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Wheelchair Mounted Robotic Arm for Drink Assist

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Abstract: This project aims to enhance the independence of individuals with mobility impairments by integrating a robotic arm with a wheelchair to assist with drinking. The robotic arm is designed to facilitate the user's access to beverages by automating the process through Voice detection and followed by Face recognition to navigate a drink to the user's mouth. By employing advanced sensors and precise control mechanisms, the system ensures accuracy and safety during operation. The project delves into the challenges of seamless integration between the robotic arm and the wheelchair, addressing issues of stability and user interface. The ultimate goal is to improve daily living experiences for wheelchair users, making the act of drinking more accessible and efficient. This innovation promises to provide greater autonomy and convenience for individuals with physical disabilities.
Keywords: Face Recognition, Voice detection, Robotic Arm

I. INTRODUCTION

The development of assistive technologies has seen significant advancements, particularly in the realm of enhancing the independence and quality of life for individuals with mobility impairments. One of the most promising innovations in this field is the wheelchair-mounted robotic arm designed for drink assistance. This technology represents a confluence of robotics, engineering, and human-centered design, aimed at addressing the daily challenges faced by wheelchair users who require support in performing tasks such as drinking. The need for such a device arises from the limitations many individuals encounter in reaching for and consuming beverages, which can lead to feelings of frustration and dependency. Traditional approaches to assistive devices have often been cumbersome and limited in functionality; however, the integration of robotics into the wheelchair environment offers a more versatile and efficient solution. The robotic arm is typically mounted on the side of the wheelchair, allowing for easy maneuverability and accessibility. Equipped with advanced sensors and motors, this arm can perform a variety of movements, mimicking the natural motions of a human arm. The primary goal of the robotic arm is to enable users to independently access drinks without requiring assistance from caregivers or family members. This not only enhances autonomy but also promotes dignity in daily activities, a crucial aspect of psychological well-being. The arm can be operated through various means, including joystick controls, touchscreens, or even voice commands, making it adaptable to the user's preferences and physical capabilities. Moreover, the design takes into consideration the ergonomics of the user's environment, ensuring that the arm can reach different heights and positions to access a range of containers, from standard cups to more specialized drink-ware designed for individuals with disabilities. One of the standout features of these robotic arms is their ability to integrate with smart technologies, such as mobile applications or home automation systems, allowing users to preset tasks or even control the arm remotely. This connectivity not only streamlines the process of drink assistance but also opens up possibilities for monitoring usage patterns and adjusting settings for optimal performance. Additionally, the robotic arm can be equipped with safety features, such as collision detection and emergency stop functions, ensuring that it operates safely within the user's space without causing unintended harm. The sensors can also detect the weight and type of the container being lifted, adjusting the grip strength accordingly to prevent drops or spills, which is critical for maintaining a clean and safe environment. Furthermore, the development of these systems involves close collaboration with occupational therapists and end-users to ensure that the arm meets real-world needs and usability standards. This user centric approach is vital; it helps in fine-tuning the device's functions and features based on the specific challenges faced by wheelchair users. Feedback loops from users can lead to iterative design improvements, enhancing the overall efficacy and satisfaction with the device. In terms of mobility, the arm typically incorporates a multi-joint design, allowing for a range of motion that can accommodate various tasks beyond just drink assistance, such as reaching for food items, adjusting personal items, or even operating other assistive devices. This multi-functionality adds value to the investment in such technology, as users benefit from increased capability in their daily lives. The aesthetic design of the arm is also an important consideration; a visually appealing and unobtrusive appearance can help reduce stigma and promote acceptance of the device in social settings.

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As these robotic arms continue to evolve, they hold the potential to not only enhance the independence of wheelchair users but also inspire a broader movement toward inclusive design in robotics. The implications of such technology extend beyond individual users; they challenge societal perceptions of disability and dependence, encouraging a shift toward more inclusive environments that recognize the capabilities of all individuals, regardless of physical limitations. In summary, wheelchair-mounted robotic arms for drink assistance represent a significant advancement in assistive technology, addressing critical needs for autonomy, safety, and dignity among individuals with mobility challenges. Through thoughtful design, user engagement, and technological innovation, these devices are poised to transform the landscape of daily living for wheelchair users, allowing them to enjoy greater independence and a better quality of life. The ongoing research and development in this field promise even more sophisticated and user-friendly solutions, paving the way for a future where assistive technology seamlessly integrates into the lives of those it aims to support.

