Abstract

In this paper, we introduce an innovative way to enhance the lives of individuals with mobility impairments. Our focus is on developing a voice-enabled wheelchair system that empowers users by providing them with greater independence and autonomy. Through cutting-edge speech recognition technology and advanced wheelchair control mechanisms, we aim to design a wheelchair that can be easily operated and navigated using voice commands.

The voice-enabled wheelchair brings numerous advantages, particularly for those who have limited hand dexterity or physical mobility. This groundbreaking technology allows users to efficiently move the wheelchair, adjust speed, come to a stop, and perform various functions simply by speaking natural language voice commands.

In summary, our research presents a fresh approach to empower individuals with mobility impairments through a voice-enabled wheelchair system. Our main goal is to create a wheelchair that can be controlled and navigated using voice commands, providing users with improved independence and autonomy.

The technology in this wheelchair allows users to easily navigate, control speed, stop, and perform various functions simply by using natural language voice commands. In our paper, we delve into the detailed technical aspects of the system, including the speech recognition software, interface for wheelchair control, and safety measures. We also explore the user experience, accessibility, and potential challenges that come with using voice commands in real-life situations.

Based on early user testing and feedback, it seems that this voice-enabled wheelchair has the potential to greatly improve the quality of life for individuals facing mobility challenges. Moving forward, our focus will be on refining the system, adding more features, and addressing customization options to further enhance the user experience.

To sum up, the voice-enabled wheelchair is a major step towards closing the gap in mobility and independence for people with disabilities. This technology can have a huge positive impact on the everyday lives of its users, making it easier for them to effortlessly navigate their surroundings.

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CHAPTER 1: INTRODUCTION

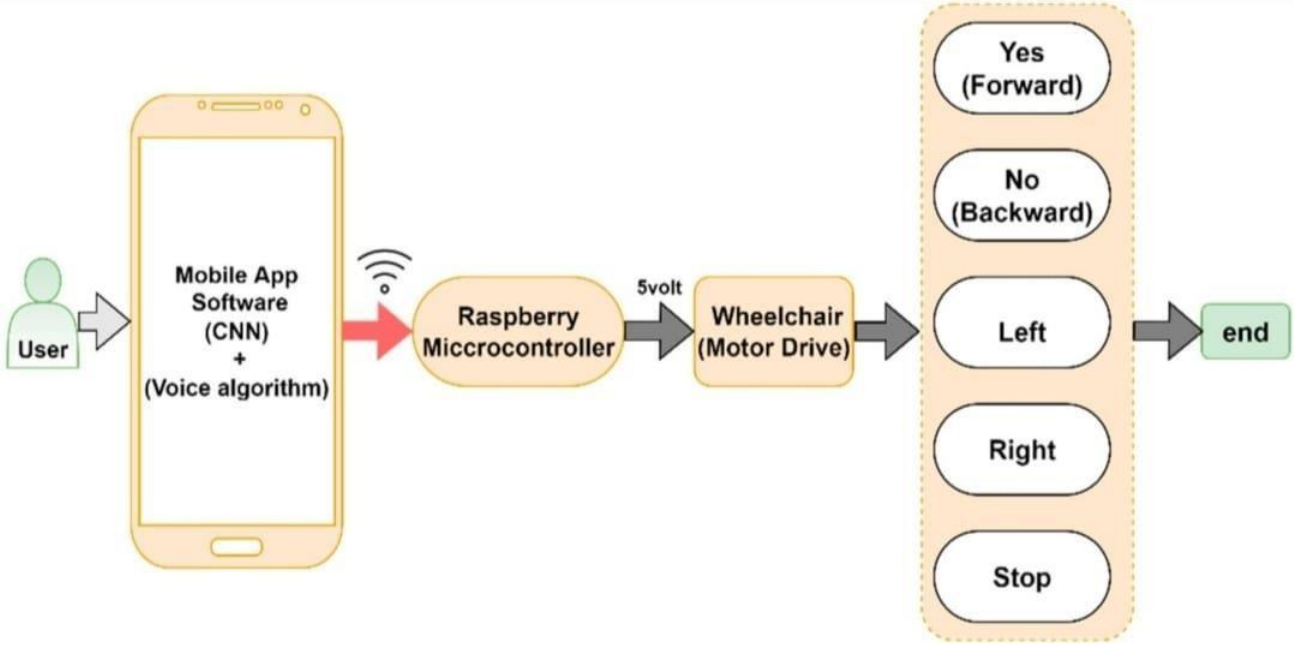
1.1 Background

People who have difficulty moving around due to physical impairments like spinal cord injuries, paralysis, or certain neuromuscular disorders often struggle to maintain their independence and mobility in their daily lives. Traditional wheelchairs, whether manual or powered, require users to have good hand control and upper body strength to operate them effectively. Unfortunately, many individuals with severe mobility impairments may lack these abilities, which can greatly restrict their freedom of movement and ability to do simple tasks. Thankfully, assistive technologies have come a long way in addressing these challenges. One exciting advancement is the development of voice-enabled wheelchairs. These innovative systems are specifically designed to offer an alternative and more accessible way of controlling and manoeuvring wheelchairs by using voice commands. By simply speaking, individuals can easily take charge and move around with greater independence and convenience. This technology opens up a whole new world of possibilities for those facing mobility impairments, making their everyday lives easier and more enjoyable.

The concept behind voice-enabled wheelchairs revolves around three important factors:

- **Technological Breakthroughs**: The incredible advancements in speech recognition technology, particularly in natural language processing and machine learning, have paved the way for the development of robust voice control systems. These innovative technologies now allow wheelchair users to give spoken commands that are accurately understood and responded to
- **Accessibility and Inclusivity**: The creation of voice-enabled wheelchairs perfectly aligns with the principles of accessibility and inclusivity. Its main goal is to empower individuals with severe mobility impairments, giving them the ability to regain control over their movements and cherish their independence once again.
- **User-Oriented Design**: An extensive amount of effort has been put into designing voice-enabled wheelchairs that prioritize the specific needs and preferences of users.
- **Improved Quality of Life**: Voice-enabled wheelchairs have the potential to greatly enhance the lives of users. They provide a new level of freedom and independence, enabling individuals to move more efficiently, interact with their surroundings, and actively participate in social and daily activities with ease.
- **Continuous Research and Development**: The field of assistive technology is constantly

evolving, with ongoing research focused on perfecting voice- enabled wheelchairs, expanding their capabilities, and addressing any limitations or challenges that may arise in real-life situations.**WorkFlow**



1.2 Objectives

The main goals of a voice-activated wheelchair system are to improve the mobility and independence of individuals with disabilities. These goals can be further divided into several key aspects:

- Accessibility and Inclusivity:
  - Make sure that the voice-enabled wheelchair is easily accessible to a wide range of users with different types and levels of disabilities.
- Efficient Navigation and Control:
  - Empower users to effortlessly navigate the wheelchair by using voice commands, enabling movement in any direction, controlling speed, and stopping without difficulty.
- Safety and Reliability:
  - Give utmost importance to safety by implementing strong collision detection and avoidance mechanisms to prevent accidents.
- Ability to Adapt to Different Environments:
  - Make sure the voice-controlled wheelchair can easily adjust to various surroundings, both indoors and outdoors.
- Prioritizing User Comfort and Ergonomics:
  - Give high importance to the comfort of the user by designing the wheelchair with ergonomic features in mind.
  - Optimize the chair and controls' design to minimize user fatigue during extended usage.
- Improving Voice Recognition Accuracy:
  - Continuously enhance the accuracy of voice recognition technology to make the system more responsive and reduce errors in understanding commands.
- Seamless Integration with Assistive Technologies:
  - Enable effortless integration with other assistive devices and technologies, including environmental control systems and communication aids.
- Supporting Users with Training and Assistance:
  - Develop comprehensive training programs to help users become proficient in operating the voice-controlled wheelchair.
- Affordable Technology:
  - Strive to make the technology cost-effective, ensuring it remains affordable for users.
  - Advancing Voice-Enabled Wheelchairs through Research and Development
- Dedicate resources to continuously enhance the capabilities of voice-enabled wheelchairs, keeping up with emerging technologies and meeting the evolving needs of users.

- Improving Systems with User Feedback and Iteration:
- Gather feedback from users and incorporate their input into system improvements.
    - Actively seek feedback from users and actively involve them in shaping system improvements for a more user-friendly experience.

1.3 Purpose

The aim of a voice-controlled wheelchair is to empower individuals with limited mobility, such as those with physical disabilities or difficulty using their hands, by giving them a convenient and easy way to operate their wheelchairs through voice commands. Here are the main objectives and benefits of a voice-controlled wheelchair:

- **Improved Mobility**: Our goal is to provide people facing mobility challenges with the ability to move independently and navigate their surroundings with enhanced efficiency, thus enhancing their overall mobility.
- **Independence**: We strive to promote greater independence and self- sufficiency for wheelchair users by enabling them to control their wheelchairs without relying on external assistance. With a voice-controlled wheelchair, individuals gain more freedom and autonomy in their daily lives.
- **Accessibility**: We aim to make mobility technology accessible to a broader range of users, regardless of their physical or cognitive abilities. By utilizing voice commands, which are more inclusive than traditional manual controls, we ensure that everyone can benefit from this technology regardless of their individual capabilities.
  By incorporating lightweight markdown language, we can effectively convey the purpose and objectives of voice-enabled wheelchairs in a clear and friendly manner.
- **Enhancing Quality of Life**: Our goal is to improve the quality of life for individuals with disabilities, making it easier for them to actively participate in various activities, interact with their environment, and smoothly carry out their social and daily routines.
- **Prioritizing Safety**: Safety is paramount to us. We integrate advanced features like collision detection and avoidance mechanisms to prevent accidents, ensuring a secure and reliable means of mobility.
- **Intuitive Operation**: We designed our system with user-friendliness in mind. The intuitive interface minimizes the learning curve, making it simple and easy for users to operate the wheelchair.
- **Improved Communication:** We believe in enhancing communication between users and their wheelchairs. Our system allows users to interact with their wheelchair, express their intentions, and receive valuable feedback or updates on their wheelchair's status. This way, communication becomes more efficient and convenient for everyone involved.
- **Continuous Advancements**: We are dedicated to driving ongoing research and development in the field of assistive technology. Our aim is to continuously enhance the capabilities and functionality of voice-enabled wheelchairs. keeping up with the evolving

