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VOICE ACTIVATED SMART WHEELCHAIR FOR PHYSICALLY DISABLED PERSON

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Abstract
Modern, hands-free wheelchair meant to enable those with physical limitations move around more readily and freely is the Voice-activated Smart Wheelchair (V-SW). It operates by listening to vocal commands, therefore enabling users to control the wheelchair merely with words. It also makes use of sensors and smart technology to identify hazards, grasp the surroundings, and pick the best course of action for a safe travel. It improves over time at varying speed and direction depending on user desire thanks to machine learning.

***Keywords*—Wheelchair, voice commands, IoT technologies, Obstacle detection, mapping, machine learning methods, Management of movement.**

I. Introduction

This project aims to enable persons with physical limitations to operate a wheelchair just using their voice, therefore supporting them. For persons with restricted mobility, simply speaking to navigate can make a significant difference rather than depending on their hands to steer or touch buttons. To guarantee a seamless and secure ride, the system employs contemporary technologies including AI Human AI Detector report by 2025-05-17 12:15 PM Version 2025-v5.3.1 3,842 Words Bluetooth to manage communication between several wheelchair sections and ultrasonic sensors to identify impediments. Giving those with disabilities more liberty and autonomy is one of the main objectives of this project. Technology is being applied to enhance mobility and health in line with an increasing trend. Particularly in healthcare and assistive equipment, small and reasonably priced microcontrollers— tiny processors able to run devices—are being increasingly utilized. Describe real-world situations in which a hands-free wheelchair might enhance consumers' quality of life. In hospitals or rehabilitation , these wheelchairs could enable patients with limited arm movement go outside, visit friends, or attend events more easily. Someone living alone could move freely around their house without need of a caregiver. This project aims to provide a reasonably priced low-cost solution based on a well-known singleboard computer with proven simplicity and affordability. The concept is to create a gadget that is not only reasonably priced and user-friendly but also functionally sound. The system becomes both strong and straightforward for users by leveraging speech recognition software and Python programming tools. This project distinguishes itself from others in that it seeks to make sure the technology is within reach for as many people as feasible, not only create a high-tech wheelchair. Many people find cost to be a major obstacle; thus, by keeping expenses low, this project intends to bring actual transformation to the life of more people. Assistive technology has transformed the life of people with physical disabilities in recent times by giving them more autonomy and freedom. The creation of voice-activated wheelchairs, meant to replace manual controls and enable users to easily negotiate their environment, is one such breakthrough. Whether it's getting about their house or attending social activities, those with physical limitations often face several challenges in their daily life. Regular wheelchairs can be difficult to operate, particularly given their typically high human effort required and their potential to restrict a person's freedom of movement. Thanks to modern technologies including small computer chips (microcontrollers), Bluetooth, and sensors that identify impediments (such as ultrasonic sensors), we now have the opportunity to create smarter, more useful products that simplify life and provide users more independence life.

II. Problem statement

People with physical limitations can find it difficult to move around, which influences their degree of independence. Regular wheelchairs must be pushed by hand, which can be difficult to control and draining. There are several high-tech choices available, but they are frequently not easily obtained, costly, or difficult to use. This project intends to create a voice-activated wheelchair employing contemporary microprocessor, Bluetooth, and ultrasonic sensor technologies. The objective is to design a wheelchair that, for people who require it, is reasonably priced, simple to use, and more accessible. This kind of voice-activated wheelchair can significantly change people's life and advance smart technology, assistive tools, and healthcare among other sectors.

Key Challenges Addressed:

Finding your way without help is challenging.
Restricted user autonomy.
One finds overwhelming complexity in systems.
There are worrying safety hazards.
The voice-activated wheelchair project has great potential to enhance the life of people with physical disabilities by tackling three main obstacles.

III. Objectives

This project's primary objective is to design a reasonably priced voice-activated wheelchair enabling persons with physical limitations to live more independently and move around more freely. Here are the main goals:
Create a reliable speech control system such that the wheelchair reacts precisely to voice commands.
Add robust safety elements; use ultrasonic sensors to identify objects and assist in accident prevention.
Make the system run without problems and guarantee the wheelchair runs effectively.

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Support independent living by helping people have a more active and fulfilling life, participate in social events, visit schools or businesses, and so-called.

Make the wheelchair pleasant, simple to operate, and something users feel safe and confident utilizing so they have a better experience.