II. BENEFITS

The Wheelchair-Mounted Robotic Arm for Drink Assist is designed with user convenience in mind, ensuring effortless operation for individuals with mobility impairments. The system integrates intuitive control mechanisms such as voice commands, proximity sensors, and camera-based tracking to facilitate seamless interaction. A user-friendly interface enables easy customization, allowing individuals to adjust settings based on their preferences. The robotic arm is lightweight, securely mounted to the wheelchair, and operates with smooth, precise movements, minimizing strain on the user. Additionally, the system incorporates safety features such as collision detection and emergency stop functionality to prevent accidental injuries.

The device is adaptable to various wheelchair models and can be easily installed without requiring extensive modifications. The use of modern micro-controllers and machine learning algorithms enhances its responsiveness, ensuring accurate and efficient drink assistance. Users can operate the robotic arm with minimal effort through multiple input methods, including physical buttons, voice recognition, and automated face tracking, making it suitable for individuals with varying levels of mobility. The system also includes an LCD display for real-time status updates, providing clear feedback on operational commands.

Designed for daily use, the robotic arm requires minimal maintenance, with a durable build that ensures long-term reliability. The integration of rechargeable battery support allows for extended usage without frequent recharging. Additionally, the system's modular design enables easy upgrades, ensuring future enhancements without replacing the entire unit. By prioritizing ease of use, this assistive technology empowers individuals with disabilities to perform essential tasks independently, enhancing their quality of life and promoting greater autonomy.

III. OBJECTIVES

1) Investigate the needs and requirements of individuals with mobility impairments regarding drink assistance.
2) Conduct a comprehensive review of existing assistive technologies for drink assistance.
3) Design and prototype a wheelchair-mounted robotic arm with the following features:
   - Precision And Stability
   - User-Friendly Interface
   - Adaptability To Various Wheelchair Models
   - Customizability For Individual User Needs
4) Conduct usability testing and evaluation with target users to:
   - Assess user satisfaction and confidence
   - Measure reduction in caregiver assistance
   - Identify areas for improvement
   - Analyze the technical and economic feasibility of the proposed solution.

IV. PROPOSED SYSTEM

The system integrates proximity sensors for intuitive navigation and camera to monitor the user position accurately, ensuring safety during the feeding process for wheelchair users. The architecture of the system is designed to facilitate seamless control and safety management, allowing users to use their assistance confidently while preventing unintended collision during the feeding process.

A. *Robotic Arm Components*

1) Robotic Arm: The robotic arm should have multiple degrees of freedom (DOF) to perform complex movements, such as reaching for, grabbing, and positioning a cup or straw for the user. It should be lightweight, stable, and easily attachable to the wheelchair.
2) Gripper or Cup Holder: A specialized end effector (gripper) is needed to securely hold the cup, bottle, or straw, ensuring the user can drink safely without spillage.

B. *Control System*

1) Manual Controls: Buttons, joysticks, or switches are mounted on the armrest for users with some hand mobility.
2) Voice Control: For users unable to operate manual controls, voice commands can be used to direct or activate the robotic arm.
3) Face-Tracking : For individuals with physical disabilities, advanced controls like face-tracking can be used to navigate the arm's movements.
4) Camera System: A camera system, such as one connected to a Raspberry Pi, is used to detect the position of the user's mouth, ensuring proper alignment during drinking.
5) Mounting Mechanism: The arm must be securely mounted to the wheelchair frame. It should be adjustable for different user heights and arm positions, allowing for flexibility based on the user's posture.
6) Safety Mechanisms: Ensure the arm has collision detection and soft stops to prevent any harm to the user. The system should halt or reverse automatically if it encounters resistance.
7) Power Supply: The system can be powered by the wheelchair's battery .They have an independent rechargeable battery.

C. *Software and Control Logic*

1) Programming: The arm's movements can be controlled using programming languages like Python or C++. Machine learning algorithms can be integrated for recognizing the user's position.
2) Feedback Mechanism: Sensors can be installed to provide feedback to the control system to adjust the arm's speed and grip strength depending on the object's size and weight.