- **Inclusivity**: At the heart of our solution is inclusivity. We strive to create a technology that caters to the diverse needs of individuals with mobility impairments. By taking into account various disabilities,

1.4 Scope

The possibilities of voice-enabled wheelchairs are vast and cover multiple areas, including technology advancements, accessibility, healthcare, and social impact. Let's explore some key dimensions of these possibilities:

- **Advancements in Assistive Technology**: The scope involves continuous progress in speech recognition and wheelchair control systems. This includes research and innovation aimed at enhancing the accuracy, responsiveness, and adaptability of voice control for wheelchairs.
- **Making Wheelchairs More Accessible and Inclusive:** Voice-enabled wheelchairs strive to enhance accessibility and inclusivity for individuals with mobility impairments. The scope encompasses efforts to make these devices available to a broader range of users and cater to the diverse needs of people with disabilities.
- **Healthcare and Rehabilitation:** Voice-enabled wheelchairs have a valuable role in supporting healthcare and rehabilitation. They can be integrated into rehabilitation programs and home healthcare, empowering users with the tools they need to regain their mobility and independence.
- **User-Centred Design**: Our focus is on designing voice-enabled wheelchairs with a user-centric approach. This means tailoring the technology to cater to the specific needs, preferences, and physical capabilities of each individual user.
- **Safety and Usability**: Ensuring the safety and ease of use for voice-enabled wheelchairs is of utmost importance to us. With our comprehensive approach, we develop features that not only prevent accidents but also ensure user comfort and provide a seamless experience.
- **Social Inclusion**: Voice-enabled wheelchairs have a tremendous impact on promoting social inclusion. They empower users to actively participate in social interactions, education, work, and community activities, opening up new avenues for engagement in all aspects of life.
- **Personalization and Flexibility**: We understand that every user has unique requirements, which is why our voice-enabled wheelchairs are designed to be adaptable. You have the freedom to customize other settings according to your preferences.
- **Seamless Integration with Other Technologies:** Our voice-enabled wheelchairs go beyond just providing mobility. They can seamlessly integrate with other technologies, like smart home systems, to create an interconnected environment that enhances your overall living experience. This expands our scope to include IoT integration and the development

of a smart living ecosystem.

- **Ethical and Legal Considerations**: In addition to the technical aspects, we must also take into account the ethical and legal considerations related to protecting user privacy, ensuring data security, and adhering to disability rights and accessibility regulations.

- **Global Impact**: By introducing voice-enabled wheelchairs, we can make a positive difference in the lives of people with mobility impairments all over the world. Our aim is to ensure that these devices are accessible and affordable in different regions, allowing individuals from various backgrounds to benefit from this technology.

1.5 Applicability

The applicability of voice-enabled wheelchairs is wide-ranging and can benefit various individuals and situations. Here are some key areas where these devices can be applied:

- **Individuals with Mobility Impairments:**
  - People with spinal cord injuries
  - Individuals with neuromuscular disorders
  - Those with severe physical disabilities

- **Rehabilitation Centers:**
  - Voice-enabled wheelchairs can be used in rehabilitation centers as part of physical therapy and rehabilitation programs to help patients regain mobility and independence.

- **Home Healthcare:**
  - Individuals who require long-term home healthcare can benefit from voice- enabled wheelchairs to move around their homes independently.

- **Assisted Living Facilities:**
  - Assisted living facilities can integrate voice-enabled wheelchairs to enhance the quality of life and independence for residents with mobility impairments.

- **Schools and Educational Institutions:**
  - Students with disabilities can use voice-enabled wheelchairs to navigate school campuses, attend classes, and participate in extracurricular activities.

- **Workplace:**

- Voice-enabled wheelchairs can enable individuals with mobility impairments to work in

- **Social and Community Activities:**
  - Users can actively participate in social events, community activities, and gatherings with the assistance of voice-enabled wheelchairs.

- **Public Transportation:**
  - Some public transportation systems are exploring the use of voice-enabled wheelchairs to improve accessibility for commuters with disabilities.

- **Research and Development:**
  - Researchers and developers continue to explore new applications and features for voice-enabled wheelchairs, expanding their applicability.

- **Emergency Response:**
  - Voice-enabled wheelchairs can be equipped with safety features to assist users during emergencies, ensuring their well-being.

- **Healthcare Facilities:**
  - Hospitals and healthcare facilities can use voice-enabled wheelchairs to improve the mobility of patients with limited physical capabilities.

- **Aging Population:**
  - As the population ages, voice-enabled wheelchairs can provide mobility solutions for seniors with mobility challenges.

- **Outdoor Activities:**
  - These wheelchairs can be used for outdoor activities like parks, trails, and recreational areas, allowing users to enjoy nature and leisure.

- **Customization for Individual Needs:**
  - The applicability extends to tailoring voice-enabled wheelchairs to meet the specific needs and preferences of users, ensuring a personalized experience

1.6 Achievements

Voice-enabled wheelchairs have reached significant milestones and made great strides in technology development and implementation. Notable achievements in this field include:

- **Enhanced Mobility and Independence**: Voice-enabled wheelchairs have successfully empowered individuals with mobility impairments, granting them a higher level of independence. This technology enables them to effortlessly navigate their surroundings, carry out daily tasks, and actively participate in various activities.
- **Cutting-Edge Speech Recognition**: Remarkable achievements in speech recognition technology have resulted in highly accurate and responsive voice control. This advancement makes the interaction between users and their wheelchairs more natural and efficient, allowing for a more intuitive and satisfying experience.
- **Safety First**: Thanks to advancements in safety features, wheelchair systems now prioritize user safety, effectively preventing accidents and collisions even when controlled through voice commands.
- **Healthcare and Rehabilitation Support**: Voice-enabled wheelchairs have seamlessly entered healthcare and rehabilitation programs, assisting individuals in their recovery journey and significantly improving their overall quality of life, especially for those with mobility impairments.
- **Education for All**: These innovative wheelchairs have found their place in educational institutions, allowing students with disabilities to effortlessly access classrooms, libraries, and actively participate in various school activities.
- **Workplace Inclusion**: Voice-enabled wheelchairs are making a difference in promoting workplace inclusivity, enabling individuals to effectively navigate their work environments while using lightweight and efficient technology.
- **Integration with Public Transportation**: Some public transportation systems have taken a great step towards accessibility by incorporating voice-enabled wheelchairs. This integration makes it much easier for individuals with disabilities to use public transit and navigate through their journeys seamlessly.
- **Research and Innovation**: A continuous achievement in the field of voice- enabled wheelchairs is the ongoing research and innovation to enhance the technology. This helps in expanding its capabilities and finding solutions for user- specific challenges, ensuring a more advanced and user-friendly experience.
- **Positive Impact on Quality of Life**: Arguably the most impactful achievement of voice-enabled wheelchairs is the major improvement they bring to the quality of life for people with

mobility impairments. These devices empower users, granting them more independence, increased activity, and a more fulfilling life overall.

CHAPTER 2. SYSTEM ANALYSIS

2.1 Existing System

Wheelchairs have a long history of providing mobility and independence to individuals with mobility impairments. Before the advent of voice-enabled wheelchairs, traditional manual and powered wheelchairs were the primary means of transportation for people with disabilities. Here's how these conventional wheelchairs worked:

- **Manual Wheelchairs:**

- Manual wheelchairs are typically self-propelled by the user or pushed by a caregiver. They consist of a lightweight, sturdy frame, two large rear wheels, and two smaller front casters.
- Users propel the chair by pushing the large rear wheels with their hands, providing the necessary force for movement.
- The maneuverability of a manual wheelchair depends on the user's upper body strength and dexterity.
- These wheelchairs are suitable for users with sufficient upper body strength and mobility.

- **Powered Wheelchairs:**

- Powered wheelchairs, also known as electric wheelchairs, are equipped with electric motors and a rechargeable battery.
- Users control the wheelchair's movement through a joystick or other input devices, such as chin or head controls.
- The electric motors drive the wheels, allowing users to move forward, backward, and turn with ease.
- Powered wheelchairs are suitable for individuals who may have limited upper body strength or mobility.

- **Joystick Control:**

- Powered wheelchairs typically feature a joystick control, which is operated by the user's hand, chin, or head movements.
- The joystick allows precise control of the wheelchair's speed and direction.

- **Tilt and Recline:**

- Some powered wheelchairs offer tilt and recline features, enabling users to adjust their seating position for comfort and pressure relief.

- **Battery Power:**

- Powered wheelchairs are powered by rechargeable batteries, and users need to charge the battery regularly to ensure continuous operation.

- **Steering and Navigation:**

- Steering and navigation in traditional powered wheelchairs are achieved through the joystick control, allowing users to drive their chairs indoors and outdoor

2.2 Proposed System

A proposed system for a voice-enabled wheelchair should be designed with a focus on user needs, safety, and efficiency. Here's an outline of the components and features that such a system might include:

- **Speech Recognition System:**
  - Advanced speech recognition software that accurately interprets natural language voice commands.
  - Training and customization options to adapt to the user's specific speech patterns and preferences.

- **Wheelchair Control Mechanisms:**
  - Integration with the wheelchair's control system, enabling precise movement and other functions.
  - Safety features, such as emergency stop commands and obstacle detection to ensure user safety.

- **User Interface:**
  - A user-friendly and intuitive interface that guides users through initial setup
  - Voice feedback or confirmation to acknowledge user commands.

- **Safety Sensors:**
  - Incorporate sensors to prevent accidents and ensure safe navigation.
  - Emergency features that allow the user to quickly halt the wheelchair in case of unexpected situation

- **Feedback Mechanism:**

- A feedback system for users to report any problems, suggest improvements, or provide comments on their experience

2.3 Survey of Technologies

A survey of technologies for voice-enabled wheelchairs reveals a range of innovations aimed at enhancing mobility and independence for individuals with mobility impairments. Here are key technologies involved:

- Speech Recognition:
  - Cutting-edge speech recognition software allows the wheelchair to accurately interpret natural language voice commands.
- Voice Control Interfaces:
  - Voice-controlled interfaces, such as microphones and speakers, facilitate communication between the user and the wheelchair system.
- Safety Sensors:
  - sensors and collision detection technology help prevent accidents and ensure safe navigation by detecting obstacles and automatically stopping or adjusting the wheelchair's path.
- Safety Features:
  - Emergency stop commands and other safety features are built-in to ensure user protection and peace of mind.
- Mobile App Integration:
  - Companion mobile apps enable users to configure and monitor the wheelchair.
  -
- Data Privacy and Security:
  - Robust security measures are implemented to protect user data and privacy, ensuring compliance with data protection regulations.

