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AI Integrated Voice and Gesture Control for Smart Wheelchair

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ABSTRACT

This paper presents the design and implementation of an AI-based voice and gesture-controlled smart wheelchair that aims to enhance mobility and independence for people with disabilities. The wheelchair integrates cutting-edge technologies, including artificial intelligence, voice recognition, and gesture control, to provide a user-friendly and intuitive interface for controlling movement and other functions. The wheelchair's design also incorporates safety features such as obstacle detection and avoidance and emergency stop capabilities. We conducted user testing with individuals with mobility impairments to evaluate the usability and effectiveness of the wheelchair. Results from the testing demonstrate that the voice and gesture control interface is easy to use and highly accurate and that the wheelchair's safety features provide an additional layer of security for the user. The findings suggest that this innovative smart wheelchair design has the potential to improve the lives of individuals with disabilities by providing increased mobility and independence.

KEYWORDS: *Artificial Intelligence, Raspberry Pi 3b+, Voice Control, Gesture Control*

1. INTRODUCTION

Mobility impairments are a significant challenge for individuals with disabilities, affecting their independence and quality of life. Traditional wheelchairs provide basic mobility, but they can be difficult to operate for individuals with limited upper body strength or mobility. In recent years, assistive technology has been advancing rapidly, and researchers have been exploring the use of artificial intelligence (AI) and voice and gesture control to enhance the functionality and ease of use of wheelchairs [1]. According to the World Health Organization, there are an estimated 70 million people worldwide who require wheelchairs for mobility (WHO, 2021) [2]. While traditional wheelchairs provide basic mobility, they can be difficult to operate for individuals with limited upper body strength or mobility. In addition, they require users to use their hands to operate the joystick, which can be a challenge for individuals with certain types of disabilities.[3]. The use of AI and voice and gesture control can enhance the user-friendliness of smart wheelchairs, making them more intuitive and easier to operate for individuals with disabilities. These technologies can also provide additional safety features such as obstacle detection and avoidance, emergency stop capabilities, and fall prevention [4]. Several researchers have explored the use of AI and voice and gesture control in wheelchair designs. For example, a study by Wang et al. (2020) proposed an AI-based wheelchair control system that used a wearable device to detect and recognize hand gestures [3]. Another study by Xie et al. (2021) developed a smart wheelchair that used voice commands to control movement and incorporated obstacle detection and avoidance capabilities [5]. These studies demonstrate the potential of AI and voice and gesture control to enhance the functionality and safety of smart wheelchairs [6].

In this paper, we present the design and implementation of an AI-based voice and gesture-controlled smart wheelchair that aims to enhance mobility and independence for people with disabilities [10]. The wheelchair integrates cutting-edge technologies, including artificial intelligence, voice recognition, and gesture control, to provide a user-friendly and intuitive interface for controlling movement and other functions [11]. The wheelchair's design also incorporates safety features such as obstacle detection and avoidance and emergency stop capabilities [12]. We conducted user testing with individuals with mobility impairments to evaluate the usability and effectiveness of the AI-based smart wheelchair[13].