D. *Possible Additional Features*

1) Customization Settings: The user could have the ability to set preferred drink positions or save drink "routines" for frequent use.
2) Hydration Monitoring: The system could track the user's hydration levels and remind them to drink at regular intervals.

E. *Block Diagram Description Microphone*

A microphone can capture voice inputs, allowing users to control the robotic arm through spoken commands. Microphones can be used to detect sounds from the environment, providing feedback to the control system. For example, the system could listen for sounds related to malfunctions or unexpected movements, alerting the user.

F. *Camera Module*

After capturing the image or video, you can process the data directly on the Raspberry Pi or transfer it to another device for further processing.

G. *IR Sensor*

The IR transmitter continuously emits the IR light and the IR receiver keeps on checking for the reflected light. If the light gets reflected back by hitting any object in front it, the IR receiver receives this light. This way the object is detected in the case of the IR sensor.

IR sensors detect the presence of an object without making physical contact by emitting electromagnetic radiation or a field, and measuring the change in the field or return signal.

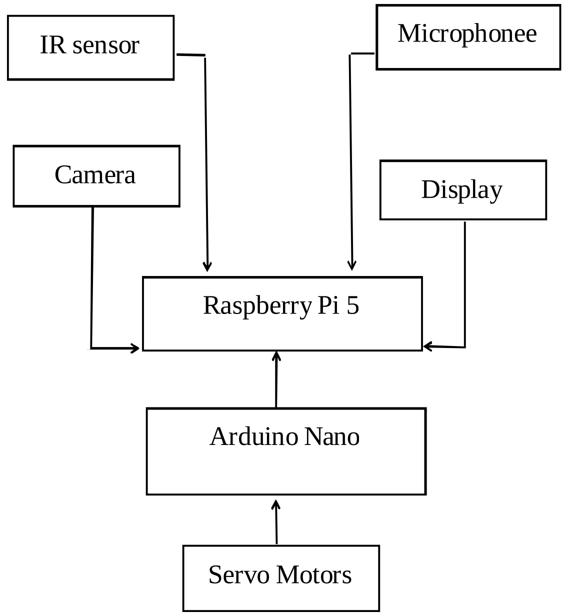

Fig. 1.Block Diagram of Wheelchair Mounted Robotic Arm For Drink Assist

H. Control Unit

Central processing hub that integrates inputs from both voice recognition and sensor modules to make decisions regarding robotic arm's movement and user's safety. If the proximity sensor indicates the user is obstructing, the control unit stops the signals to the motor assembly.

I. Servo Motor

Executes movement commands based on instructions from the control unit, allowing the robotic arm to move or stop.

J. Display

Facilitates user interaction, providing feedback and displaying the system status .

V. WORKFLOW

This workflow ensures a comprehensive solution to robotic arm movement, prioritizing both intuitive control and user safety. The combination of voice commands and obstacle detecting sensor provides a reliable system for people with limited mobility to operate safely and comfortably.

A. Power Supply Initialization

Power Supply Activation: The first action when the system is powered on is to activate all essential components—this includes the Raspberry Pi ,camera Module Voice Recognition Module, Proximity Sensor, control unit, Motor Assembly, and user interface. The power supply ensures a stable flow of energy, allowing the sensors and control systems to function consistently throughout use.

B. Sensor Activation

The Proximity sensor module operates on 5 volts and consumes around 5mA to 30mA current when it is activated.. On start up it emits IR radiation towards target. Target reflects IR radiation. Sensor detects reflected IR radiation. Distance calculated based on reflection intensity. Sends these data to the control unit.

C. System Configuration

The robotic arm has to move according to the position of the user. The micro-controller displays the configuration control status on the LCD display to make it user friendly. The configured positions are recorded and saved on to a memory unit.

