels for driving the wheelchair chassis using nuts and bolts. 2x Omni caster robot wheels mounted at the front of the acrylic sheet. 2x motor driving wheels mounted at the rear side of the chassis. These motor driving wheels are attached to the DC gear motors mounted at the bottom of the chassis. At the top of the acrylic base, Arduino UNO microcontroller is placed holding all the connection of the hardware. Above the acrylic sheet layer, is another layer made with cardboard sheet to hold the breadboard and GSM module as per the requirement. For the finishing look of the wheelchair, we used foaming sheets as the seating, back, and arm rests of the wheelchair. Figure 3.11 on p.49 demonstrates overall chassis design of the wheelchair.

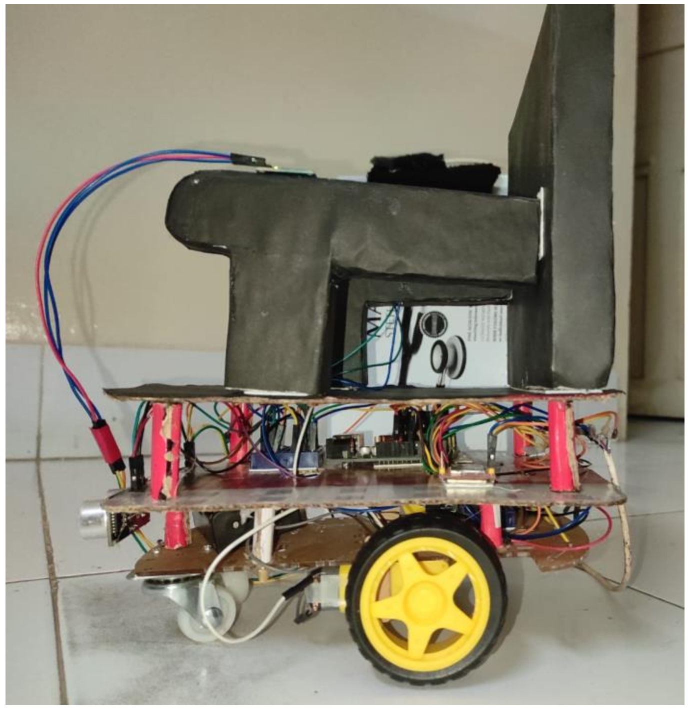

Figure 3.11 Wheelchair Chassis Design

3.4 COMPONENTS MOUNTED ON CHASSIS

Wheelchair's chassis contains some of the very vital components of our project. Hardware components that are mounted on chassis, include IR sensor, Ultrasonic sensors, GSM module, DC power supply and Microcontroller. Their placement is further discussed below. To ensure the presence of user's hand in order to activate the Gyro, IR sensor is placed on top of arm rests of the chassis design. Whenever the user places his hand in the range of IR sensor, it will send the signals to activate the wheelchair to function, in accordance with the touch sensor. Next comes the mounting of Ultrasonic sensors. According to the proposed system requirements, two ultrasonic sensors are attached to the chassis. Both at the front-bottom part of the chassis. These sensors will play the role of the eyes of the system and monitor any obstacle coming in the way of wheelchair. GSM is attached with the microcontroller and placed at the bottom layer of the chassis along with the Arduino. The 12V DC supply is given to the system by two rechargeable Lithium batteries of 5000mAH. These are also placed at the bottom layer of the chassis.

3.5 SETTING UP SOFTWARE REQUIREMENTS

3.5.1 SETTING UP ARDUINO IDE

Setting up the Arduino Integrated Development Environment (IDE) is a foundational step in preparing our project for success. In this project, we rely on Arduino IDE version 1.8.19 as the central hub for programming and communicating with the embedded circuitry. The choice of the Arduino UNO microcontroller is pivotal, serving as the project's core for seamless communication between the array of sensors and the wheelchair's control system. Additionally, the Gyroscope Sensor Board (GY-521) stands as the linchpin of our project, enabling precise gesture recognition and intuitive control. Equally significant are the Infrared (IR) Sensor Boards, strategically positioned on the wheelchair to detect the user's hand presence and aid in controlling the wheelchair's movements. The Ultrasonic Sensor Board enhances the system's safety by detecting obstacles and aiding in obstacle avoidance. To ensure real-time communication and alert generation, the GSM Module plays a vital role. This customized Arduino IDE configuration ensures that our project is well-equipped for intuitive and secure control of the gesture-driven wheelchair.

3.6 CIRCUIT DIAGRAM

A circuit diagram, also referred to as an electrical circuit diagram or electronic schematic, serves as a visual representation of an electrical circuit. It employs standardized symbols to portray the various components and connections present in the circuit, facilitating a clearer comprehension of the circuit's layout and operational principles. These diagrams encompass an array of components and they detail how these elements are interconnected. This visual representation aids in grasping the circuit's functioning and identifying and rectifying issues. Figure 3.12 on p.51 shows the circuit diagram of our project.