- Feedback Mechanism:
    - Systems include feedback mechanisms for users to report problems, suggest improvements, or provide comments on their experience.

- Continuous Development and Updates:
    - A commitment to ongoing research and development ensures the system's performance continually improves and remains up-to-date with technological advancements.

These technologies collectively create a comprehensive ecosystem for voice-enabled wheelchairs, offering individuals with mobility impairments a powerful tool for independence and mobility. Continuous advancements and innovations in these areas further enhance the capabilities and accessibility

- Web Development and Frameworks:
    - C++ ,HTML and Javascript for building the web application's frontend and backend.
    - Python frameworks for creating the backend serverand handling web requests.

- Natural Language Processing (NLP) Libraries:
    - including text analysis, language understanding, and document summarization.

- API Integrations:
    - Integration with third-party APIs for legal research, citation databases,and external data sources.

Requirement Analysis

Requirements analysis for a voice-enabled wheelchair is a critical phase in the development process to ensure that the system meets the needs of users effectively. Here's an overview of key requirements:

- **User Requirements:**
  - Independence: Enable users to control the wheelchair independently, promoting autonomy and self-reliance.

- **Wheelchair Control:**
  - Responsive Control: Ensure that voice commands result in immediate and precise control of the wheelchair, allowing for smooth and intuitive movement.
  - Safety Mechanisms: Integrate safety sensors, such as sensors and collision detection, to prevent accidents and ensure safe navigation.

- **User Interface:**
  - Intuitive Design: Develop a user-friendly and intuitive interface that guides users through initial setup and customization.

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- **Safety and Emergency Features:**
  - Emergency Stop: Include an emergency stop command for users to halt the wheelchair in critical situations.

    Obstacle Detection: Implement sensors and algorithms to detect obstacles and automatically adjust the wheelchair's path.

- **Mobile App Integration:**
  - Companion App: Develop a mobile app that allows users to configure and monitor the wheelchair, providing real-time tracking and status updates.
  - Remote Control: Include remote control capabilities for caregivers or family members through the app.

- **Data Privacy and Security:**

- Data Protection: Implement robust security measures to protect user data and ensure compliance with relevant data protection regulations.

- Maintenance Alerts: Provide users with timely alerts and reminders for routine maintenance.

2.4 Software Requirements

The software requirements for a voice-enabled wheelchair system are crucial for ensuring its functionality, user-friendliness, and safety. Here are the key software requirements:

- **Speech Recognition Software:**
  - Implement advanced speech recognition technology to accurately interpret natural language voice commands.
  - Ensure high recognition accuracy and adaptability to different users' speech patterns.

- **User Interface Software:**
  - Develop a user-friendly and intuitive interface that guides users through setup and customization

- **Safety and Collision Detection Software:**
  - Implement safety mechanisms, including collision detection and obstacle avoidance algorithms.
  - Ensure the wheelchair can detect and respond to potential safety hazards, such as obstacles or abrupt commands.

- **Mobile App Software:**
  - Create a companion mobile app for configuring and monitoring the wheelchair system.
  - Include status updates, and remote-control features through the app.

- **Data Privacy and Security :**

  - Implement robust security measures to protect user data and ensure compliance with data protection regulations.

Justification of Selection of Technology

- Python for AI Development:

Python is widely recognized as one of the best languages for AI and machine learning development. It offers a rich ecosystem oflibraries and frameworks (e.g., scikit-learn, TensorFlow, etc.) that are essential for developing AI components like natural languageprocessing (NLP) and machine learning models.

- Android for Web Development:

It is well-suited for developing modern, responsive web applications. It offers a seamless development experience, enabling a single team to handle both frontend and backend development.

CHAPTER 3: REQUIREMENTS AND ANALYSIS

3.1 Problem Definition

Defining the problem statement for developing a voice-enabled wheelchair involves clearly articulating the challenges and objectives to be addressed. Here is a problem definition for creating a voice-enabled wheelchair:

Problem Statement:

"Many individuals with mobility impairments, such as those with spinal cord injuries or neurological disorders, face limitations in operating traditional wheelchairs due to reduced upper body strength or dexterity. The problem lies in the lack of an intuitive and accessible means of controlling wheelchairs, leading to reduced independence and mobility for these individuals.

Developing a voice-enabled wheelchair aims to address this problem by creating a mobility solution that allows users to control the wheelchair through natural voice commands. This system will offer a more user-friendly and accessible method of navigation, enhancing the quality of life, independence, and mobility of individuals with limited physical abilities.

Key Objectives:

- Voice Control: Enable users to control the wheelchair's movement, speed, and direction using voice commands, ensuring precise and reliable recognition of user inputs.
- Safety: Implement robust safety features to prevent accidents, including obstacle detection, collision avoidance, and emergency stop capabilities.
- Accessibility: Ensure that the system is accessible to individuals
- Privacy and Security: Protect user data and privacy by implementing secure data storage and communication protocols.
- User Training and Support: Provide guidance and assistance to users for effective voice command usage and system troubleshooting.

- Reliability and Durability: Design a robust, reliable, and durable system that can withstand regular use in various environments.

The development of a voice-enabled wheelchair addresses the need for a more accessible and user-friendly mobility solution for individuals with mobility impairments. It aims to enhance their quality of life, independence, and mobility by providing an intuitive means of controlling their wheelchairs through natural voice commands, ultimately improving their overall well-being."

3.2 Requirement Specification

Requirements specifications for a voice-enabled wheelchair are crucial for guiding the development process and ensuring that the resulting system meets the needs of users effectively. Below are detailed requirements for such a wheelchair system:

- **User Requirements**:
  - Independence: The system should enable users to control the wheelchair independently, promoting autonomy and self-reliance.
  - Safety: The system must prioritize user safety by ensuring that voice commands are clear, distinct, and easy to issue, even in emergency situations.
- **Speech Recognition and Natural Language Processing:**
  - High Accuracy: The system must incorporate advanced speech recognition technology to achieve high accuracy in understanding and executing voice commands.
  - Adaptability: Implement natural language processing and machine learning to adapt to users' speech patterns and improve recognition over time.
- **Wheelchair Control**:
  - Responsive Control: The system must ensure that voice commands result in immediate and precise control of the wheelchair, allowing for smooth and intuitive movement.
  - Safety Mechanisms: Integrate safety sensors, such as proximity sensors and collision detection, to prevent accidents and ensure safe navigation.
- **User Interface:**
  - Intuitive Design: The system should feature a user-friendly and intuitive interface that guides users through initial setup and customization.
- **Customization and Personalization:**
  - Voice Command Customization: The system should allow users to create and customize voice commands for specific actions and routines.

- **Safety and Emergency Features:**
  - Emergency Stop: The system should include an emergency stop command that users can issue to halt the wheelchair in critical situations.
  - Obstacle Detection: Implement sensors and algorithms to detect obstacles and automatically adjust the wheelchair's path to avoid collisions.

- **Remote Control:** The app should offer remote control capabilities for caregivers and family members to assist.

- **Data Privacy and Security:**
  - Data Protection: Implement robust security measures to protect user data and with relevant data protection regulations

- **Maintenance and Diagnostics:**

  -Diagnostic Tools: Incorporate built-in diagnostic tools that can identify and report issues with the wheelchair's functionality.

  -Maintenance Alerts: Provide users with timely alerts and reminders for routine maintenance to ensure the system operates optimally.

- **Continuous Development and Updates**

  -Research and Innovation: Commit to ongoing research and development to improve the system's performance, adapt to new technologies, and address user feedback.

These requirements serve as a comprehensive guideline for the development of a voice- enabled wheelchair system, emphasizing safety, accessibility, and user-centric design. They address the diverse needs of users while ensuring that the system remains adaptable to technological advancements and changing user preferences.

3.3.1 PERT CHART:

- PERT stands for Program Evaluation and Review Technique.
- PERT is a method of analyzing the tasks involved in completing a given project, especially the time needed to complete each task and toidentify the minimum time needed to complete the total project.
- It is more of an event-oriented technique rather than start- and completion-oriented and issued more in those projects where time isthe major factor rather than cost.
- It is applied on very large-scale, one-time, complex, non-routineinfrastructure and on Research and Development projects.
- PERT offers a management tool, which relies "on arrow and node diagrams of activities and events: arrows represent the activitiesor work necessary to reach the events or nodes that indicate each completed phase of the total project

Word	Recognition Rate%			
	05 samples	10 samples	15 samples	20 samples
Forward	33	47	53	55
Left	41	58	63	60
Right	59	68	70	76
Stop	46	53	62	62
Backward	58	60	72	78
Avg, Rec. rate	47.4%	57%	64%	66.2%

3.3 Hardware Requirements

The hardware requirements for a voice-enabled wheelchair system are critical to ensure the system's functionality, reliability, and performance. These requirements can vary depending on the specific features and capabilities of the wheelchair, but here is a general list of hardware components and specifications to consider:

- **Microphone and Audio System:**
  - High-quality microphone(s) for clear voice input.
  - Audio processing hardware to capture and preprocess voice commands.

- **Speaker or Voice Output System:**
  - Speaker for providing voice feedback and confirmation to the user.

- **Control System:**
  - Control unit or microcontroller to process voice commands and control the wheelchair's movements.
  - Connectivity with other system components.

- **Sensors**:
  - sensors for obstacle detection.
  - Collision detection sensors.

- **Battery and Power Management:**
  - High-capacity rechargeable batteries for extended operation.
  - Power management system to optimize battery life.
  - Charging system and port for recharging.

- **Drive Mechanism:**
  - Wheelchair drive system, which may include motors and wheels,
- **User Interface Components:**
  - User interface components like buttons, touchscreen displays, or other input devices for manual control (in addition to voice control).

- **Mobile App Integration Hardware (if applicable):**
  - Bluetooth or Wi-Fi module for communication with a companion mobile app.

- **Emergency Systems:**
  - Emergency stop buttons or switches for immediate halting of the wheelchair.
  - Backup systems or manual controls in case of system failure.