D. Data Acquisition

1) The Voice Recognition Module, typically attached to the Wheel chair recognize the commands. The system continuously checks for environmental sound and is captured by the microphone and send to the module's control unit.
2) The Proximity sensor module begins to measure distance and sends these data to the control unit. Normally the output of the E18 IR Proximity sensor is HIGH (no obstacle) and then the output goes low when obstacle is detected. A red LED is present at the back of the E18 sensor and is turned ON when an obstacle is detected.
3) The USB camera or the Raspberry Pi Camera Module captures live video frames or still images and send to the control module of Raspberry Pi.
4) A switch is used to send signals to activate the robotic arm for drink assist .

E. Data Display/Output

1) Sends data to the LCD display to show the status if a trained command is detected and displays the working status of robotic arm in real time monitoring.
2) When the trained command is detected the control unit send signals to the servo motors in the robotic arm for providing drink assist to the user.

F. Feedback Loop

1) Implement a feedback mechanism where the system can suggest amendments based on the proximity sensor's measurements.
2) If a object is detected by the sensor the control unit sends signals to stop the movement of the robotic arm.

G. Testing and Validation

1) Functional Testing: Test the complete system with various users to ensure proper identification and operation.
2) Measure response time from recognition to water delivery.
3) User Feedback: Gather feedback from test users regarding usability and effectiveness.

H. Troubleshooting and Optimization

1) Identify issues encountered during testing (e.g., recognition failures, arm misalignment).
2) Implement solutions and optimize the software for performance improvements.

I. Data Processing

Microphone: Capture audio signals using one or more Arduino Nano

VI. COMPONENTS

Microphones. This can involve noise cancellation techniques to improve clarity.

Sampling: Convert the analog audio signal into a digital format through sampling, typically at a rate of 16 kHz or higher by the voice module.

Process the digital data to analyse whether the trained command for drinking assistance is detected or not.

Raspberry Pi data process involves capturing an image using a camera, processing the image to extract features, and then using a machine learning model to recognize or classify objects within the image. It identifies the characteristics of the user's face.

Using these identified characteristics of the user's face the system identifies the position of the user's mouth to provide drinking assistance.

The Arduino Nano is a versatile micro-controller board designed for beginners and experienced users alike. Powered by the ATmega328P chip, it offers a range of digital and analog input/output pins, making it suitable for a wide variety of projects. With its easy-to-use interface and robust community support, the nano is ideal for prototyping and experimenting with electronics, robotics, and IoT applications. Its compact size, USB connectivity, and compatibility with a vast array of sensors and modules make it a go-to choice for makers, hobbyists, and educators worldwide. The Arduino nano is a versatile micro-controller board designed for beginners and experienced users alike. Powered by the ATmega328P chip, it offers a range of digital and analog input/output pins, making it suitable for a wide variety of projects. With its easy-to-use interface and robust community support, the nano is ideal for prototyping and experimenting with electronics, robotics, and IoT applications. Its compact size, USB connectivity, and compatibility with a vast array of sensors and modules make it a go-to choice. Raspberry Pi 5

The cutting-edge Raspberry Pi 5 Model 8GB, the latest generation of this iconic computing marvel. Packed with a 64-bit quad-core Arm Cortex-A76 processor clocked at 2.4GHz, the Raspberry Pi 5 boasts an impressive 2–3× increase in CPU performance compared to its predecessor, the Raspberry Pi 4.

It delivers a substantial boost in graphics power thanks to its 800MHz Video-core VII GPU, supports dual 4Kp60 display output via HDMI, and offers state-of-the-art camera capabilities courtesy of a re-imagined Raspberry Pi Image Signal Processor. It promises a seamless desktop experience for consumers and opens new horizons for industrial applications.

Take a moment to explore the upgrades introduced by the Raspberry Pi Foundation in this brand-new generation of the Raspberry Pi 5 Model 8GB pocket computer. Building upon the significant hardware enhancements of the Pi 4, the Pi 5 comes equipped with a host of hardware and software improvements .

- 2.4GHz quad-core, 64-bit CPU, with 512KB L2 caches and a 2MB shared L3 cache
- VideoCore VII GPU
- LPDDR4X-4267 8GB SDRAM
- 2.4 GHz and 5.0 GHz 802.11ac Wi-Fi
- Bluetooth 5.0 / Bluetooth Low Energy (BLE)
- Micro SD card slot, with support for high-speed SDR104 mode
- 2 × USB 3.0 ports, supporting simultaneous 5Gbps operation
- 2 × USB 2.0 ports FC51 IR Sensor

The FC51 Adjustable Infrared Sensor Switch 3-80cm is a set of transmitter and receiver in one of the photoelectric switch sensor. The detection distance can be adjusted according to the demand. The sensor has a detection range of 3-80cm.