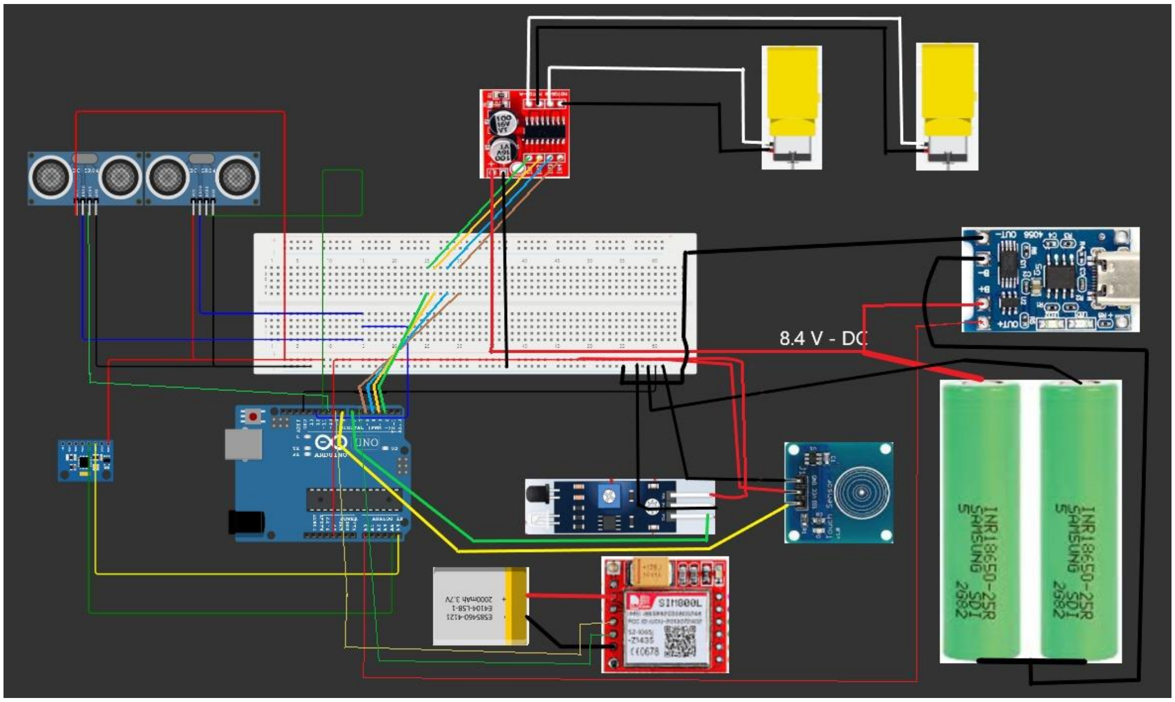

Figure 3.12 Circuit diagram of the system

3.7 WORKING FLOW OF PROJECT

3.7.1 FLOW CHART

A flowchart is a visual representation of a process or algorithm. It employs various shapes and symbols to illustrate the steps or actions involved in a sequence, providing a clear and concise way to understand complex procedures. Flowcharts are utilized in a wide range of fields, from software development to business process management, to help individuals and teams comprehend, analyze, and communicate processes and make informed decisions. Flow chart of the proposed system is given in Figure 3.13 on p.52.