- **Frame and Chassis:**
  - Sturdy and durable frame or chassis to support the hardware components and ensure user safety.

- **Connectivity and Communication Hardware:**
  - Communication modules for connectivity and remote assistance

3.4 Software Requirements

The software requirements for a voice-enabled wheelchair are essential for enabling the system to understand voice commands, control the wheelchair, and provide a safe and user-friendly experience. Here are the key software components and requirements for such a system:

- **Speech Recognition Software:**
  - High-quality speech recognition technology that can accurately transcribe spoken words into text.
  - Support for multiple languages and dialects to accommodate a diverse user base.
  - Noise cancellation algorithms to improve voice recognition accuracy in various environments.

- **Natural Language Processing (NLP) Software:**
  - NLP algorithms to analyze and understand the meaning of voice commands.
  - Contextual understanding to interpret complex commands and conversations.
  - Machine learning capabilities to adapt to individual user speech patterns and preferences.

- **User Interface Software:**
  - User-friendly interface with voice feedback for users to set up and customize the system.
  - Intuitive design to guide users through initial setup and customization processes.
  - Accessibility features for users with different abilities, such as voice navigation for the interface.

- **Wheelchair Control Software:**

- Responsive control software to translate voice commands into precise and safe wheelchair movements.
- Integration with the hardware control system to manage speed, direction, and other parameters.
- Safety features, including obstacle detection and avoidance algorithms.

➢ **Safety and Emergency Features Software:**

- Emergency stop command recognition and immediate system response.
- Obstacle detection algorithms to prevent collisions and adjust the wheelchair's path.

➢ **Continuous Development and Updates Software:**

- Commitment to ongoing research and development to improve system performance, adapt to new technologies, and address user feedback.
- Mechanisms for delivering software updates and new features to users.

These software requirements are essential for creating a comprehensive and user- centered voice-enabled wheelchair system. Collaboration with experts in speech recognition, mobility technology, and software development is crucial to meet these requirements effectively and provide a high-quality solution.

3.5 Conceptual Models

3.6.1 Class Diagram

- The Class diagram is a static diagram. It represents the static view of anapplication. The Class diagram is not only used for visualizing, describing, and documenting different aspects of a system but also for constructing executable code of the software application. The Class diagram describes the attributes and operations of a class and also the constraints imposed on the system.

- The class diagrams are widely used in the modeling of object-oriented systems because they are the only UML diagrams, which can be mappeddirectly with object-oriented languages. Class diagram shows a collection of classes, interfaces, associations, collaborations, and constraints. It is also known as a structural diagram.

3.6.2 Object Diagram

- Object diagrams are derived from class diagrams so object diagrams are dependent upon class diagrams. Object diagramsrepresent an instance of a class diagram. The basic concepts are similar to class diagrams and object diagrams.

- Object diagrams also represent the static view of a system but this static view is a snapshot of the system at a particular moment. Object diagrams are used to render a set of objects and their relationships as an instance.

3.6.3 Use Case Diagram

- A use case diagram is a type of Unified Modeling Language (UML) diagram used in software engineering to visually represent the functional requirements of a system from the perspective of its users or external entities.

- Use case diagrams are an important tool for understanding and documenting the interactions between system components and users or other systems. They are particularly valuable in the requirements analysis and design phases of software development.

3.6.4 System Flowchart

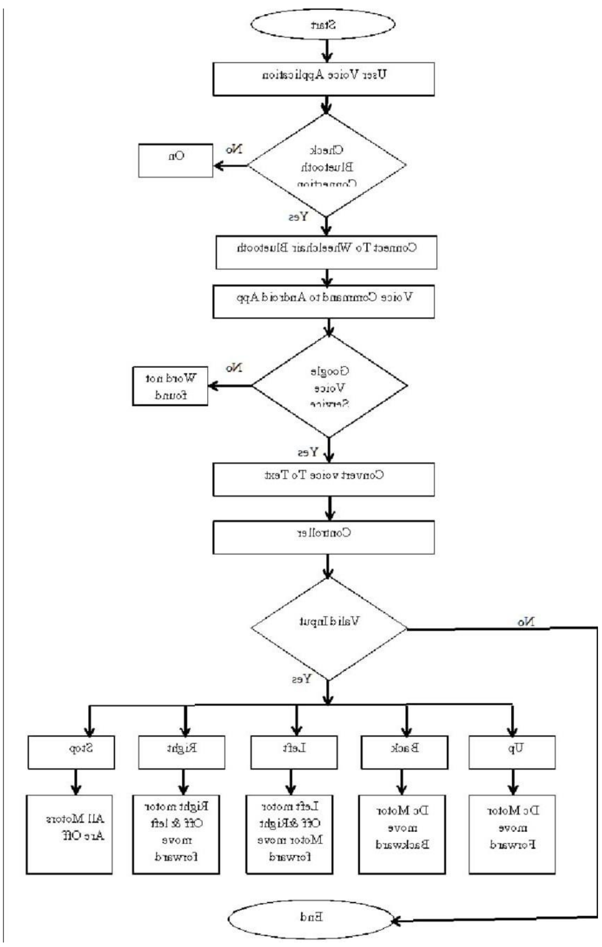
- A flowchart is a type of diagram that represents a workflow or process.

- A flowchart can also be defined as a diagrammatic representation of an algorithm, a step-by-step approach to solving a task.

- The flowchart shows the steps as boxes of various kinds and their orderby connecting the boxes with arrows.

- This diagrammatic representation illustrates a solution model to a given problem. Flowcharts are used in analyzing, designing, documenting, ormanaging a process or program in various fields.

Diagram:



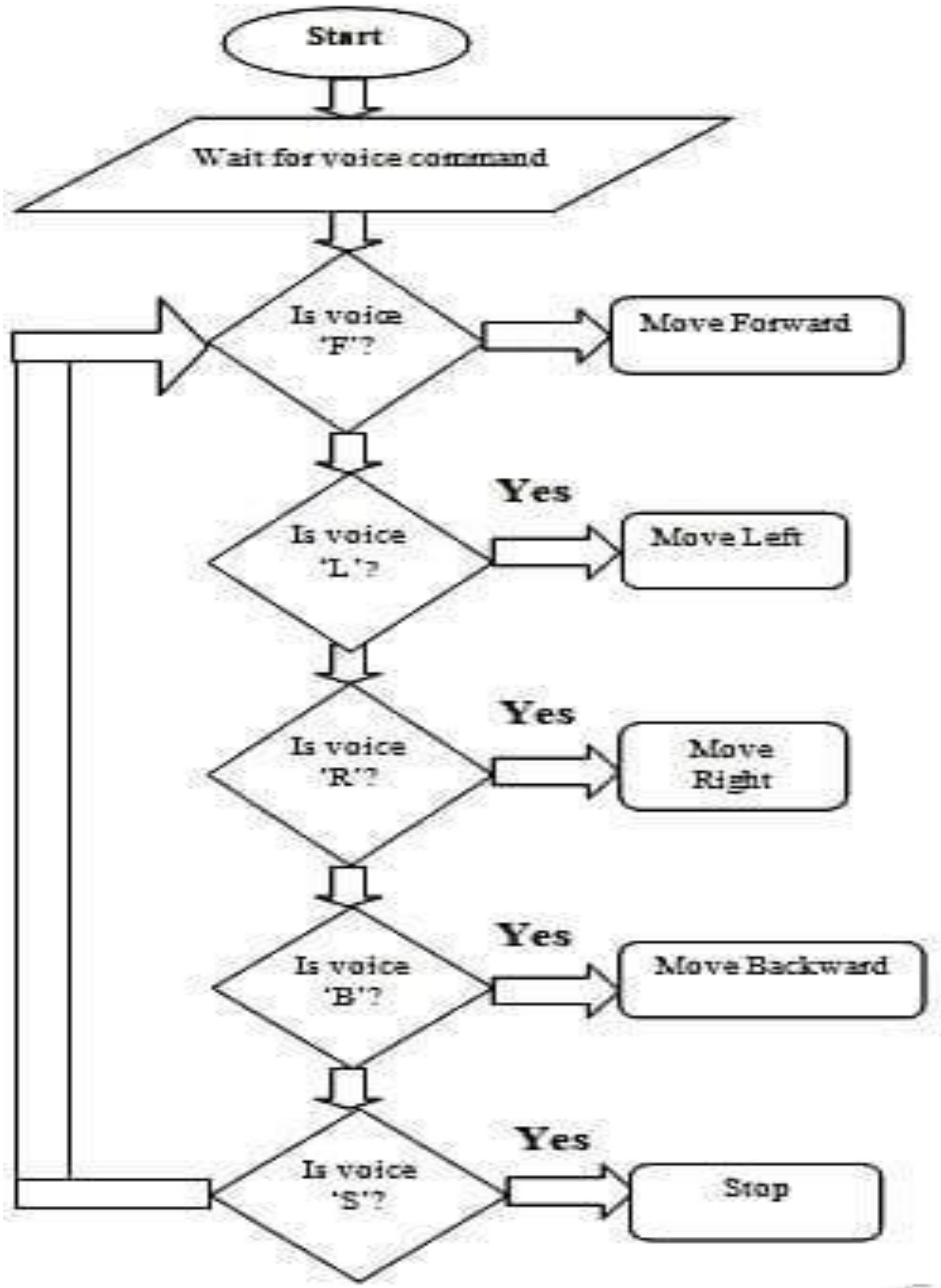
3.6.5 Data Flow Diagram

- Also known as DFD, Data flow diagrams are used to graphically represent the flow of data in a business information system.

- DFD describes the processes that are involved in a system to transfer data from the input to the file storage and reports generation.

- Data flow diagrams can be divided into logical and physical. A data-flow diagram has no control flow, there are no decision rules and no loops.

Level 0


Start
Wait for voice command
Is voice 'F'?
Move Forward
Yes
Is voice 'L'?
Move Left
Yes
Is voice 'R'?
Move Right
Yes
Is voice 'B'?
Move Backward
Yes
Is voice 'S'?
Stop

3.6 Feasibility Study

3.7.1 Operation Feasibility

Operational feasibility for a voice-enabled wheelchair project assesses whether it is practical and achievable to implement the system within the given operational environment. It involves evaluating factors related to the system's design, development, and long-term operation. Here are some considerations for assessing operational feasibility:

- **Technical Feasibility:**
  - Determine whether the required technology and expertise are available or can be acquired to develop and maintain the voice-enabled wheelchair system.