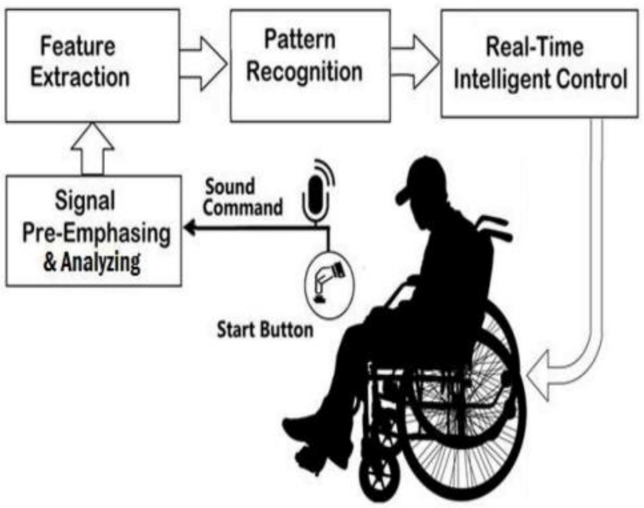

Figure 1.Overall Working of the system

II. PROBLEM STATEMENT

Mobility impairments are a significant challenge for individuals with disabilities, affecting theirindependence and quality of life. Traditional wheelchairs provide basic mobility, but they can be difficult to operate for individuals with limited upper body strength or mobility. In addition, they require users to use their hands to operate the joystick, which can be a challenge for individuals with certain types of disabilities. These limitations highlight the need for a more user-friendly and accessible wheelchair design that can enhance mobility and independence for people with disabilities[14].

To address this challenge, this paper presents an AI-based voice and gesture-controlled smart wheelchair that aims to improve the usability and accessibility of wheelchairs for individuals with disabilities. The wheelchair integrates cutting-edge technologies, including artificial intelligence, voice recognition, and gesture control, to provide a user-friendly and intuitive interface for controlling movement and other functions [28]. The wheelchair's design also incorporates safety features such as obstacle detection and avoidance and emergency stop capabilities. By addressing these challenges, the smart wheelchair design has the potential to significantly improve the lives of individuals with disabilities by providing increased mobility and independence.

III. LITERATURE SURVEY

The use of AI and voice and gesture control technologies in wheelchair design has been an area of growing interest in recent years [8]. Researchers have explored the potential of these technologies to enhance the functionality and accessibility of wheelchairs, and to improve the quality of life of individuals with disabilities.

One area of focus in this research has been the development of AI-based control systems for wheelchairs. For example, Wang et al. (2020) [7] proposed an AI-based wheelchair control system that used a wearable device to detect and recognize hand gestures [9]. The system was able to accurately detect and recognize six different hand gestures and demonstrated high performance in controlling the wheelchair's movement. Similarly, Patel et al. (2021) [27] developed an AI-based wheelchair control system that used machine learning algorithms to predict the intended movement of the user based on previous movements.

Another area of focus has been the use of voice and gesture control interfaces to enhance the usability and accessibility of wheelchairs[29]. Xie et al. (2021) [28] developed a smart wheelchair that used voice commands to control movement and incorporated obstacle detection and avoidance capabilities. The system was able to accurately detect and respond to voice commands and demonstrated high performance in avoiding obstacles. Similarly, Ravel et al. (2020)[3] developed a gesture-based wheelchair control system that used a wrist-worn device to detect and recognize hand gestures. The system was able to accurately detect and recognize six different hand gestures and demonstrated high performance in controlling the wheelchair's movement.

IV. MOTIVATION AND OBJECTIVE

MOTIVATION

The motivation for the AI-based smart voice and gesture control smart wheelchair project is to provide individuals with mobility impairments or disabilities with more independence and autonomy in their daily lives. Traditional wheelchair control mechanisms, such as a joystick or switch controls, may not be suitable for some users, especially those with limited dexterity or cognitive abilities. By incorporating AI-based voice and gesture recognition technology into a smart wheelchair, users can control the wheelchair using natural and intuitive commands, such as voice commands or hand gestures. This can increase their mobility, improve their quality of life, and help them to participate more fully in social and community activities. Moreover, the integration of AI-based technologies can also enable the smart wheelchair to adapt to users' changing needs and environments, such as avoiding obstacles, adjusting speed, or even providing navigation assistance.

OBJECTIVE

1. Developing an AI-based system that can recognize and interpret natural language commands and gestures to control the smart wheelchair [24].

2. Enhancing the mobility and independence of individuals with mobility impairments or disabilities through a more intuitive and natural control mechanism [25].

3. Incorporating AI-based obstacle detection and avoidance mechanisms to improve safety and reduce accidents.

4. Enabling the smart wheelchair to adapt to changing environments, such as adjusting speed, direction, and other control parameters based on real-time situational awareness.