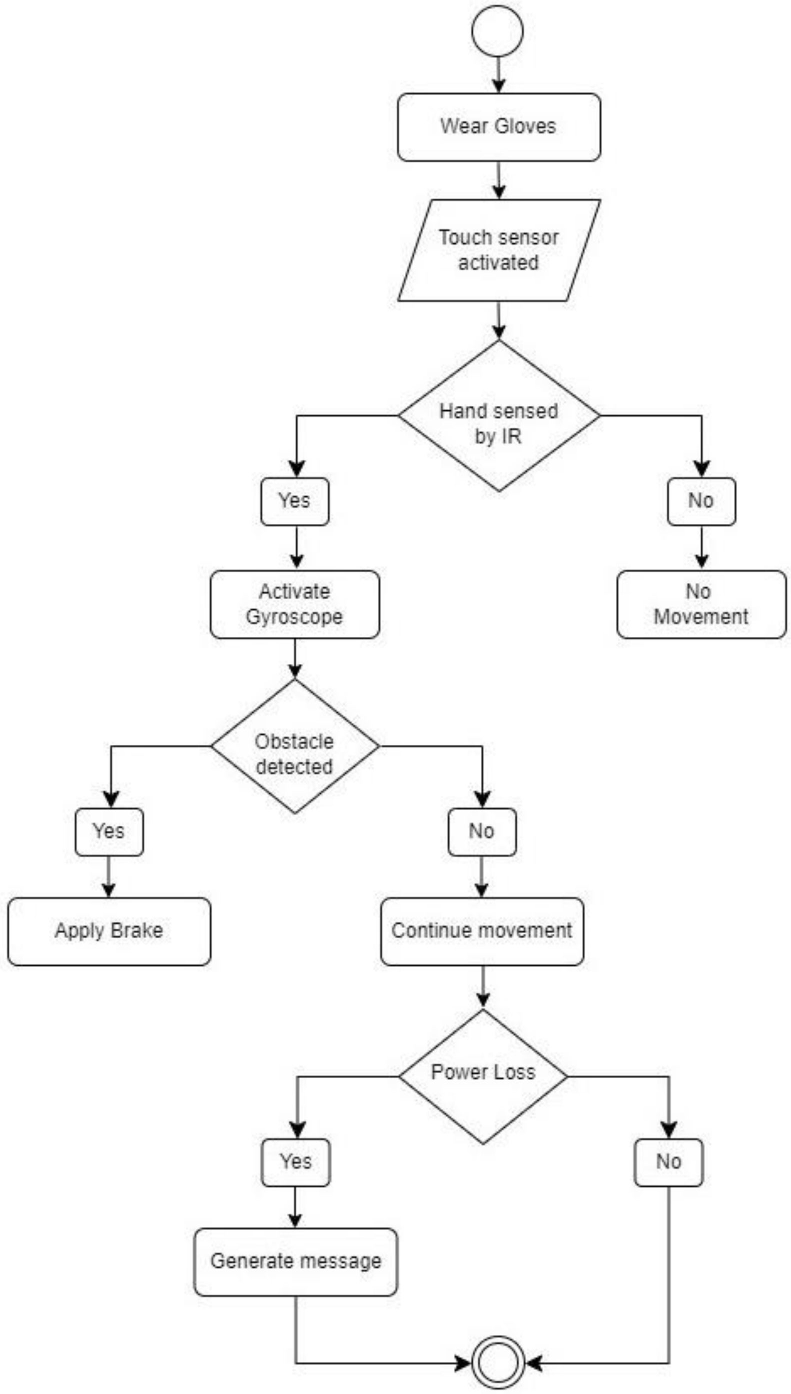

Figure 3.13 Flow chart of the system

3.7.2 BLOCK DIAGRAM OF THE SYSTEM

A block diagram is a visual representation of a system or process, utilizing labeled geometric shapes like rectangles or squares to symbolize interconnected components or stages. Each block corresponds to a specific function, operation, or component within the system, and these blocks are connected by lines or arrows to depict the flow of information, signals, or materials between them. Block diagrams are widely employed in engineering, electronics, and various fields to offer a graphical overview of intricate systems or processes, aiding in the comprehension of the system's architecture and functionality. They play a crucial role in system design, analysis, and communication across different stakeholders. The block diagram of our designed system is given below in Figure 3.14.

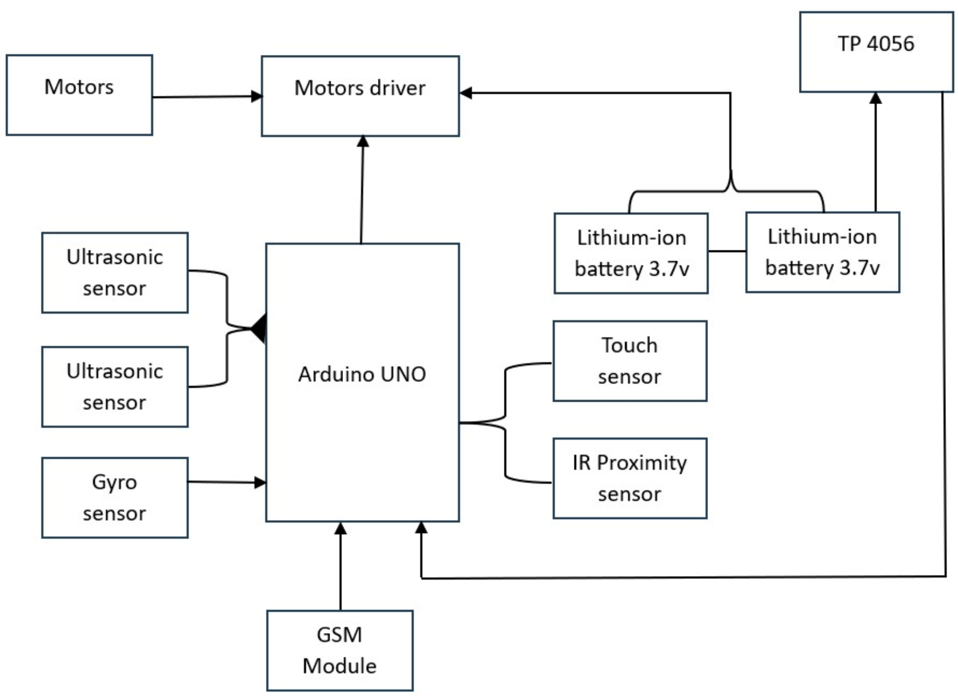

Figure 3.14 Block diagram of the system

3.8 UML DIAGRAMS

3.8.1 ACTIVITY DIAGRAM

An activity diagram is a type of UML (Unified Modeling Language) diagram that visually represents the dynamic aspects of a system, typically focusing on how business processes or workflows function. It employs various graphical elements to depict activities, actions, decisions, and transitions within a process. Activity diagrams help in modeling, analyzing, and understanding the flow of actions and business logic in a system, making them valuable tools in software development, business analysis, and other domains. Activity diagram for our project is shown in Figure 3.15.