- **System Scalability:**
  - Assess whether the system can be scaled to accommodate potential growth in users and additional features or integrations.

- **Integration with Existing Infrastructure:**
  - Evaluate how well the voice-enabled wheelchair system can integrate with existing infrastructure, including hardware and software components, such as smart home devices and mobile platforms.

- **Environmental Compatibility:**
  - Consider whether the system can operate effectively in various environments and conditions, including indoor and outdoor settings.

- **User Training and Acceptance:**
  - Evaluate the feasibility of providing user training to ensure that individuals with disabilities can effectively use the system.

- **Maintenance and Support:**
  - Assess the feasibility of providing ongoing maintenance and user support to keep the system in working order and address user concerns.

- **Cost Analysis**:
  - Perform a comprehensive cost analysis to determine the financial feasibility of the project, including development, manufacturing, and ongoing operational costs.

- **Return on Investment (ROI):**
    - Consider the potential benefits and returns from the project, such as improved mobility for users, enhanced quality of life, and the potential for market adoption.

- **Risk Assessment:**
    - Identify and assess potential risks and challenges that may impact the operational success of the project, including technical, regulatory, and market risks.

- **Market Demand and User Needs:**
    - Investigate the demand for such a system among individuals with disabilities and their caregivers to ensure that it meets their needs and preferences.

- **Stakeholder Buy-In:**
    - Ensure that stakeholders, including users, caregivers, healthcare providers, and regulatory authorities, are supportive of the project.

3.7.2 Technical Feasibility

Technical feasibility for a voice-enabled wheelchair project assesses whether the required technology and resources are available or can be developed to create a functional and effective system. It involves evaluating the technical aspects of the project to ensure that it can be successfully implemented. Here are key considerations for assessing technical feasibility:

- **Hardware Requirements:**
  - Evaluate whether the necessary hardware components, such as microphones, speakers, sensors, and motors, are available and suitable for building the voice-enabled wheelchair.

- **Software Requirements:**
  - Assess the availability of the required software components, including speech recognition, natural language processing, and control systems, and determine if they can be integrated effectively.

- **Speech Recognition Technology:**
  - Analyze the state of speech recognition technology to determine if it can accurately and reliably transcribe voice commands into text.

- **Voice Command Processing:**
  - Assess the feasibility of developing or integrating voice command processing systems that can execute user commands accurately and safely.

- **Safety Systems:**
  - Determine the feasibility of incorporating safety systems, such as obstacle detection and collision avoidance, to ensure user safety during operation.

- **Mobile App Integration:**
    - Determine if a companion mobile app can be developed to provide remote control and monitoring features for caregivers or family members.

- **Data Privacy and Security:**
    - Evaluate the feasibility of implementing robust data privacy and security measures to protect user data and ensure compliance with privacy regulations.

- **Maintenance and Diagnostics:**
    - Assess the feasibility of incorporating maintenance and diagnostic tools to monitor the system's health and identify issues for timely maintenance.

- **Continuous Development and Updates:**
    - Evaluate the feasibility of ongoing research and development to improve the system, adapt to new technologies, and address user feedback through software updates.

- **Scalability:**
    - Consider the potential for scalability to accommodate a growing user base and expanding feature set.

- **Technical Expertise:**
    - Ensure that the required technical expertise, including software development, hardware engineering, and system integration, is available or can be acquired.

- **Technology Trends:**

- Stay updated on technology trends and advancements to ensure the system remains relevant and competitive.

Technical feasibility is a critical aspect of project planning and helps ensure that the necessary technology and resources are in place to build a reliable and functional voice-enabled wheelchair system. It also involves considering potential challenges and risks associated with the technology components and their integration.

3.7.3 Economic Feasibility

Economic feasibility for a voice-enabled wheelchair project assesses whether the project is financially viable and justifiable. It involves evaluating the costs and potential benefits associated with the project. Here are key considerations for assessing economic feasibility:

- **Cost Analysis:**
  - Estimate the total costs associated with the project, including development costs, hardware and software costs, labor, materials, and ongoing operational costs. This should also include costs related to research, development, testing, manufacturing, and distribution.

- **Return on Investment (ROI):**
  - Analyze the potential benefits and returns that the project can generate, both in financial and non-financial terms. Consider factors like increased user mobility, improved quality of life, and market adoption.

- **Market Demand**:
  - Evaluate the demand for a voice-enabled wheelchair system among individuals with disabilities and their caregivers. Consider the size of the target market and potential growth.

- **Pricing Strategy:**
  - Determine the pricing strategy for the product, considering factors like affordability for users and the ability to cover development and operational costs.

- **Competitive Analysis:**
  - Assess the competitive landscape to understand how the project's offerings compare to existing solutions and potential competitors.

- **Revenue Streams:**
  - Identify potential revenue streams, including product sales, subscription services, and maintenance agreements.

- **Cost Reduction Strategies:**
  - Explore strategies for reducing development and operational costs, such as optimizing supply chain management and minimizing overhead expenses
- **Risk Analysis:**
  - Identify and assess potential financial risks associated with the project, including technical risks, market risks, and regulatory risks.
  -
- **Break-Even Analysis:**
  - Determine the point at which the project's total revenue equals its total costs, indicating when the project will start generating profits.

- **Sensitivity Analysis:**
  - Assess how changes in key economic variables, such as pricing, market demand, or operational costs, can impact the project's financial viability.

- **Long-Term Viability:**
  - Consider the project's sustainability and profitability over the long term, including factors like technology advancements and evolving market conditions.

- **Non-Financial Benefits:**
  - Recognize and quantify potential non-financial benefits, such as improved accessibility and inclusivity, and consider their value.

Economic feasibility helps project stakeholders understand the financial implications of developing and operating a voice-enabled wheelchair system. It's crucial for decision- makers to weigh the potential economic benefits against the costs and risks to make informed choices

CHAPTER 4: SYSTEM DESIGN

4.1 Basic Modules

The basic modules for a voice-enabled wheelchair system include the essential components required to enable users to control the wheelchair using voice commands. Here are the fundamental modules:

- **Voice Command Recognition Module:**
  - This module is responsible for capturing and recognizing voice commands spoken by the user. It typically includes:
  - Speech recognition software and algorithms.
  - Noise cancellation and audio processing capabilities.
  - Language and dialect support.

- **User Interface Module**:
  - This module provides the user interface for setup and customization of the system. It includes:
  - A graphical user interface (GUI) for initial configuration.
  - Voice feedback for guiding users through setup and customization.

- **Wheelchair Control Module:**
  - The core module responsible for translating voice commands into wheelchair movements. It includes:
  - Control algorithms for speed, direction, and precision.
  - Integration with the wheelchair's hardware control system.

- **Safety and Collision Avoidance Module:**
  - Safety features are critical for preventing accidents. This module includes:
  - Obstacle detection sensors.
  - Collision avoidance algorithms.
  - Emergency stop command recognition.

- **Data Privacy and Security Module:**
  - To protect user data and privacy, this module includes:
  - Encryption of user data.

- Secure storage practices.
- Compliance with data protection regulations.

- **User Profile Management Module:**
  - Users can customize their preferences

- **Continuous Development and Updates Module:**
  - This module allows for system improvement and adaptation:
  - Ongoing research and development to enhance performance.
  - Mechanisms for delivering software updates and new features.

These basic modules provide the foundation for a voice-enabled wheelchair system. Depending on the specific requirements and advanced features, additional modules and components may be integrated to enhance functionality and user experience

4.2 Data Design

4.2.1 Schema Design

- Designing a schema for a voice-enabled wheelchair system involves creating a structured representation of the system's data and its relationships. While a comprehensive schema can be complex, I'll provide a simplified schema to illustrate the concept:

Entities:

- **Users:**
  - Relationships: One-to-Many with Voice Commands, Many-to- Many with Favorite Destinations, Many-to-Many with Controlled Devices

- **Voice Commands:**
  - Attributes: CommandID (Primary Key), Command Text, User ID (Foreign Key), Timestamp
  - Relationships: Many-to-One with Users

- **Wheelchair System:**
  - Attributes: SystemID (Primary Key), Version, Configuration Settings
  - Relationships: Many-to-Many with Users

Schema Diagram:

This schema simplifies the data structure for a voice-enabled wheelchair system. It includes essential entities like Users, Voice Commands, Favorite Destinations, Smart Home Devices, and the Wheelchair System. The relationships between these entities are represented as well.

In a real-world application, this schema would be more detailed and would include additional attributes and relationships, depending on the specific requirements of the system. Additionally, data storage and retrieval mechanisms would be implemented based on the chosen database technology (e.g., relational database management system).

4.2.2 Data Integrity and Constraints

- Entity Integrity:

Ensure that each table has a primary key to uniquely identify records. Prevent the insertion of duplicate or null values in primary key columns.

- Referential Integrity:

Enforce relationships between tables through foreign keys.

Ensure that foreign key values match primary key values in therelated table, preventing orphaned records.

- Domain Integrity:

Define data types and constraints for each column to restrict thetypes and ranges of allowable values.
Enforce constraints like check constraints to ensure that dataconforms to specific rules (e.g., date format, length).

- Default Values:

Set default values for columns to ensure that fields are populatedeven when a user or application does not explicitly provide a value.