Methodology –

1. **System Design**:
- Choose the system's components, software, and user controls as well as their working order.
- Select hardware and software that complement one another.
- Create a user-friendly, easily available interface for every one of them.
- Install backups and safety elements to guarantee dependability and security of the system.

2. **Voice Recognition System Development**:
- Choose the best machine learning technique to faithfully identify voice commands.
- To teach the system well, compile and sanitize voice data.
- Create an accurate and fast dependable voice recognition model.

3. **Safety Feature Integration**:
- Detect impediments using sensors to aid to prevent mishaps.
- Provide an emergency stop mechanism so users may rapidly stop the wheelchair should a need arise.

4.**Hardware and Software Development**:
- Select microcontrollers and sensors that complement one another.
- Design strong algorithms-based voice control software.

5. User Interface Design:
- Create a straightforward, intuitive interface.
- Make sure the system can be used by persons with several kinds of disabilities.

6. Algorithm Development:
- Write clever algorithms that precisely identify speech commands.
- Create mechanisms meant to spot and evade challenges.
- Create mechanisms that safely and gently lead the wheelchair.

IV. System Architecture

The voice-activated wheelchair is composed of numerous components cooperating. Among these are safety elements, navigation and control systems, voice recognition software, and a simple interface. Taken together, they offer a seamless and customized experience that enables those with physical limitations to move more freely, safely, and boldly.

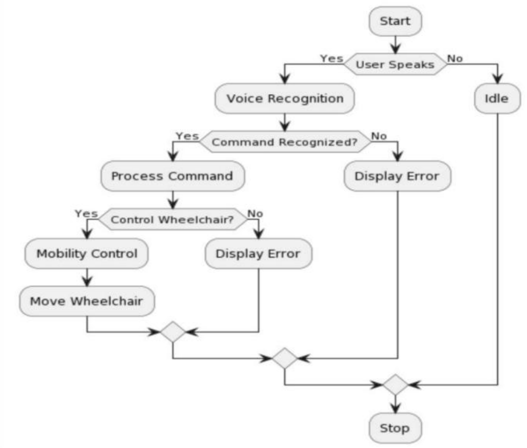

Fig 1.1.System Block Diagram

1. System Workflow

The mechanism operates in many phases to guarantee the wheelchair runs safely and without problems:

- The user voices a command, such as "move forward"which a microphone picks up.
- The system then knows what the user wants and handles it. Knowing the commandthat is, whether the user asked to turn, halt, forward, or backwardsthe system determines.
- The system determines wheelchair movement based on command and tells the motors to go in the correct direction.
- The technology employs sensors to monitor for hazards and adjusts direction or stops if necessary to help to prevent mishaps while you are going.
- Reacting to the user, the wheelchair guarantees everything runs properly by following their command and providing feedback (such as moving or stopping).

The system continuously monitors how everything is running and adjusts should it in any problems. Top concern always is safety.

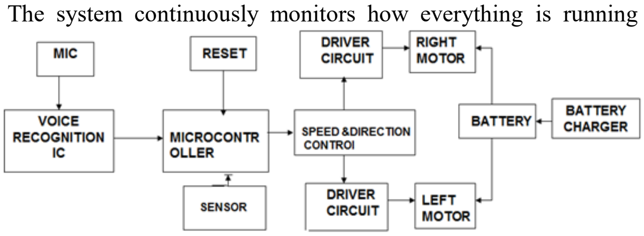

Fig 1.2.System Workflow Architecture

2. Components of the System

The system consists of numerous main parts, each in charge of particular chores:

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- ESP32 Microcontroller: Comparable to wheelchair brain is this. It pushes the wheelchair under direction and responds to vocal commands.
- DC Motor Driver: This component regulates the motors, therefore guiding the wheelchair in the correct path with appropriate force.
- The HC-05 Bluetooth Module lets the system wirelessly link to the phone or other device of the user.
- Running the wheelchair and all its components need the energy found in a 12V battery.
- Hardware and Sensors: The wheelchair detects hurdles with an ultrasonic sensor. Other components including wires, screws, and boards keep everything together and guarantee correct operation.