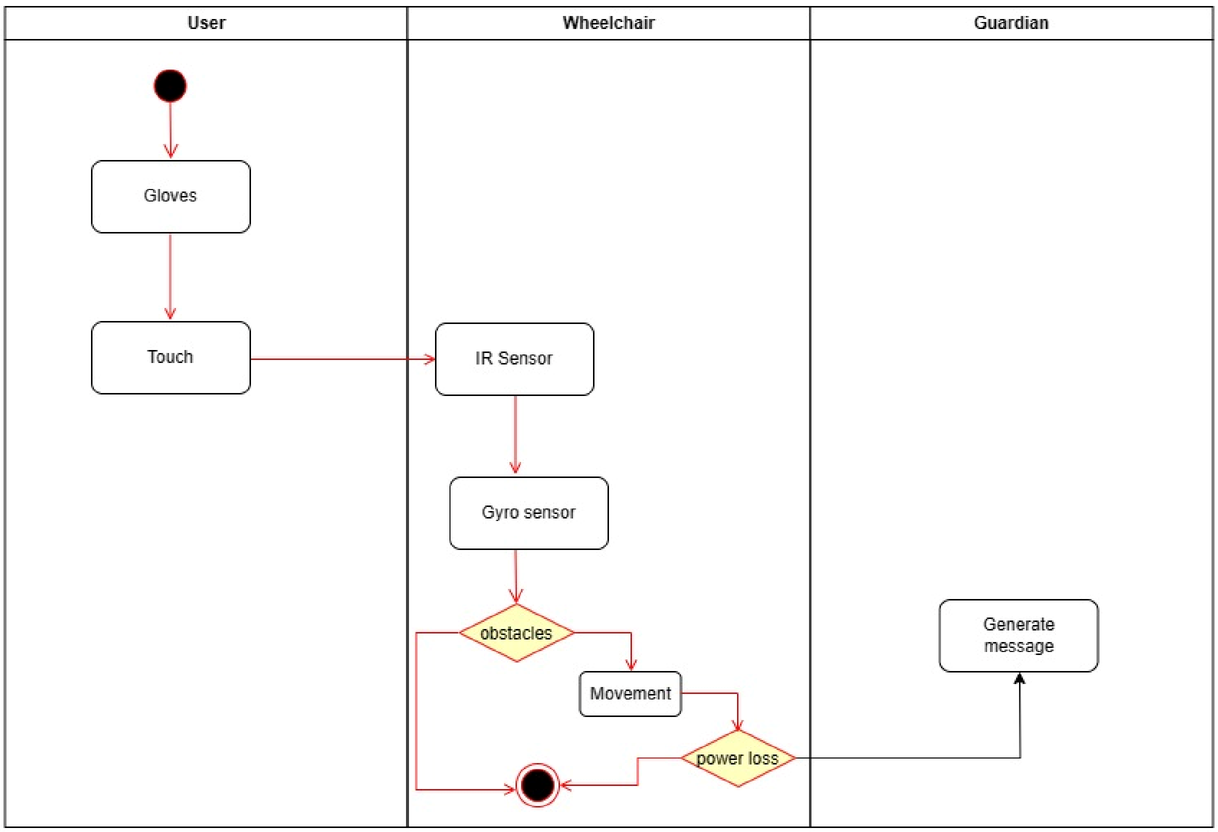

Figure 3.15 Activity Diagram

3.8.2 USE CASE DIAGRAM

A use case diagram is a visual representation within the Unified Modeling Language (UML) that illustrates interactions between external actors (users or systems) and a system under consideration. Use case diagrams depict the functionalities a system provides and how different actors interact with it. They consist of actors, use cases, and their associations, helping to clarify system requirements and facilitate communication between stakeholders, particularly in software and system design. Use case diagram for our project is given in Figure 3.16 on p.55.