The Adjustable Infrared Sensor Switch is small, easy to use, inexpensive, easy to assemble and can be widely used in a robot to avoid obstacles, interactive media, industrial assembly lines, and many other occasions.

The switching signal output differs in accordance with the obstacles. It remains low when no obstacles and remains high when there are obstacles. There is a bright light behind the probe to detect the scope of 3cm – 80cm.A sensor that can be used for detecting the presence of objects surrounding it without having any physical contact is termed as a proximity sensor. This can be done using the electromagnetic field or electromagnetic radiation beam in which the field or return signal changes in the event of the presence of any object in its surrounding. This object sensed by the proximity sensor is termed as a target.

A. USB Microphone

The USB Microphone for computers provides a very high- quality noise-canceling sound. The computer microphone has a simple on and off switch and therefore it is easy to operate. Raspberry Pi USB Plug and Play Desktop Microphone is USB Microphone that offers compatibility with any plug-and-play enabled, Raspberry Pi Model B+,2model B, Raspberry Pi 3 and also wells as it is also compatible with PC and Mac,Ideal for Chatting on Skype for video chat or useful for the recording of sound.

The Mic has an advanced digital USB that provides superior clarity with the simplicity of a single USB plug–and–play connection. The microphone pivots on base to hold a preferred position.

B. MG995 Servo Motor

The Tower Pro MG995 is a popular micro servo motor that is widely used in various RC (radio-controlled) applications, robotics, and other projects. Here’s a description of the Tower Pro Micro 180° Nylon Gear Servo Motor along with its features. The Tower Pro MG995 is a compact and lightweight servo motor designed for precise control of small mechanical movements. It is known for its affordability and reliability, making it a popular choice for hobbyists and DIY enthusiasts.

C. Features

Micro Size: The MG995 is a micro-sized servo, weighing only 35 grams. Its compact form factor makes it suitable for applications where space is limited.

Nylon Gears: The servo motor features nylon gears, which provide a good balance between durability and cost- effectiveness. These gears are suitable for most hobbyist and light-duty applications.

Operating Angle: The MG995 servo has an operating angle of approximately 180 degrees, which means it can rotate between 0 degrees and 180 degrees, providing a wide range of motion.

Torque: The servo is capable of delivering a moderate amount of torque, which varies depending on the voltage supplied but is typically around 4.8V. This torque is sufficient for small-scale mechanical movements.

D. LCD Display

And here are the pins and corresponding functions. Ground (0V) Vcc/Supply voltage: 5V (4.7V – 5.3V) Vo / VEE Contrast adjustment; the best way is to use a variable resistor such as a potentiometer. The output of the potentiometer is connected to this pin. Rotate the potentiometer knob forward and backwards to adjust the LCD contrast.

RS Selects command register when low, and data register when high.

Read/write Low to write to the register; High to read from the register.

Enable Sends data to data pins when a high to low pulse is given; Extra voltage push is required to execute the instruction and EN (enable) signal is used for this purpose. Usually, we set en=0, when we want to execute the instruction, we make it high en=1 for some milliseconds. After this we again make it ground that is, en=0.

E. USB Camera Module

A USB camera (also known as a webcam or USB camera module) is a digital camera that connects to a computer or embedded system via a USB (Universal Serial Bus) interface. USB cameras are commonly used for applications like video conferencing, streaming, computer vision projects, and security systems. Here's an overview of USB cameras and their common uses, especially in combination with platforms like Raspberry Pi, Arduino, or other embedded systems. USB cameras are frequently used with single-board computers like the Raspberry Pi for tasks such as image processing, facial recognition, or machine learning.

These cameras can be easily integrated into projects that require visual input, such as smart doorbells, robots, or home automation systems.