3. Data Flow Diagram

The data flow within the system is shown below:

- Using a smartphone or another gadget, the user commands a voice call.
- Bluetooth drives this command wirelessly to the system.
- Listening to the command, the primary controller (ESP32) works out what to do.
- It then tells the motor controller to move the wheelchair as required. A sensor looking for any hazards around the wheelchair also works concurrently.
- The controller changes the movement depending on the command from the user and the input of the sensor to maintain safety. One can view the outcomes or status on a web page for the user.

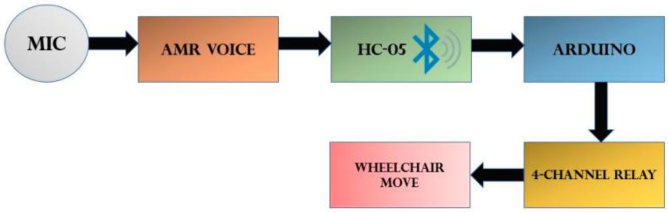

Fig 1.3.Data Flow Architecture Diagram

4. System Design Considerations

- Make sure the system detects hazards and prevents mishaps thereby ensuring the user's safety.
- Create the system to run faultless, effectively, and without problems. Guard the user's data and stop anyone from utilizing the system without authorization.
- Design the system such that it is inclusive for everyone by making it simple for persons with many kinds of disabilities to utilize.
- Considering these elements will help the system to be built to give persons with mobility problems a safe, dependable, and user-friendly experience.

I. LITERATURE REVIEW

1. Toward Developing A Framework For Standardizing The Functional Assessment And Performance Evaluation Of Assistive Robotic Manipulators

The research and development of assistive robotic manipulators (arms) aims to enhance the upper-extremity daily functioning of individuals with disability.

Limitations:

- The system was limited to a specific set of voice commands, which may not be sufficient for all users..
- Can be complex and costly to implement.
- May face resistance and become rigid over time.

2. Voice Recognition Based Intelligent Wheelchair AndGps Tracking System.

Voice module v3 is used to record patient's voice and recognize that voice to follow the instructions of thepatient.

Limitations:

- Voice recognition may face accuracy issues and privacy concerns.
- Increased complexity and cost, with potential challenges.

3. Voice Controlled Wheelchair

The purpose of assistive robotic manipulators (arms) is to improve daily upper-extremity functioning of people with disabilities.

Limitations:

- The system could not be sufficient for every user since it only allowed a restricted collection of voice commands.
- Can be difficult and expensive to put into use.
- May encounter opposition and grow inflexible with time.

4. Development of a voice-controlledintelligent wheelchair system using raspberry pi

One of these barriers is concerning the accessibility and affordability of assistive technologies (ats) that help to enhance the quality of life of these persons.

Limitations:

- May face limitations in real-time performance and durability.
- Integration and power consumption can be challenging.

5. Smart autonomous wheelchair controlled by voice commands-aided by tracking system

Patient's voice is recorded using Voice Module v3, which also helps one to identify that voice to follow patient's directions.

Limitations:

- Privacy questions and accuracy problems with voice recognition could arise.
- More complexity and expenses; possible difficulties with battery life and technological reliance.

II. DATASET DESCRIPTION

Gathering voice data is one of the most critical phases in working on a voice-activated wheelchair. Recording individuals as they speak various orders, such as "go forward" or "stop," helps the wheelchair grasp what people are saying in many tones, accents, and surroundings.

1.Data Collection

We must gather voice recordings in several forms if we are to create a strong system:

- Clearly capturing spoken orders with microphones. compiling voices from many people, maybe via surveys or internet channels, to

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guarantee a broad spectrum of speaking dialects and styles.

- Recording in calm, enclosed settings such as labs, wherebackground noise is minimal, to produce pure audio.
- The method is more flexible if background noises and real-life events arecaptured via recording in real-world locations such as homes or streets.

2.Data Structure

The audio must be appropriately arranged once it has been gathered so machines may make good use of it. Usually this entails:

- Usually kept in WAV or MP3, audio les are the original recordings.
- Labels or comments explain what each recording says, for instance "turn left" or "stop."
- Additional data including who recorded it, where it was kept, and under what circumstances. e.g., noisy or quietis called metadata.

3. Data Preprocessing

Eliminating background noise clarifies the command.

- Extracting salient characteristics from the audio, such as sound patterns (MFCCs) facilitating word identification.
- Standardizing the audio helps all recordings to have a constant loudness and format.
- Adding some noise or adjusting pitch will help to augment the data, therefore simulating various scenarios and strengthening the model.