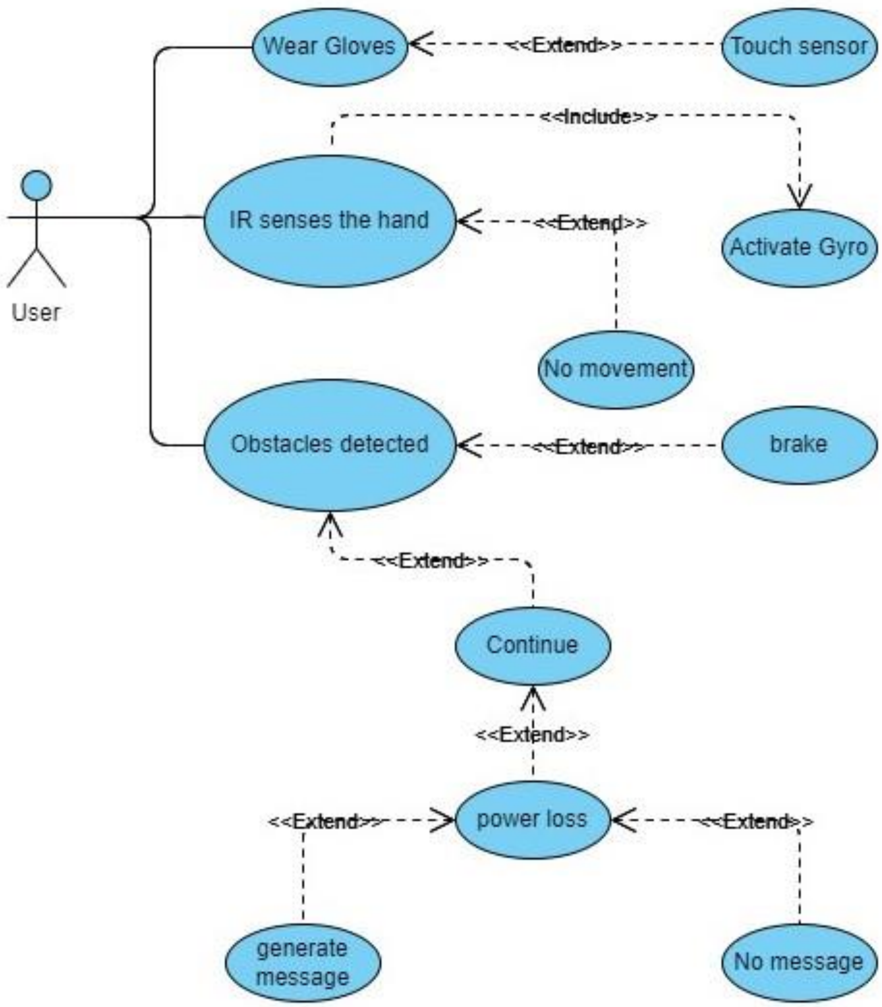

Figure 3.16 Use case diagram

3.8.3 SEQUENCE DIAGRAM

A sequence diagram is a type of UML diagram that illustrates how objects in a system interact with one another and in what sequence. It displays the chronological flow of messages and interactions among objects over time. Sequence diagrams are commonly used in software engineering to depict the dynamic behavior of a system and to understand the order of operations and interactions between various components or objects. They help visualize and analyze the exchange of messages and control flow within a system's functionality. Sequence diagram for our project is given in Figure 3.17 on p.56.