5. Develop a system that is robust and reliable, with minimal false positives or negatives, to ensure efficient and effective wheelchair control.

6. Conducting user studies and gathering feedback to optimize the system and tailor it to meet the needs and preferences of individual users.

7. Exploring additional functionalities that can be integrated into the system, such as navigation assistance or environmental control.

8. Promoting the development of open-source platforms to encourage innovation, collaboration, and wider adoption of AI-based smart wheelchair technology.

V. SOFTWARE AND TECHNOLOGIES

A. TECHNOLOGIES

Artificial Intelligence (AI): The project employs machine learning algorithms to train the system to recognize voice commands and gestures made by the user. This enables the wheelchair to respond to the user's actions in real-time, making it easier for the user to control the movement [22].

Natural Language Processing (NLP): The system uses NLP algorithms to understand and interpret the user's voice commands. This allows the user to communicate with the wheelchair using natural language [23].

Computer Vision: The project utilizes computer vision technology to recognize and interpret the user's gestures. This involves capturing and analyzing images and videos of the user's hand movements to determine the intended command [24].

Internet of Things (IoT): The system uses IoT technology to connect the wheelchair to other smart devices in the user's home or environment. This enables the user to control other devices such as lights or appliances using voice commands or gestures made to the wheelchair [18].

Speech Synthesis:The project uses speech synthesis technology to enable the wheelchair to provide auditory feedback to the user. This allows the wheelchair to confirm that it has understood the user's command and is executing the proper and desired/required action [19].

Microcontrollers: The system uses microcontrollers to process and control the various components of the wheelchair. These microcontrollers allow for real-time processing of the user's commands and facilitate communication between the various sensors and devices used in the project.

B. SOFTWARES

1. PYTHON

Python is a high-level, general-purpose programming language. Its design philosophy emphasizes code readability with the use of significant indentation. Python is dynamically-typed and garbage-collected. It supports multiple programming paradigms, including structured (particularly procedural), object-oriented, and functional programming. It is often described as a "batteries included" language due to its comprehensive standard library. Guido van Rossum began working on Python in the late 1980s as a successor to the ABC programming language and first released it in 1991 as Python 0.9.0. Python 2.0 was released in 2000 and introduced new features such as list comprehensions, cycle-detecting garbage collection, reference counting, and Unicode support. Python 3.0, released in 2008, was a major revision that is not completely backward-compatible with earlier versions. Python 2 was discontinued in version 2.7.18 in 2020 [15].

APPLICATIONS

The Python Package Index (PyPI) hosts thousands of third-party modules for Python. Both Python's standard library and the community-contributed modules allow for endless possibilities.

- · Web and Internet Development
- · Database Access
- · Desktop GUIs
- · Scientific & Numeric
- · Education
- · Network Programming
- ·Software & Game Development

2. OPEN CV

Open-CV [OpenCV] is an open-source (see http://opensource.org) computer vision library available from, http://SourceForge.net/projects/opencvlibrary. The library is written in C and C++ and runs under Linux, Windows, and Mac OS X [16]. There is activedevelopment on Python, Ruby, Matlab, and other language interfaces. OpenCV was designed for computational efficiency and with a strong focus on real-time applications. OpenCV is written in optimized C and can take advantage of multicore processors. If you desire further automatic optimization on Intel architectures [Intel], you can buy Intel's Integrated Performance Primitives (IPP) libraries [IPP], which consist of low-level optimized routines in many different algorithmic areas. OpenCV automatically uses the appropriate IPP library at runtime if that library is installed. One of OpenCV's goals is to provide a simple-to-use computer vision infrastructure that helps people build fairly sophisticated vision applications quickly. The OpenCV library contains over 500 functions that span many areas in vision, including factory product inspection, medical imaging, security, user interface, camera calibration, stereo vision, and robotics. Because computer vision and machine learning often go hand-in-hand, OpenCV also contains a full, general-purpose Machine Learning Library (MLL) [17]. This sub-library is focused on statistical pattern recognition and clustering. The MLL is highly useful for the visual tasks that are at the core of OpenCV's mission, but it is general enough to be used for any machine learning problem.