- Unique Constraints:

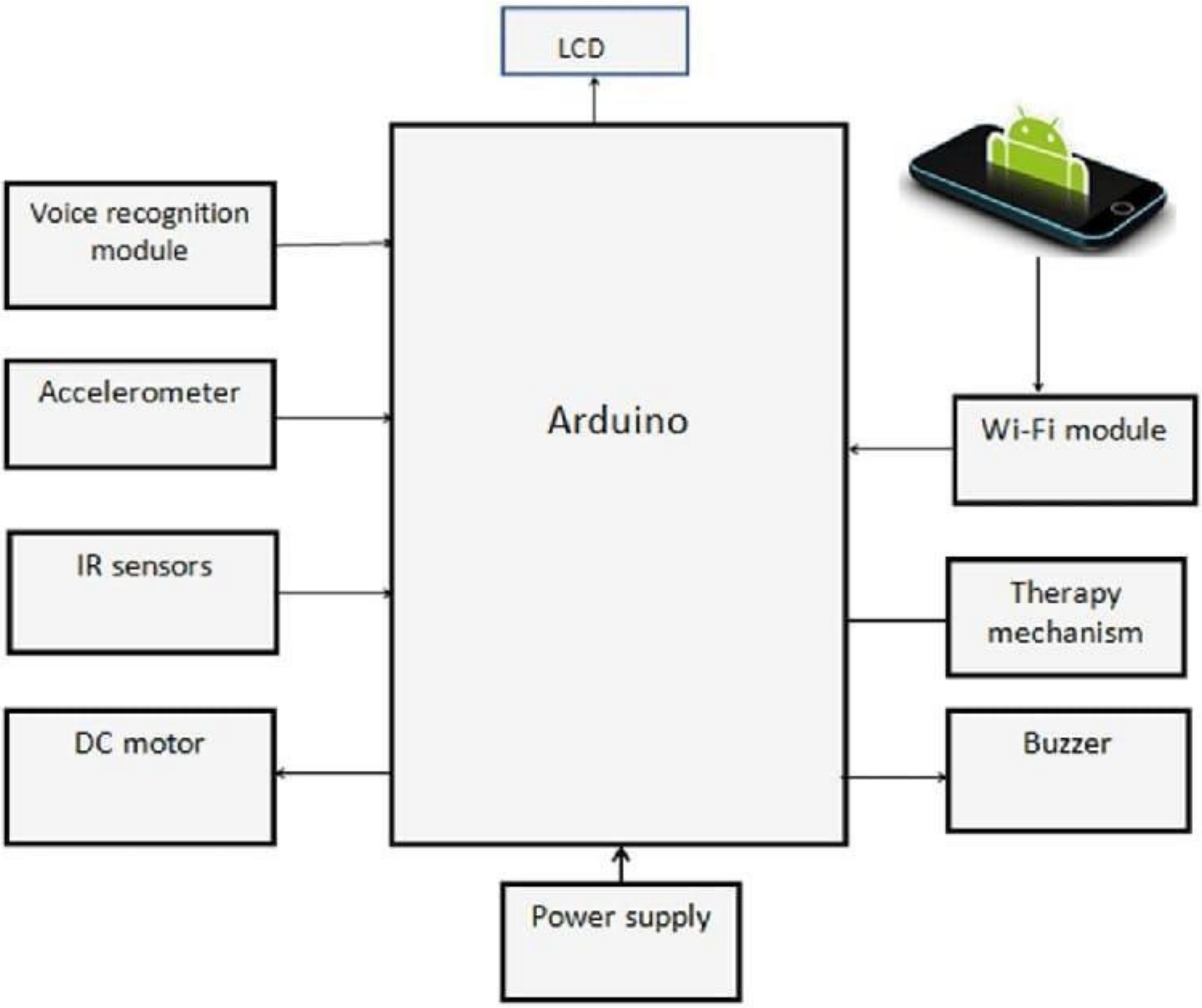
Use unique constraints to enforce the uniqueness of data in specific columns, preventing the insertion of duplicate values.

4.3 Logic Diagrams

4.3.1 Sequence Diagram

A sequence diagram shows object interactions arranged in time sequence. It depicts the objects involved in the scenario and the sequenceof messages exchanged between the objects needed to carry out the functionality of the scenario.

Diagram



4.3.2 Activity Diagram

- An activity diagram is a flowchart to represent the flow from one activity to another activity. The activity can be described as an operationof the system.
- The control flow is drawn from one operation to another. This flow can be sequential, branched, or concurrent. Activity diagrams deal with all types of flow control by using different elements such as fork, join, etc.

4.4 Security issues

- Data Security:
  - Protecting user data and legal documents stored in the system fromunauthorized access and data breaches.
  - Implementing encryption to secure data both in transit and at rest.

- Authorization and Access Control:
  - Managing user roles and permissions to restrict access to sensitivelegal information and system functionality.
  - Regularly reviewing and updating access controls to reflect changesin user roles and responsibilities.

- Data Backup and Recovery:
  - Implementing data backup and recovery mechanisms to mitigatedata loss due to system failures or cyberattacks.

- Secure Coding Practices:
  - Adhering to secure coding practices to prevent common vulnerabilities like SQL injection, cross-site scripting (XSS), and cross-site request forgery (CSRF).

- Legal Compliance:
  - Ensuring that complies with all relevant legal and regulatory requirements, especially those related to the legal domain.

- Secure Development Lifecycle:
  - Incorporating security into the development lifecycle by conductingsecurity reviews and assessments at various stages of system development.

4.5 Test Cases Design

- A Test Case is a set of actions executed to verify a particular feature or functionality of your software application.

- A Test Case contains test steps, test data, preconditions, and postconditions developed for specific test scenarios to verify any requirement.

- The Test Case includes specific variables or conditions, using which a testing engineer can compare expected and actual results to determine whether a software product is functioning as per the requirements of thecustomer.

Voice Recognition:

- Test Case 1: Ensure the system recognizes and correctly interprets the command "Move forward."

- Test Case 2: Verify that the system responds appropriately to variations of the command, such as "Go forward" or "Move ahead."Movement Control:

- Test Case 3: Check that the wheelchair moves forward when the "Move forward" command is given.

- Test Case 4: Ensure the wheelchair stops when the "Stop" command is issued.

- Test Case 5: Verify that the wheelchair turns left when the

"Turn left" command is given.

- Test Case 6: Check that the wheelchair turns right when the "Turn right" command is issued.Emergency Stop:
- Test Case 7: Confirm that the wheelchair immediately stops all movement when the emergency stop button is pressed.
- Test Case 8: Verify that the emergency stop functionality overrides any other command in progress.Battery Status:
- Test Case 9: Check that the system accurately reports the current battery status when requested by the user.
- Test Case 10: Ensure the wheelchair behaves appropriately when the battery is low, such as providing a warning message or limiting functionality.Error Handling:
- Test Case 11: Verify that the system handles unrecognized commands gracefully, such as by providing a helpful response or requesting clarification.
- Test Case 12: Ensure the system responds correctly to unexpected inputs, such as noise or interference, without triggering unintended actions.

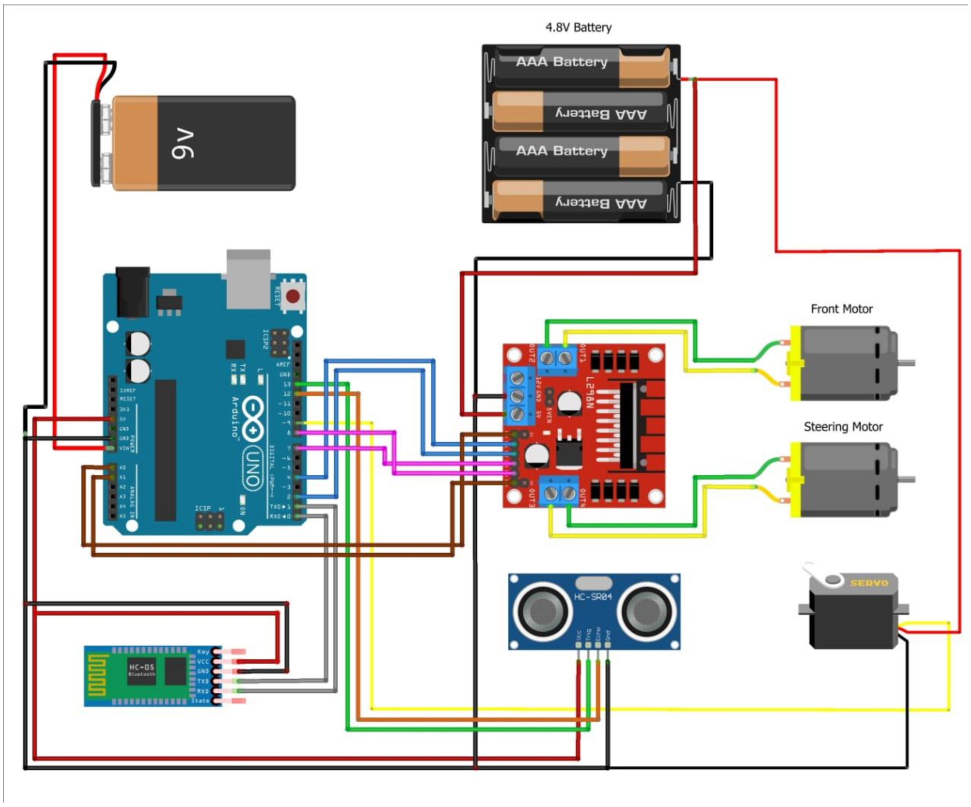
CHAPTER 4: IMPLEMENTATION AND TESTING

Hardware Components

Components Used

- Arduino Nano
- L298N motor driver module
- DC motors
- Bluetooth module
- HC-SR04 ultrasonic sensor
- Other necessary electronic components

Circuit Diagram



Software Components

Programming Languages and Frameworks

- Arduino IDE for programming the Arduino Nano
- Possibly other libraries or frameworks for voice recognition and Bluetooth communication
- Separate modules for each control mode (manual, automatic, voice)

- Functions for motor control, Bluetooth communication, and sensor integration

System Architecture

Interaction Between Hardware and Software

- The Arduino Nano receives commands from the Bluetooth module and processes them based on the selected control mode.
- Sensor data is used for obstacle detection in automatic mode.

Features

Control Modes

- Manual: Direct control using buttons or a joystick.
- Automatic: Autonomous navigation using obstacle detection.
- Voice: Control using voice commands for basic movement (forward, backward, left, right).

Implementation Details

- Manual mode: Button or joystick inputs mapped to motor control.
- Automatic mode: Ultrasonic sensor data used to navigate and avoid obstacles.
- Voice mode: Speech recognition software processes voice commands and converts them into motor control signals.

Voice Control

Command Processing

- Voice commands captured by a microphone.
- Speech recognition software processes the commands into text.
- Text commands interpreted by the Arduino Nano for corresponding actions.