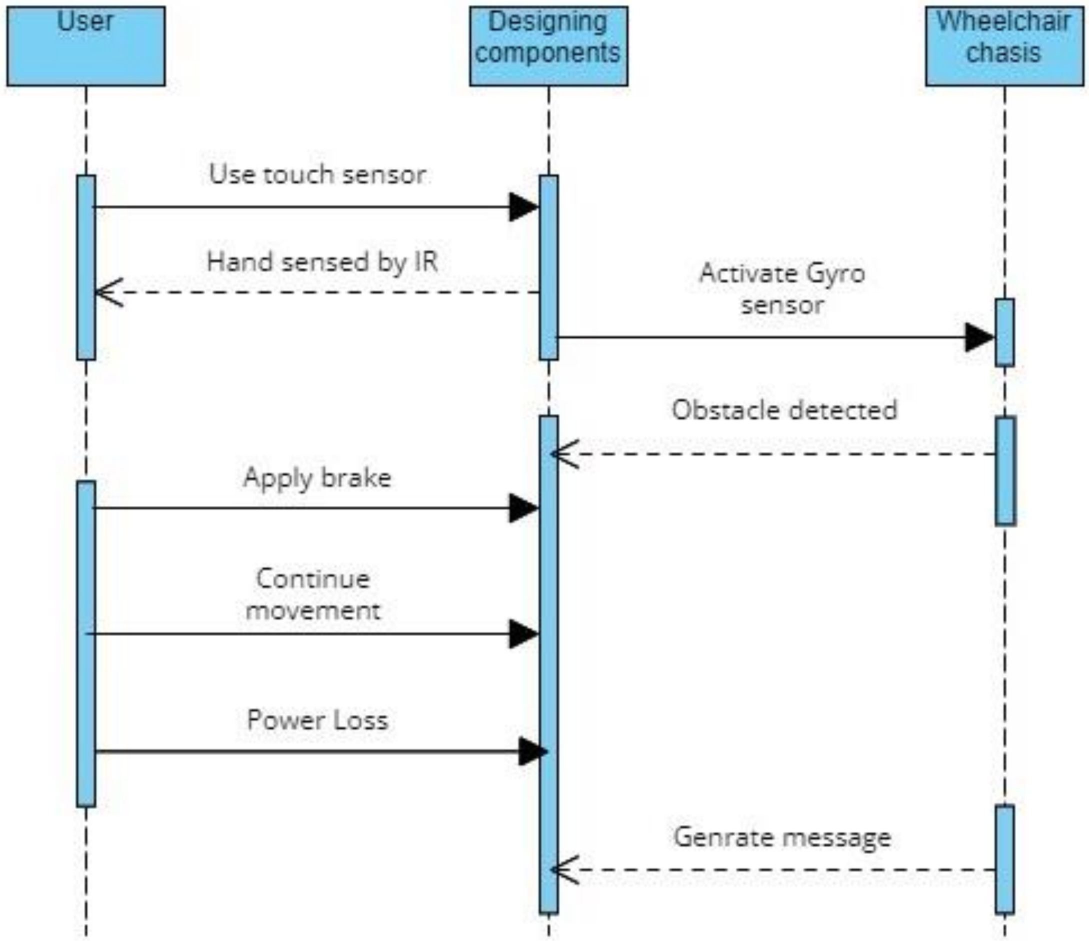

Figure 3.17 Sequence diagram

Chapter-4

RESULTS AND DISCUSSION

The journey towards innovation and the development of an assistive technology solution is a path paved with the commitment to ensure reliability, safety, and user satisfaction. In this pivotal chapter, we embark on the rigorous phase of testing and validation, where the culmination of ideation, design, and implementation is put to the ultimate scrutiny. Our gesture-controlled wheelchair system, meticulously designed to empower individuals facing mobility challenges, now faces the litmus test of its capabilities. Here, we delve into a comprehensive examination of our creation, assessing its gesture recognition accuracy, mobility, safety features, user interface usability, and more. Beyond functionality, we explore the system's response in emergency scenarios such as hurdle sensing, power loss, and motion restriction. Through this journey of testing and validation, we endeavor to ensure that our innovative solution not only meets but exceeds the expectations of those who rely on it for enhanced mobility and independence.

4.1 TESTING GYROSCOPE SENSOR

The integration and calibration of the gyroscope sensor are fundamental to ensuring the accurate and reliable recognition of hand movements. The gyroscope sensor, specifically the GY-521 model, was seamlessly integrated into the system as per the defined connection scheme. The physical connection between the sensor and the Arduino UNO was rigorously inspected to ensure that the sensor could communicate with the microcontroller effectively. All wiring, pin assignments, and communication protocols were verified to confirm that the gyroscope was an integral part of the system.

To assess the reading accuracy of the gyroscope, a series of controlled hand movements was performed. These movements were carefully recorded and compared with the corresponding sensor data. The system's ability to accurately capture hand movements along the X and Y axes was confirmed, with minimal deviation or discrepancy between the expected and measured values. The gyroscope consistently delivered precise readings, enabling the system to respond effectively to user gestures.

Recognizing and interpreting hand gestures is at the core of the gesture-controlled wheelchair system. This section assesses the system's ability to identify predefined hand gestures accurately and respond to user commands. Defining the gyroscope's axes and validating the accelerometer's range is vital for accurate hand movement tracking, ensuring that the sensor's axes are correctly defined, enabling precise tracking, and that the accelerometer operates within specified limits.

The accuracy of gesture recognition was determined by comparing the user's executed gesture with the system's interpretation. Success rates were calculated for each predefined gesture, measuring the system's ability to correctly identify and execute the corresponding command. The results indicated a high level of accuracy, with the system consistently recognizing user gestures as intended. The four hand gesture are incorporated for forward, backward, left and right motion.

Testing involved evaluating the system's ability to distinguish between different hand movements along these axes and accurately translate them into corresponding wheelchair commands. The axes' definitions were confirmed to be precise, allowing for a seamless gesture-to-movement conversion. Figure 4.1 illustrates all four gestures that recognize the wheelchair direction. Figure 4.1(a) shows hand gesture for forward direction, Figure 4.1(b) for backward direction, Figure 4.1(c) for left direction and Figure 4.1(d) for right direction.

Figure 4.1 Representation of hand gestures for gyro readings (a) For forward direction (b) For backward direction (c) For left direction (d) For right direction.

4.2 TESTING TOUCH SENSOR

To assess the efficacy of the touch sensor in detecting user interaction, a comprehensive set of controlled tests was conducted. These tests focused on the deliberate movement of the user's hand in and out of the sensor's designated field of view. The system's responsiveness to these intentional movements was meticulously observed.

During the testing phase, it was confirmed that the touch sensor accurately detected the presence of the user's touch, effectively signaling the activation and deactivation of the system. The controlled tests verified the reliability of the touch sensor in interpreting user inputs, thereby facilitating a responsive and intuitive interaction between the user and the gesture-controlled wheelchair system. Figure 4.2 shows calibration and activation of touch sensor.