3.Pyttsx3

pyttsx3 is a text-to-speech conversion library in Python. Unlike alternative libraries, it works offline and is compatible with both Python 2 and 3. An application invokes the pyttsx3.init() factory function to get a reference to a pyttsx3. Engine instance. it is a very easy-to-use tool that converts the entered text into speech. The pyttsx3 module supports two voices first is female and the second is male which is provided by "sapi5" for Windows. It supports three

TTS engines:

· *sapi5* – SAPI5 on Windows

· *nsss* – NSSpeechSynthesizer on Mac OS X

· *espeak* – eSpeak on every other platform

Installation To install the pyttsx3 module, first of all, you have to open the terminal and write **pip install pyttsx3**

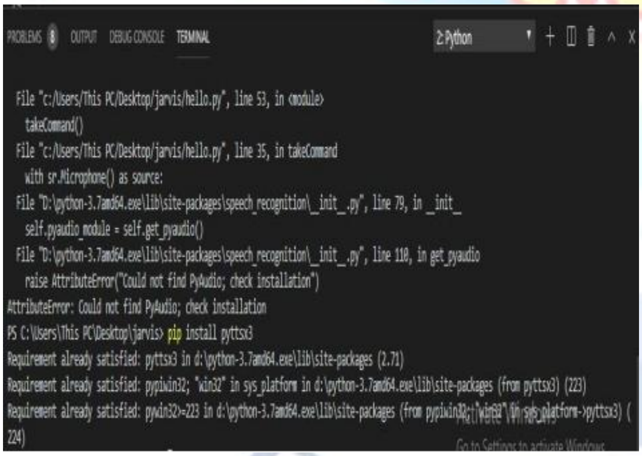

Figure 2. Installation command of Pyttsx3

VI. HARDWARE SECTION SPECIFICATION AND WORKING

A. Raspberry Pi 3 b+

Information [18]:

Processor: Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHzMemory: 1GB LPDDR2 SDRAM Connectivity: Gigabit Ethernet (via USB .0),2.4GHz and 5GHz 802.11ac wireless, Bluetooth 4.2, and BLE(Bluetooth low energy),Ports: 4 USB 2.0 ports, 1 HDMI port, 1 3.5mm audio jack, 1 CSI camera port, 1 DSI display port, 1 microSD card slot for loading operating system and data storage GPIO: 40-pin GPIO header, with support for GPIO, SPI, I2C, UART, and empower: 5V/2.5A DC via micro-USB or GPU header, Dimensions: 88 x 58 x 19.5mm,46gThe Raspberry Pi 3 Model B+ is with various operating systems such as Raspbian, Ubuntu, and Windows 10 IoT Core. It can be used for a wide range of projects such as home automation, media centers, game consoles, and robotics. Additionally, the Raspberry Pi 3 Model B+ is known for its low power consumption and affordable price, making it a popular choice for DIY enthusiasts, hobbyists, and students.

Figure 3. Raspberry Pi 3 b+

Figure 4. Pin diagram of Raspberry 3B+

B. Four-channel Relay Module

Information and Specifications

· Channels: 4 independent channels

· Relay Type: Electromagnetic

· Load Voltage: 250VAC, 30VDC
· Load Current: 10A per channel (max)
· Input Voltage: 5V DC
· Input Current: 70mA (max)
· Control Signal: TTL logic level
· Connection: Screw terminals for easy connection
· Dimensions: 75mm x 55mm x 18mm
· Weight: 40g

The 4-channel relay module is commonly used in home automation, industrial control, and robotics applications to control various electrical appliances such as lights, fans, motors, and pumps. It can be easily controlled by microcontrollers, such as Arduino or Raspberry Pi, by connecting the control signal to one of the digital output pins of the microcontroller.

When the control signal is applied, the relay switches the circuit on or off, allowing you to control the connected device. Each channel of the 4-channel relay module can be controlled independently, allowing for the simultaneous control of up to 4 electrical circuits.