4. Data Splitting

- The system learns commands by use of a training set.
- Used in training to alter settings and hone the system, validation sets.
- Designed at the end to evaluate system performance using fresh data is the testing set.

5.Dataset Challenges

- Establishing a high-quality dataset is challenging. These are few typical issues:
- Unbalanced data: Should some commands show more frequency than others, the system may get biassed.
- The system may find it more difficult to correctly identify commands depending on background noise, varying accents, or speaking manner.

Understanding these difficulties and acting to solve them helps researchers create more efficient voice-activated wheelchair systems that satisfy consumers' needs.

III. Algorithm used

The machine must grasp speech precisely in this endeavour. MFCCs (Mel-Frequency Cepstral Coefficients) are among the better methods applied for this. These unique aspects taken from audio enable computers to comprehend human speech. Every stage is explained in great detail here:

Key Steps in Algorithm Implementation:

1. **Pre-emphasis:**

- This is the first stage in which we somewhat raise the audio signal's high-pitched tones.
- We give high-frequency sounds a small boost to help things clear since although they are normally weaker but carry significant information.
- Consider it as stepping up the treble on your stereo.

2. **Framing:**

- Usually spanning 20 to 40 milliseconds, the audio is divided into little segments known as frames.
- Small segment analysis helps us to catch the fast changes in speech signals.
- Often overlapping a little to ensure we don't overlook any crucial information between sections, these frames help us.

3. **Windowing:**

- Every frame is next multiplied by a windowing functionakin to the Hamming window.
- This helps each frame's edges to be more even, therefore preventing abrupt leaps or cuts.
- To create a smoother transition, it seems as though the in and out of each frame are slowly fading.

4. **Fast Fourier Transform (FFT):**

- We now translate every framefrom a waveform (time-based)into its frequency components.
- This reveals the frequenciesthat is, pitchespresent in every section of the audio.
- To ensure the FFT is efficient and detailed, we often select sizes like 256 or 512 points.

5. **Mel-filterbank:**

- We then run the frequency data across a Mel-filterbank.
- We are more sensitive to some frequencies than others, hence this modulates the frequencies to respect how humans truly hear.
- This stage lets the system "hear" more like a person.

6. **Logarithmic Compression:**

- At last, we log the Mel-scaled data.
- This stage lessens the effect of loudness and emphasizes more on the real speech patterns.
- It increases the stability of the features and facilitates machine learning from them.

MFCCs brilliantly capture the distinct sound patterns of human speech. This is why they are extensively employed in speech recognition systems—including those used to operate wheelchairs by voice. Even in demanding surroundings like farms ornoisy regions, the system can run more safely and effectively if one understands spoken orders more consistently.

Experimental Setup

Configuring hardware and software components to properly train, evaluate, and implement the pest detection model forms the experimental setup.

Hardware Configuration:

The model training and testing system has the following features:

- The brain of the system is the ESP32 microcontroller, which handles wheelchair motion control and spoken instructions processing.
- The wheelchair's motors are run under supervision of a DC motor driver (Smart Elex 15S), which has a maximum current of 15A.
- Receiving voice commands from a smartphone or another Bluetooth-enabled device comes from the HC-05 Bluetooth module.
- The power supply board supplies DC motor drivers, ESP32 microprocessor, and HC-05 Bluetooth module among other components of the system.
- The 12V 7Ah lead-acid battery supplies power to the system therefore enabling prolonged operation.
- Obstacles are detected and collision avoidance is accomplished using ultrasonic sensor HC-04.

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Software Configuration:
Modern machine-learning frameworks are used in development of the project:
- Programming Language: embedded c
- TensorFlow: Lite Micro, Edge ML framework
- *Libraries: TensorFlow Lite Micro library, microcontrollers' machine learning libraries (arm CMSISDSP)*
- *Dataset size: Variable (depending on application, say, voice commands, obstacle detection)*
- *Operating system: lightweight or bare-metal (FreeRTOS)*

Training Parameters:
- Learning rate: The model's learning speed derived from the training set.
- Batch size: The total count of samples used across every training cycle.
- Epochs: The total count of times the model runs on the whole dataset.
- Optimizer: e.g., Adam, SGD, the method applied to change the weights of the model.

Training Duration:
- Without GPU (based on CPUs): About thirty hours.
- GPU acceleration brings down to about five hours.