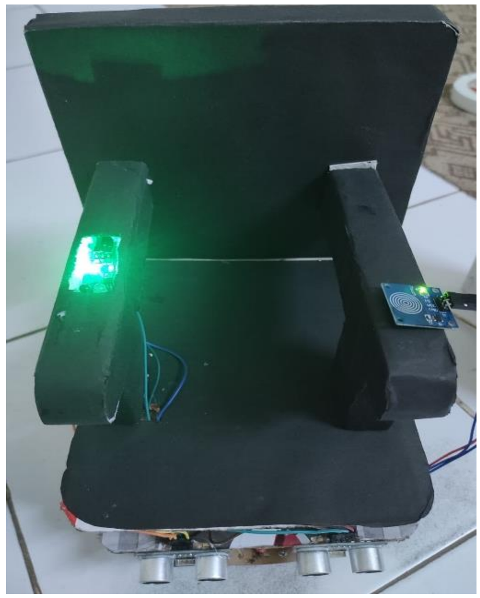

Figure 4.2 Calibration of touch sensor

4.3 TESTING IR SENSOR

The IR sensor for motion restriction in the gesture-controlled wheelchair system, is specifically integrated into the system as per the predefined configuration. The successful integration ensured that the IR sensor is seamlessly incorporated into the system's safety features.

To evaluate the effectiveness of IR sensor in detecting the presence of the user's arm/hand, a series of controlled tests were conducted. Arm were moved in and out of the sensor's field of view. The system's response to these movements was carefully monitored. The tests confirmed that the IR sensors accurately detected the user's arm/hand, allowing the system to activate and deactivate based on these inputs. The calibration of IR sensor is shown in Figure 4.3 (a) and successful working of IR is shown in Figure 4.3(b) on p.60.

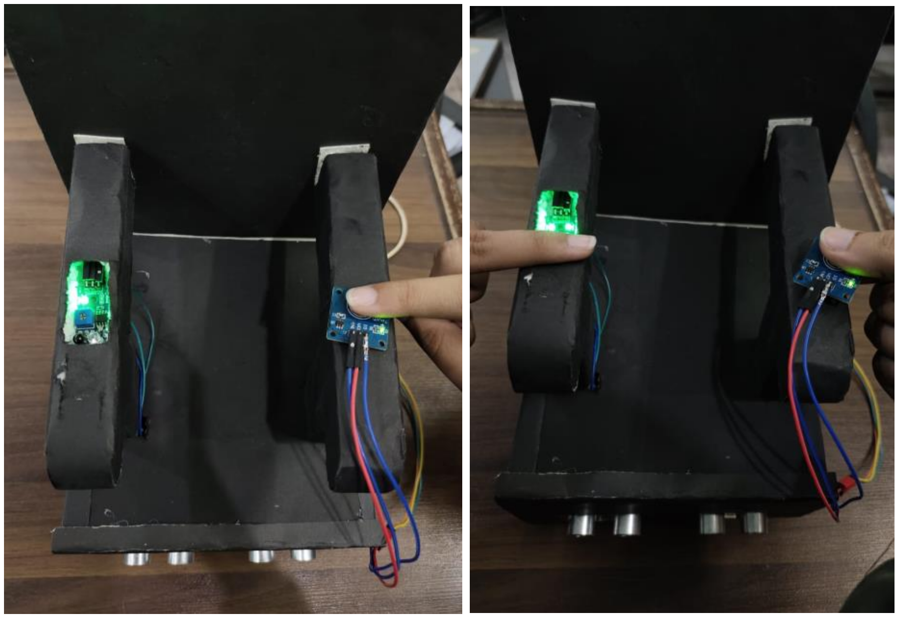

Figure 4.3(a) calibration of IR sensor (b) Hand sensed by IR sensor

4.4 TESTING ULTRASONIC SENSORS

The ultrasonic sensors, responsible for obstacle detection, were seamlessly integrated into the system. The integration process involved verifying the physical connections, setting up communication between the sensors and the microcontroller, and configuring software logic to interpret sensor data. This comprehensive integration ensured that the ultrasonic sensors were an integral part of the system's safety mechanisms.

Testing the sensors' ability to detect obstacles within their specified range was a critical aspect of the evaluation. Objects and obstacles of different sizes were placed within the sensors' 15 cm range to assess their obstacle-sensing capabilities. The results demonstrated that the ultrasonic sensors accurately detected obstacles, contributing to enhanced safety by preventing collisions. Figure 4.4 on p.61 represents the hurdle sensing by the prototype.

Figure 4.4 Hurdle sensing by ultrasonic sensors

4.5 TESTING GSM MODULE

The GSM module plays a significant role in ensuring that the user can navigate in the outdoor environment safely and for the reliable communication and alert mechanisms. When the battery is about to run out of power, and the system is near to shutdown, the GSM is instructed to trigger an alert message to the predefined contact numbers and inform the guardian beforehand. The two lithium batteries incorporated in our system to supply power, collectively give 8.4V to the Arduino. The testing of these batteries lead to the conclusion that batteries would start getting low of power at 3.4V. Thus, a threshold value of 3.6V is provided to the GSM for message generation. The testing has been done multiple times in this regard. Battery’s power consumption is also observed and analyzed thoroughly to implement the accurate threshold value of low voltage supply. Figure 4.5 on p.61 shows the estimated threshold value for battery to alert for power loss. The message generated by GSM for sending alerts to the guardian is shown in Figure 4.6 on p.61.