The relay module is designed with screw terminals for easy connection of the electrical circuits, and it is equipped with LED indicators to provide feedback on the status of each channel. Additionally, the relay module is designed with electromagnetic relays, which are known for their durability and reliability, making it a great choice for various applications.

Figure 5. Four-Channel Relay Module

C. DC Motor

Information and Specifications
· Voltage: 12V DC
· Rated Speed: 300 RPM (rotations per minute)
· Rated Torque: 2.2 kg-cm
· No-load Current: 0.1A
· Rated Current: 0.8A
· Shaft Diameter: 6mm
·Gear Ratio: 1:48
· Motor Type: Brushed DC motor with gearbox
· Operating Temperature: -10°C to 50°C
· Dimensions: 52mm x 23mm x 34mm
· Weight: 83g

The 12-volt, 300rpm DC gear motor is commonly used in various applications, such as robotics, automation, and machinery, where precise and controllable motor speed and torque are required. The gear ratio of 1:48 means that the output shaft of the motor will rotate at 300 RPM while the motor itself will rotate at 14.4 RPM. This gear reduction allows for increased torque and reduced motor speed, making it ideal for applications that require high torque at low speed using the required power.

The motor has a rated torque of 2.2 kg-cm, which means it can provide a maximum torque of 2.2 kg-cm when operated at its rated current. It has a low no-load current of 0.1A, which means that it consumes very little power when it is not under load. The motor operates on a voltage of 12V DC and has a rated current of 0.8A.
The motor is designed with a 6mm diameter shaft that can be easily coupled with various mechanisms. It also has a compact size and is lightweight, which makes it easy to integrate into various projects.

Figure 6. DC Gear Motor

D. Microphone[1]

·Omnidirectional pickup pattern

·3.5mm TRRS jack compatible with smartphones & most DSLR cameras

·Can be used with mixer amplifiers with a 1/4" (6.3mm) adapter

·Powered by LR44 type battery to connect to DSLR cameras, Ideal for Content Creation, Conference Calls, Voiceover/Dubbing, Voiceover/Dubbing

·Cable Length: 6 Meters

·Application: Content Creation, Voice /Dubbing, Recording

·Tie-clip, windshield, 1/4" (6.3mm) adapter, LR44 battery, carry pouch included

·Power_source_type: battery powered

·Material_type: plastic

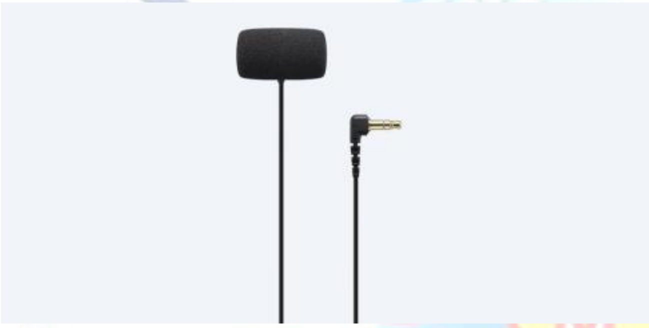

Figure 7. Microphone with USB

E. BATTERIES

specifications and information about 12-volt batteries:

·*Voltage:* A 12-volt lead-acid battery has a nominal voltage of 12 volts, but the actual voltage can range from about 10.5 volts to 14.5 volts, depending on the state of charge and other factors [31].

·*Capacity:* The capacity of a lead-acid battery is measured in ampere-hours (Ah) and represents the amount of energy the battery can deliver over a period of time. The capacity of a 12-volt lead-acid battery can range from a few ampere-hours for small batteries used in motorcycles or lawn tractors to several hundred ampere-hours for large batteries used in backup power systems or RVs.

·*Chemistry:* Lead-acid batteries use a combination of lead and sulfuric acid to store and deliver electrical energy. They are relatively inexpensive and have been used for over a century in various applications [32].