Combining the hardware and software configuration enables the voice-activated wheelchair system to give accurate and dependable control, therefore enabling users to securely and effectively manner.

IV. MODEL EVALUATION METRICS

One can assess the performance of a wheelchair controlled by voice using several criteria. These measures reveal information about the correctness, dependability, and efficiency of the system recall.

1. Accuracy
- Accuracy calculates, from all given commands, the percentage of accurately identified spoken commands.
- Formula: Accuracy = (Total number of commands) / (Number of correctly identified commands) High precision guarantees the wheelchair responds properly to voice commands, which is absolutely essential for user dependability and safety.
- For instance, the accuracy is 90% if the system properly recognizes 90 of the 100 commands.
- Accurate predictions are indicated in the confusion matrix by a diagonal line.
- Errors come from o- diagonal values. Higher values along the diagonal of a well-performance model will indicate improved classification accuracy.

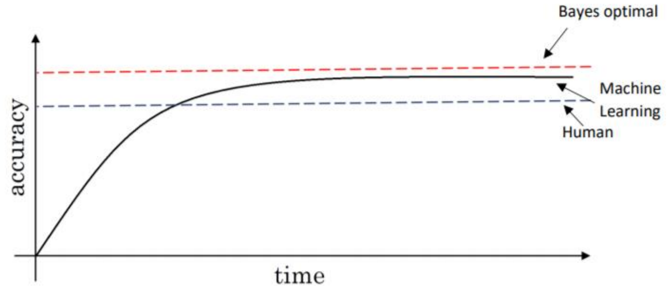

Fig.1.4.Accuracy matrix

2. Precision
- Precision gauges among all the system's positive predictions the percentage of true positive voice commands.
- Formula: True Positives (TP) / (True Positives (TP) + False Positives (FP)) High precision guarantees that the wheelchair does not react to erroneous or vague commands, therefore lowering the danger of accidents.
- For instance, the precision of the system is 87.5% if it forecasts 80 orders as "move forward" and 70 of these are indeed "move forward".
- Accuracy: The model's general performance over all pest types.

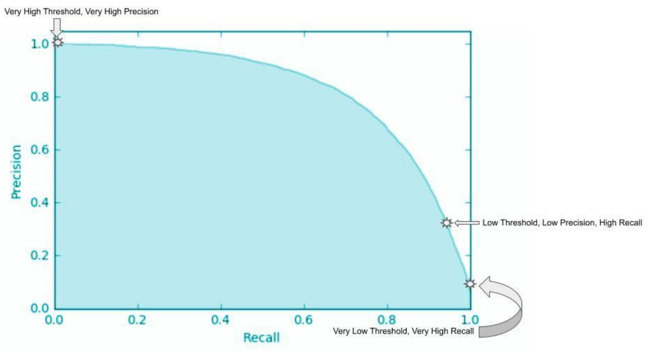

Fig.1.5.Precision

3. ROC Curve (Receiver Operating Characteristic Curve)
- The ROC Curve tests the model's capacity for species-based differentiation between pests.
- Plans: On the Y-axis, True Positive Rate (TPR) sometimes known as Recall. x-axis false positive rate (FPR).
- Reflecting great sensitivity and low false-positive rates, an ideal model would show a curve rising quickly toward the top-left corner.

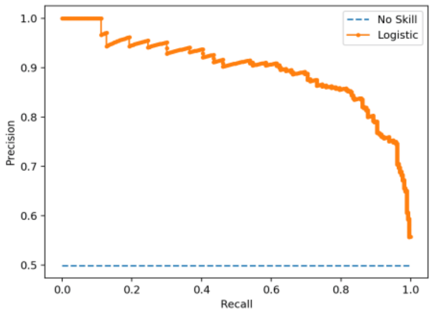

Fig.1.6.Receiver Operating Characteristic Curve

4. F1-Score

- The F1-score is a harmonic mean of precision and recall, so offering a fair assessment of both.
- Two times (Precision * Recall) divided by (Precision + Recall) is F1-score.
- A high F1-score guarantees both accuracy and dependability by indicating that the system strikes a decent mix between recall and precision.
- Should recall be 0.9 and precision be 0.8, the F1-score would be roughly 0.85.