Integration

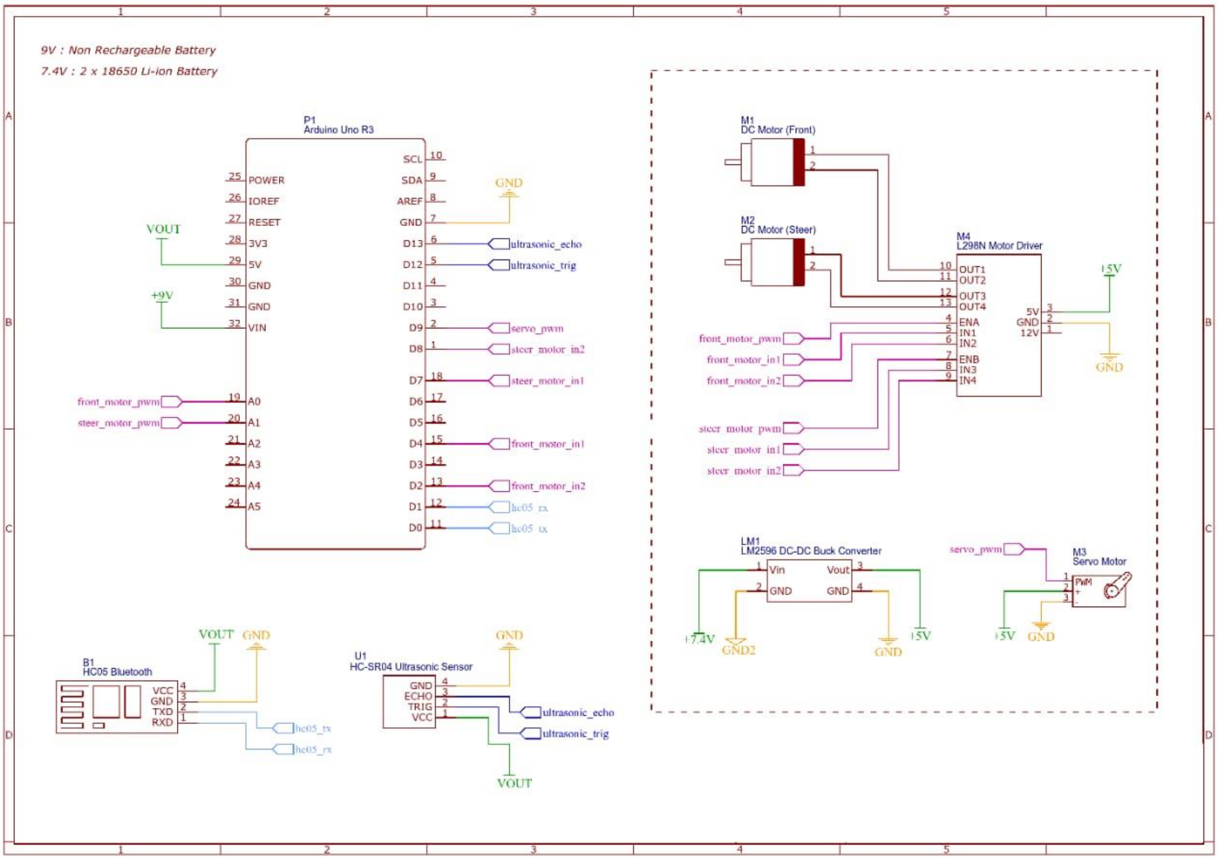
- Arduino Nano receives interpreted commands and executes corresponding motor control actions.

Implementation

Hardware Setup

The hardware components were connected as follows:

- Arduino Nano: Connected to power and ground, and used digital pins for motor control and communication with other modules.
- L298N motor driver module: Connected to the Arduino Nano for controlling the DC motors.
- DC motors: Connected to the L298N motor driver module for controlling the wheelchair's movement.
- Bluetooth module: Connected to the Arduino Nano for wireless communication with external devices.
- HC-SR04 ultrasonic sensor: Connected to the Arduino Nano for obstacle detection.



Software Development

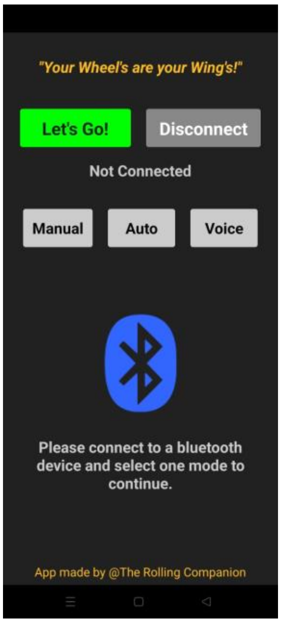
The software architecture involved separate modules for each control mode (manual, automatic, voice) and functions for motor control, Bluetooth communication, and sensor integration. The Arduino Nano was programmed using the Arduino IDE, with specific code for each control mode to interpret commands and control the wheelchair's movement accordingly.

Voice Control Implementation

Voice control was integrated using speech recognition software to process voice commands captured by a microphone. The software converted the commands into text, which was then interpreted by the Arduino Nano for corresponding motor control actions.

Control Modes

- Manual mode: Buttons or a joystick were used for direct control of the wheelchair's movement.
- Automatic mode: The ultrasonic sensor data was used to navigate and avoid obstacles autonomously.
- Voice mode: Voice commands were used to control basic movement (e.g., forward, backward, left, right).



Safety Features

Safety features included an emergency stop mechanism that could halt all wheelchair movement in case of an emergency. Additionally, obstacle detection using the ultrasonic sensor helped prevent collisions.

Testing Approach

Types of Testing

- Unit testing: To test individual components and modules.
- Integration testing: To test the interaction between hardware and software components.
- Functionality testing: To verify the functionality of each control mode.
- Performance testing: To evaluate the speed and responsiveness of the wheelchair.
- Safety testing: To test the safety features, including the emergency stop mechanism and obstacle detection.

Test Cases

- Test cases were designed to cover all aspects of the project, including different scenarios for each control mode.
- Criteria for success included accurate movement control, effective obstacle detection, and reliable communication.

Regression Testing

- Regression testing was conducted to ensure that new features did not introduce any bugs or issues into existing functionality.
- It helped in maintaining the project's stability and reliability throughout development.

User Acceptance Testing (UAT)

- UAT was conducted to gather feedback from users and ensure the project met their needs and expectations.
- Feedback was collected and addressed to improve the project's usability and performance.

Code Efficiency

Optimization Techniques

Reducing Memory Usage: I carefully managed memory allocation and deallocation, especially when handling large data structures or buffers. This helped minimize memory fragmentation and ensured efficient use of available memory.

Minimizing Processing Time: I optimized algorithms and code structures to reduce the overall processing time. For example, I used efficient data structures like arrays and linked lists, and optimized loops and conditional statements to minimize redundant calculations.

Code Review

```
#include <Servo.h>
#include "SoftPWM.h"

/* Motor pins */
#define GREEN_LED_PIN 5
#define RED_LED_PIN 3
#define BATTERY_PIN A2
const int BATTERY_FULL = 100;
const int BATTERY_GREEN = 30;
const int BATTERY_RED = 15;
#define IN1 4
#define IN2 2
#define ENA A0
#define IN3 7
#define IN4 8
#define ENB A1

/* Ultrasonic sensor */
#define trigger 12
```

```
#define echo 13
Servo ultrasonicServo;

void setup() {
  pinMode(GREEN_LED_PIN, OUTPUT);
  pinMode(RED_LED_PIN, OUTPUT);

  digitalWrite(GREEN_LED_PIN, HIGH); // Turn on green LED initially
  digitalWrite(RED_LED_PIN, LOW);
}

void loop() {
  int batteryPercentage = getBatteryPercentage();
  controlLEDs(batteryPercentage);
}

int getBatteryPercentage() {
  int sensorValue = analogRead(BATTERY_PIN);
  float voltage = sensorValue * (5.0 / 1023.0) * 3; // Assuming a voltage divider and
a 3:1 ratio
  int percentage = map(voltage, 0, 12, 0, 100); // Assuming 12V battery
  return percentage;
}

void controlLEDs(int batteryPercentage) {
  if (batteryPercentage > BATTERY_GREEN) {
    digitalWrite(GREEN_LED_PIN, HIGH); // Green LED on
    digitalWrite(RED_LED_PIN, LOW);
  } else if (batteryPercentage <= BATTERY_GREEN && batteryPercentage >
BATTERY_RED) {
    digitalWrite(GREEN_LED_PIN, LOW); // Green LED off
    digitalWrite(RED_LED_PIN, HIGH); // Red LED on
  } else if (batteryPercentage <= BATTERY_RED) {
    digitalWrite(GREEN_LED_PIN, LOW); // Green LED off
```

```
    // Blinking red LED
    if (millis() % 1000 < 500) {
      digitalWrite(RED_LED_PIN, HIGH);
    } else {
      digitalWrite(RED_LED_PIN, LOW);
    }
  }
}


char input;
volatile bool flag = 1;

uint8_t pwm;
volatile float duration;
volatile float distance;
volatile float leftDistance;
volatile float rightDistance;
const float safeDistance = 20.0;

void setup() {
  /* Setup baud rate for serial communication */
  Serial.begin(9600);
  delay(100);

  /* Setup DC motors */
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  pinMode(ENA, OUTPUT);
  pinMode(IN3, OUTPUT);
  pinMode(IN4, OUTPUT);
  pinMode(ENB, OUTPUT);

  /* Setup servo motor */
```

```
  ultrasonicServo.attach(9);
  ultrasonicServo.write(90);

  /* Setup ultrasonic sensor pins */
  pinMode(trigger, OUTPUT);
  pinMode(echo, INPUT);

  /* Setup DC motor pwm */
  SoftPWMBegin(SOFTPWM_NORMAL);
  SoftPWMSet(ENA, 255);
  SoftPWMSet(ENB, 255);
}

void loop() {
  if (Serial.available() > 0) {
    input = Serial.read();

    /* Manual mode */
    if (input == 'G' || input == 'H' || input == 'I' || input == 'J' || input == 'K') {
      flag = 1;
      manual();
    }
    /* Automatic mode */
    else if (input == 'A') {
      flag = 1;
      ultrasonicServo.write(90);
      automatic();
    }
    /* Voice mode */
    else if (input == 'F' || input == 'B' || input == 'L' || input == 'R' || input == 'S') {
      flag = 1;
      voice();
    }
    /* Change PWM values */
```

```
  else if (input == 'X' || input == 'Y' || input == 'Z') {
    pwmChange();
  }
 }
}
```

- Features:

  - **LED Indicators**: Green and red LEDs indicate battery level and status.
  - **Manual Control**: Allows manual control of the wheelchair with commands for forward, backward, left, right, and stop.
  - **Automatic Mode**: Uses ultrasonic sensor for obstacle detection and automatic navigation.
  - **Voice Control**: Provides voice control capabilities for wheelchair movement.
  - **PWM Control**: Allows changing the PWM values for controlling motor speed.
  - **Battery Monitoring**: Monitors the battery voltage to estimate battery percentage.
  - **Resource Management**: Efficiently manages system resources for optimal performance.