Figure 4.5 Voltage threshold for power loss

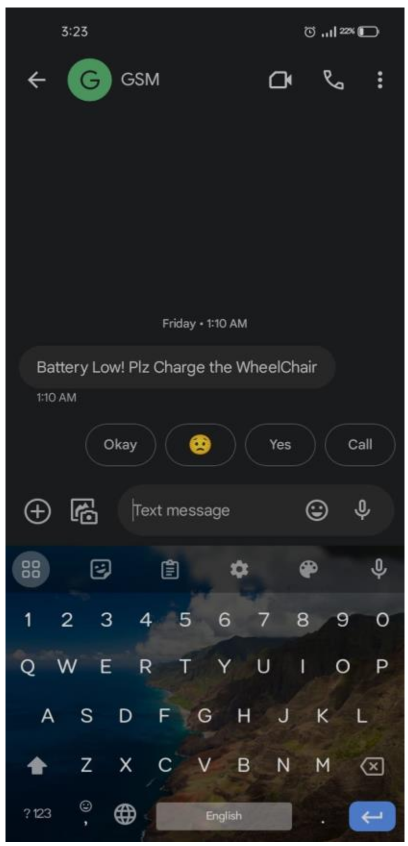

Figure 4.6 Message alert generated by GSM for low power

The message delivery speed is customized for a message to be transmitted from the system to the caregiver's device is. We have given a minimum of three contact numbers. If any of the caregiver is not present at the network, the alerts will be received by the other two with a delay of 3 seconds. In this way user would not be left helpless and alerts would not be missed by any of the caregiver or guardians.

Chapter-5

CONCLUSION AND FUTURE WORK

The concluding chapter marks the culmination of an arduous yet immensely rewarding journey, one that traversed the landscape of assistive technology to create a groundbreaking gesture-controlled wheelchair system. In this chapter, we delve deep into the intricate layers of our project, exploring not only its technical achievements but also the implications, limitations, and the promises it holds for individuals facing mobility challenges.

5.1 CONCLUSION

Our project centered on the design and integration of a comprehensive suite of hardware components. The heartbeat of our system, the gyroscope sensor mounted on a glove, serves as the neural interface, allowing users to navigate their world through nuanced hand movements. An Arduino UNO microcontroller orchestrates the system, a silent conductor translating gestures into precise actions. The infrared (IR) sensors, like vigilant sentinels, ensure that movement is initiated and halted only when necessary. The ultrasonic sensor acts as a vigilant guardian, alerting users to potential obstructions in their path. Completing this symphony of technology is the GSM module, providing real-time communication, be it a power loss or a system error, ensuring that caregivers are informed promptly.

Throughout the project, a user-centric design philosophy was our guiding star. Every aspect of our system, from the ergonomics of the gesture-controlled glove to the intricacies of safety mechanisms, prioritized the user experience. Our mission was to liberate individuals with mobility challenges, granting them newfound freedom and autonomy, and this mission has reverberated in every wire, every line of code, and every decision we made.

Upon thorough research and observance, we are able to conclude that the designed system operates at very low human efforts as compared to the manual one which costs high human intervention and resources. The design of the proposed system allows user and their caregivers a sense of freedom to navigate in the outdoor environment without being worried about constant presence of guardian. The system is successfully deployed to revolutionize the way individuals with mobility challenges, dwell in the world. Its seamless integration of cutting-edge hardware components, including the gyroscope sensor, IR sensors, ultrasonic sensors, and GSM module, not only reduces the physical wrench on users but also improves their overall quality of life. Substituting traditional joystick controls to automatic hand gestures recognition provides a new sense of autonomy empowering users, lessening the burden of care givers and encouraging independence.

The journey was marked by obstacles, from technical glitches to design challenges. Each hurdle was an opportunity for innovation. With creativity and determination, we overcame these challenges. As we conclude this phase, we also look ahead. The future promises not only refinement of our technology but also its expansion into uncharted territories of application.

5.2 FUTURE WORK

This chapter is not a conclusion, but a prologue to a future of positive change. The journey continues, lighting the way for further innovations, impact, and positive change. Though this research is based upon innovative technology implementing currently used components with new applications, there is still room for improvement of this system. Factors like power consumption and gesture recognition accuracy are areas that warrant further refinement. Some future work recommendations are given as follows:

- **i.** Inclusion of fingerprint sensor for more safety measures.
- **ii.** Backup power supply for any emergency or when the power loss occurs.
- **iii.** Powerful motors for safe lifting of the wheelchair at inclined surface.
- **iv.** GPS for the remote tracking of the wheelchair by the guardian.

With the rise in technology, there comes innovation. The proposed system can be upgraded with the span of time to bring more ease to the community of handicapped people. Our project has profound societal and ethical implications. It goes beyond mere technical innovation. It touches the lives of users, their families, and caregivers. Our technology is more than just a mechanical construct; it's a means to enrich the quality of life for individuals facing mobility challenges. This is not the end; it's a new beginning. The story of our project continues.

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