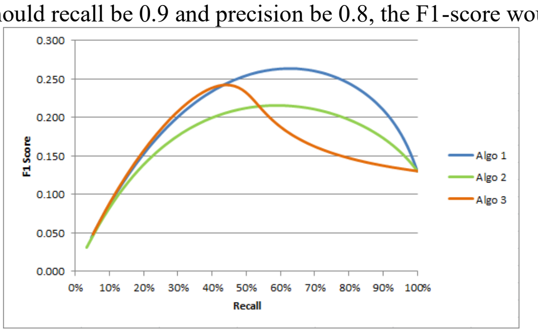

Fig.1.7.F1- Score

V. MODULE AND MODULE DESCRIPTION

Module 1: Speech Recognition Module

Recognising spoken commands given by the user falls to the speech recognition module. This module detects spoken phrases using natural language processing methods and machine learning algorithms then translates them into a machine-understandable format.

Steps:

- With a microphone or other audio input tool, record the user's speech commands.
- Use preprocessing methods to improve digital audio signal quality and eliminate noise.
- Get pertinent preprocessed audio signal attributes for use in speech recognition.
- Discover the spoken phrases or commands using deep learning models or machine learning techniques.
- Techniques could be spell checking, language modeling, or other approaches to raise the recognized speech's correctness.

Module 2: Control Module

The wheelchair's control signals are created by the control module, which also processes identified speech commands. Based on the acknowledged command, this module applies a set of preferred guidelines and logic to decide the suitable action.

Steps:

- Interpret accepted voice commands.
- Create wheelchair control signals here.
- Support several control modesthat is, speed, direction, etc.
- Interacts with the module for speech recognition to have commands acknowledged.
- Interacts to acquire sensor data with the sensor module.

Module 3: Sensor Module

To find hurdles and negotiate the surroundings, the sensor module combines several sensors, including infrared or ultrasonic ones. This module supplies important information to the control module therefore guaranteeing effective and safe navigation.

Steps:

- Discover challenges and negotiate the surroundings.
- Send control module sensor data.
- Support several sensor kinds (lidar, ultrasonic, infrared).
- Interacts to provide sensor data with the control module.
- Interacts with the module designed for user interface to over warnings or alarms.
- Data for the control module from sensors.
- Alerts or warnings for the module of user interface.

Module 4: User Interface Module

The module on user interface lets users engage with the system in an easy manner. To interact with the user, this module could incorporate tactile, visual, or audio cues.

Steps:

- Over consumers an easy-to-use interface.
- Show system output and feedback.

- Support several interaction forms (visual, aural, tactile).
- Interacts to give comments with the speech recognition module.
- Exchanges system status and feedback with the control module.
- Interacts with the user to get feedback and inputs.

Module 5: Navigation Module

The wheelchair is guided across challenging surroundings by the navigation module, which combines sensor and other module data. This module might maximize navigation using machine learning methods and mapping tools.

Steps:

- Lead the wheelchair throughout challenging surroundings.
- Apply machine learning methods and mapping algorithms.
- Support several navigation styles (such as aided, autonomous).
- Interacts with the module for sensor data acquisition communicates navigation commands with the control module.

Module 6: Power Management Module

Managing the power source to the several parts of the voice-activated wheelchair system falls to the Power Management Module.

Steps:

- Control the power supply to the components of the systemthat is, the control, sensor, user interface, and speech recognition modules.
- Guarantees that the system runs successfully and economically.
- Runs power-saving modes to lower power consumption during system non-use.

Module 7: Safety and Security Module

The Safety and Security Module is meant to guarantee the voice-activated wheelchair system's safe and secure running.

Steps:

- Track system operation constantly and find possible safety risks.
- In case of a safety concern, over emergency response systems like alarms or automatic shutdown.
- Constantly checks the running of the system and finds possible safety risks.

VI. CONCLUSION

For those with limited physical ability, the Bluetooth-based voice-activated wheelchair project marks a major breakthrough in increasing mobility and independence. The wheelchair has a user-friendly and simple interface for movement control by deftly combining voice instructions via Bluetooth connectivity. This invention not only increases accessibility but also helps users to feel empowered and autonomous so they may easily negotiate their environment. Bluetooth technology guarantees a consistent, wireless connection between the wheelchair and the voice control system, therefore enabling flexibility and simplicity in use. The concept not only solves the pragmatic issues with conventional wheelchair controls but also supports a modern and inclusive attitude to assistive technology.

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