- **Arduino Code:** The Arduino code reads voice commands from the application via Bluetooth and controls the wheelchair's motors accordingly.

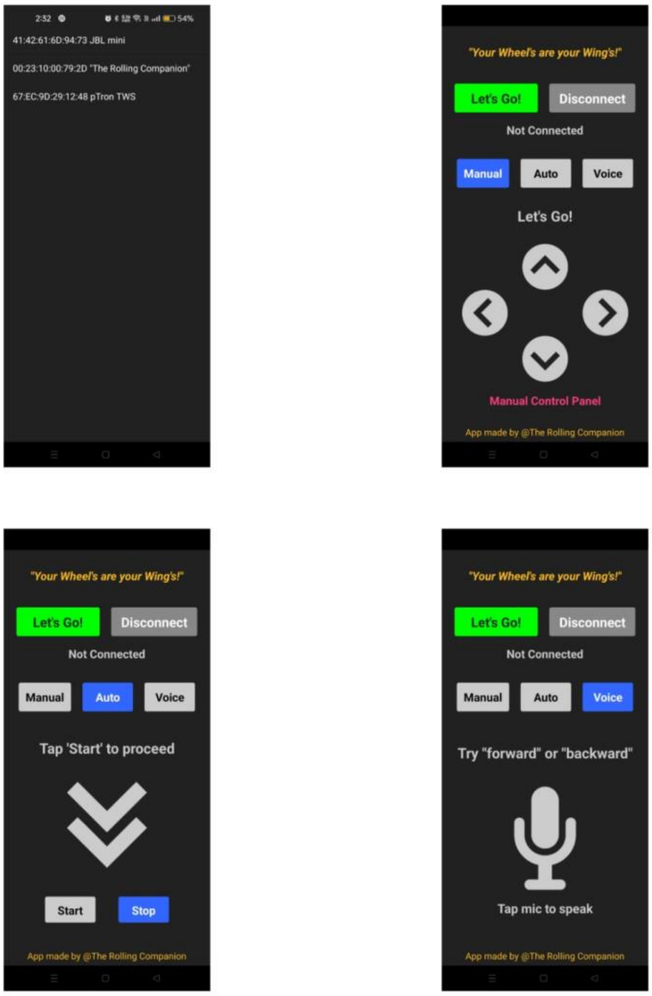
- **Comments:** Comments are used to explain the purpose of each function and how it contributes to the overall functionality.
- **Documentation:** The code is documented using docstrings to provide detailed explanations of each module, function, and variable.

Results

Functionality

The wheelchair supports three control modes:

- **Manual:** The user can control the wheelchair using physical buttons or joysticks.
- **Automatic:** The wheelchair can navigate predefined paths autonomously using obstacle detection sensors.
- **Voice:** The user can control the wheelchair using voice commands, such as "go forward," "turn left," or "stop."



Response to Voice Commands and Sensor Inputs

The wheelchair responds well to voice commands, with a high level of accuracy in recognizing and executing commands. Sensor inputs, such as those from obstacle detection sensors, are used to ensure safe navigation in automatic mode.

Performance

Speed, Responsiveness, and Accuracy

- **Speed:** The wheelchair moves at a comfortable and adjustable speed for the user.
- **Responsiveness:** The wheelchair responds promptly to voice commands and sensor inputs.
- **Accuracy:** Movements are precise, especially in avoiding obstacles in automatic mode.

- Evaluation Metrics

- **Response Time:** The time taken for the wheelchair to respond to a voice command or sensor input.
- **Navigation Accuracy:** The percentage of successful obstacle avoidance maneuvers in automatic mode.

User Feedback

Summary of Feedback

- Users have expressed satisfaction with the wheelchair's ease of use and intuitive controls.
- They appreciate the safety features, such as the emergency stop mechanism and obstacle detection.
- Some users have suggested improvements to the voice recognition system for better accuracy and additional voice commands for more control options.

Safety

Safety Features

- **Emergency Stop:** The emergency stop mechanism has performed reliably, halting the wheelchair immediately when activated.
- **Obstacle Detection:** The wheelchair's sensors effectively detect obstacles and adjust the wheelchair's path to avoid collisions.
  - Instances of Safety Features Activation
- The emergency stop mechanism has been activated in situations where immediate stopping was necessary, preventing potential accidents.

Advantages Over Current System

Enhanced Accessibility

- The voice-enabled wheelchair provides a more accessible interface for individuals with mobility impairments by allowing them to control the wheelchair using simple voice commands, eliminating the need for complex manual controls.
    - Improved Control
- The voice control feature allows users to control the wheelchair more intuitively and efficiently compared to traditional joystick controls, providing a more natural and user-friendly experience.
    - Safety Features
- The wheelchair is equipped with safety features such as emergency stop mechanisms and obstacle detection sensors, enhancing user safety compared to traditional wheelchairs.
    - Customization
- The wheelchair can be customized and adapted to meet the specific needs and preferences of individual users, providing a more personalized experience and improving overall comfort and usability.
    - Ease of Use
- The wheelchair's user interface and control modes (manual, automatic, voice) make it easier for users to navigate and operate the wheelchair in different scenarios, enhancing overall usability and user experience.
    - Integration of Technologies
- The wheelchair integrates various technologies such as Arduino, voice recognition, and sensors to provide a more advanced and feature-rich solution compared to traditional wheelchairs, offering enhanced functionality and capabilities.
    - Cost-Effectiveness
- The wheelchair's design and components offer a cost-effective solution compared to other assistive mobility devices on the market, making it more accessible to a wider range of users.
    - User Experience

- The wheelchair's design and functionality improve the overall user experience compared to existing systems, providing a more comfortable, convenient, and empowering mobility solution for individuals with mobility impairments.
    - Future Potential
- The wheelchair project has the future potential for scalability, adaptability to new technologies, and compatibility with future advancements in assistive technology, making it a sustainable and forward-thinking solution in the field of mobility assistance

Future Work

- Enhancements
- Further improve the voice recognition system for increased accuracy and expanded command vocabulary.
- Enhance the obstacle detection system with additional sensors for improved environmental awareness.
    - New Features
- Add features such as automatic path planning and navigation to further enhance the wheelchair's autonomy.
- Incorporate user customization options for control preferences and wheelchair settings.
    - Research Directions

- Explore advanced machine learning techniques for voice recognition and sensor fusion to improve the wheelchair's performance and adaptability.

Investigate the use of AI algorithms for real-time decision making and navigation in complex environments.

- Continued Development

- Continue collaborating with researchers and developers in the field of assistive technology to further enhance the wheelchair's capabilities and user experience.
- Provide ongoing support and maintenance for the wheelchair, ensuring its continued functionality and relevance.

Conclusion

The purpose of the voice-enabled wheelchair project was to create a more accessible and user-friendly mobility solution for individuals with mobility impairments. The goal was to develop a wheelchair that could be controlled using simple voice commands, enhancing user independence and mobility.

Key achievements of the project include:

- Successful implementation of voice control, allowing users to control the wheelchair with ease.
- Reliable obstacle detection system, ensuring safe navigation and collision avoidance.

- Positive user feedback on the wheelchair's functionality, performance, and user-friendly interface.

Challenges faced during the project included fine-tuning the voice recognition system and integrating the .various control modes and sensors. Solutions implemented included iterative testing and refinement of algorithms, as well as thorough testing and calibration of sensors. New skills and knowledge gained throughout the project included advanced programming techniques for sensor integration and motor control, as well as project management skills for coordinating development tasks and timelines.

The project has the potential to have a significant impact on the lives of individuals with mobility impairments, providing them with greater independence and mobility. Additionally, the project has contributed to personal development by expanding skills in robotics, assistive technology, and project management.

I would like to acknowledge the support of **Dr Hiren Dand**, who provided guidance and resources throughout the project. Their expertise and support were instrumental in the success of the project.

System Maintenance

- Regular Inspections

- **Schedule:** Conduct regular inspections of the wheelchair's hardware components, including motors, sensors, and wiring, to check for any signs of wear or damage.
- **Purpose:** This helps ensure that the wheelchair remains in good working condition and can identify any potential issues early.

- Software Updates

- **Stay Updated:** Keep the wheelchair's control system up-to-date with software updates, including firmware updates for the Arduino board or other components.

- **Benefits:** This helps improve the wheelchair's performance, security, and compatibility with new features.
  - Battery Maintenance
- **Monitor Health:** Regularly monitor the wheelchair's battery health and performance.
- **Replace as Needed:** Replace the battery as needed to ensure optimal performance and avoid unexpected failures.
  - Cleaning and Care
- **Regular Cleaning:** Regularly clean the wheelchair's exterior and components to prevent dust and debris buildup, which can affect performance and longevity.
- **Careful Handling:** Handle the wheelchair with care to avoid damage to sensitive components.
  - User Training
- **Proper Use and Maintenance:** Provide user training on the proper use and maintenance of the wheelchair, including how to safely operate and charge it.
- **User Manual:** Provide a user manual that outlines best practices for maintaining the wheelchair.
  - Documentation and Troubleshooting
- **Detailed Documentation:** Maintain detailed documentation of the wheelchair's components, wiring, and software configuration.
- **Troubleshooting Guides:** Provide troubleshooting guides for common issues that users may encounter.
  - Backup and Recovery
- **Implement Measures:** Implement backup and recovery measures for the wheelchair's software and configuration.
- **Data Protection:** Protect user data and ensure that it can be restored in case of data loss or system failure.
  - User Support
- **Ongoing Support:** Provide ongoing user support for any questions or issues that arise with the wheelchair's operation or maintenance.
- **Responsive Communication:** Respond to user inquiries promptly and offer assistance as needed.

- Future Upgrades

- **Plan Ahead:** Plan for future upgrades and enhancements to the wheelchair's hardware and software, based on user feedback and technological advancements.
- **Stay Flexible:** Remain flexible and adaptable to incorporate new features and improvements as they become available.

Reference

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