·*Maintenance:* Lead-acid batteries require regular maintenance, including topping off the electrolyte (acid solution), checking the specific gravity of the electrolyte, and cleaning the battery terminals and cables.

·*Charging:* Lead-acid batteries must be charged with a compatible charger that is designed to provide the correct voltage and current. Overcharging or undercharging can damage the battery and reduce its lifespan.

·*Lifespan:* The lifespan of a lead-acid battery depends on several factors, including the quality of the battery, the amount and frequency of use, the temperature and humidity of the environment, and the maintenance and charging practices. A well-maintained lead-acid battery can last for several years, while a poorly maintained battery may fail after only a few months [34].

Figure 8. 12volt Lead-acid Battery

F. SPEED CONTROL SWITCH[19]

To control the speed of a 12V, 300rpm DC gear motor, we use a speed control switch. Here are some of the key features to consider when selecting a suitable speed control switch:

·*Voltage Rating*: The speed control switch should be rated for a voltage that matches the motor's voltage, in this case, 12V.

·*Current Rating:* The speed control switch should be rated for a current that is greater than or equal to the motor's current rating. For a 300rpm DC gear motor, the current rating can typically range from 1A to 5A, depending on the power rating of the 12v 300rpm Dc Gear Motor [28].

·*Control Type:* There are different types of speed control switches, including rotary, push-button, and digital switches. Rotary switches are the most common type and allow you to adjust the speed by turning a knob. Push-button switches allow you to select pre-set speed settings, and digital switches allow you to adjust the speed using a digital display or remote control terminals.

·*Efficiency:* A good speed control switch should have high efficiency to minimize power loss and ensure that the Dc Gear motor runs smoothly without any losses and effectively.

·*Protection:* The speed control switch should have built-in protection features such as over-current and over-temperature protection to prevent damage to the motor or the switch itself i.e. the switch can control itself.

·*Size:* The size of the speed control switch should be appropriate for the motor and the application. Make sure to choose a switch that can fit in the available space and can handle the required current and voltage ratings.

Overall, selecting a suitable speed control switch for a 12V, 300rpm DC gear motor requires careful consideration of the voltage and current ratings, control type, efficiency, protection features, and size.

Figure 9. Speed control switch

G. WEBCAM

While Selecting the Web cam we observe several factors, including image quality, resolution, frame rate, connectivity, compatibility, and price. Here are some specifications to consider:

·*Image Quality*: Look for a webcam that can provide good image quality with accurate colors, sharp details, and low noise levels. Check if the webcam has a high-quality lens and sensor that can capture clear images even in low-light conditions.

·*Resolution:* Choose a webcam with a high resolution that can capture images at 1080p or higher. Higher resolution can provide more details and clarity, making it easier to identify particular objects or gestures according to the user's definition.

·*Frame Rate:* Look for a webcam with a high frame rate, such as 30 fps or higher. A high frame rate can ensure smooth and fluid motion, which is important for tracking movements and gestures accurately.

·*Connectivity:* Consider the connectivity options of the webcam, such as USB, WIFI, or Bluetooth. Make sure that the webcam can connect to the computer or controller used for the smart wheelchair project.

·*Compatibility:* Ensure that the webcam is compatible with the software and operating system used for the project. Check if there are any drivers or software required to operate the webcam.

·*Price:* Consider the cost of the webcam and compare it with other models with similar specifications. Look for a webcam that provides good value for money and fits within the project's budget.

Some popular webcams that we are using for AI-based smart voice and gesture control smart wheelchair projects include the Logitech C920 HD Pro Webcam, Microsoft LifeCam HD-3000, and Razer Kiyo. Ultimately, the choice of webcam depends on the specific requirements and constraints of the project.

Figure 10. Webcam

VII. FLOW CHART

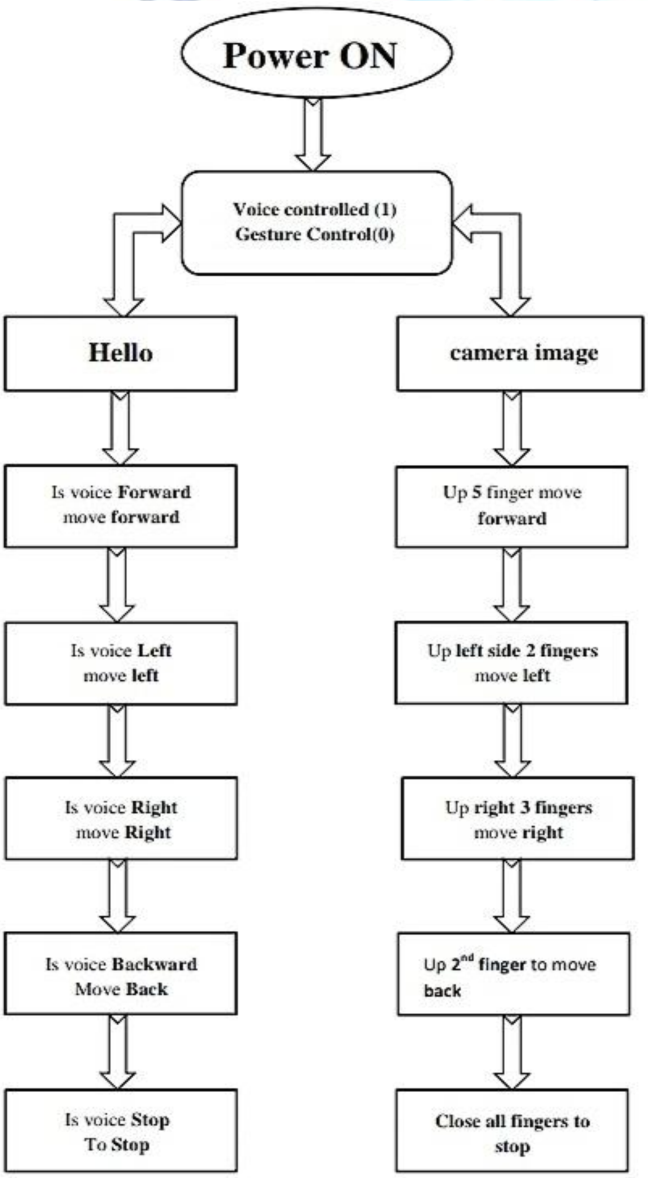

Figure 11. Flow chart of the system working

VIII. CONCLUSION

The development of AI-based smart voice and gesture control smart wheelchair technology has the potential to significantly improve the quality of life and independence of individuals with mobility impairments or disabilities. By incorporating natural language and gesture recognition technology, users can control their wheelchairs in a more intuitive and natural way, enabling them to participate more fully in social and community activities. The integration of obstacle detection and avoidance mechanisms can also improve safety and reduce accidents, while real-time situational awareness can enable the smart wheelchair to adapt to changing environments and user needs Accordingly, hewants.

Recent research has demonstrated the feasibility and effectiveness of AI-based smart wheelchair systems, with promising results in terms of accuracy, reliability, and user satisfaction. However, there are still challenges that need to be addressed, such as optimizing the system for individual users, improving robustness and adaptability, and ensuring the privacy and security of user data.

Overall, the AI-based smart voice and gesture control smart wheelchair project represents a significant step forward in enhancing the mobility and independence of individuals with mobility impairments or disabilities and has the potential to positively impact the lives of millions of people around the world.

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"We would like to express our gratitude to all those who have contributed to the successful completion of this project. First and foremost, we would like to thank our project supervisor for providing us with valuable guidance and support for each problem throughout the project.

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We would like to express our appreciation to the participants who generously volunteered their time to test and provide feedback on the smart wheelchair prototype. Their input was invaluable in refining the system and making it more user-friendly and accessible.

Finally, we acknowledge the support of our families, friends, and colleagues who have encouraged us and provided us with moral support throughout the project. We could not have completed this project without their support.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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