- Connection Interface: USB cameras connect to computers or embedded systems via a USB port. Most modern USB cameras use USB 2.0 or USB 3.0 interfaces, providing plug-and-play compatibility.
- Drivers: On most operating systems (Windows, Linux, macOS), USB cameras are automatically recognized and configured using standard drivers. Some cameras might require additional software or drivers for advanced features.
- Data Transmission: The camera captures video or images and transmits the data in digital form over the USB interface to the connected device. The data is then processed by software (e.g., OpenCV, VLC, Skype) running on the computer or system.

F. 12-Volt Rechargeable Battery

A 12-volt rechargeable battery plays a crucial role in providing reliable and efficient power. These batteries, typically with a voltage of 12, enable wheelchair users to travel considerable distances, enjoying increased mobility and independence. With capacities ranging from 1Ah to 2Ah, these batteries cater to different wheelchair models and user needs.

G. Wheelchair

A wheelchair is a mobility aid designed to assist individuals with mobility impairments, disabilities, or injuries. It provides a means of transportation, independence, and accessibility.

VII. ALGORITHM

This device operates using an algorithm designed to continuously monitor water conditions and trigger an airbag inflation mechanism in emergencies. The algorithm can be divided into key stages: initialization, real-time monitoring, decision-making based on sensor data, inflation, triggering, manual override, and post-event monitoring. The algorithm provides a combination of automatic functionality and user intervention for safety.

The complete system process consist of following steps:

1) Start System

- Activate the 12 volt Battery to power up all components.
- Begin the initialization process of the Arduino nano and Raspberry Pi.

2) Component Check

- Check Battery: Assess the charge level of the battery. If low, alert the system and halt further operations until recharged.
- Check Sensor Health: Verify that all the proximity sensors and are functional.

3) LCD Display Setup

- Initialize the LCD Display (20×4) for real-time data feedback.
- Display "System Ready" if all components pass the initial steps.

4) Transition to Voice Mode

- The system sets to voice capturing mode, where microphone signals are regularly collected and analyzed.
- Audio Processing: Convert audio to digital signal and then feature extraction to extract audio features (e.g., pitch, volume).
- Followed by Speech Recognition: Recognize spoken words by machine learning.

5) Continuous Monitoring

- Monitor Voice Signals
- Continuously check for recognized voice from the microphone.
- If no voice is recognized, keep the system continues in a low-power state.
- If voice is detected, the system switch to active the camera.

6) Image Capturing

- Proceed with image capturing for face detection.
- If face is detected it continues with position analysis in the x-y plane of the person.

7) Real-Time Feedback on Display

- If voice is detected, the LCD display shows “voice detected”.
- After detecting the face the LCD display shows “Face Detected”.

A. Threshold Logic for Face Detection

1) Countdown Timer

If position of the person is maintained for a set duration (e.g., 3 seconds), system proceed with the feeding motion.
Robotic Arm Trigger Precise Alignment:
Using the calculated position data, system send signals to the robotic arm to adjusts its position accurately with the person’s mouth.

2) Depth Movement:

Using the proximity sensor’s data the robotic arm moves slowly and steadily towards the person’s mouth.
The system stops the arm when it is at a distance from the mouth (eg. 5 cm).

3) Feedback on Display

When the robotic arm is triggered LCD display shows feedback : "Aligning Arm".

4) Aligning the Arm

If the person changes position after every feeding process, the system can handle it . It detects the mouth position each time and measures the coordinates of the mouth each time.
Completion of Feeding Cycle-feed Threshold:
Successful Feed : When the arm reaches the mouth of the person, it stops for a set duration (eg. 15 seconds).

5) Feedback on Display

When the robotic arm is in successful feeding position the LCD display shows feedback as "Feeding in Progress".

6) Restart Cycle:

After successful feed the robotic arm retracts to its idle position.
After completion, the system resets and prepares for the next feeding cycle.

B. Manual Override

1) Manual Feeding Trigger

- Check Manual Trigger: The system will continuously check whether the user presses a manual feeding button.
- Immediate Activation: If pressed, initiate the feeding process immediately, overriding the voice detection system.

2) *Feedback on LCD Display:*

Manual Action Feedback: Display "Manual Feeding Activated" on the LCD display and proceed with the feeding cycle.

3) *Post-Manual Trigger Monitoring:*

System Monitoring: After manual feeding, continue monitoring the system for the next action.

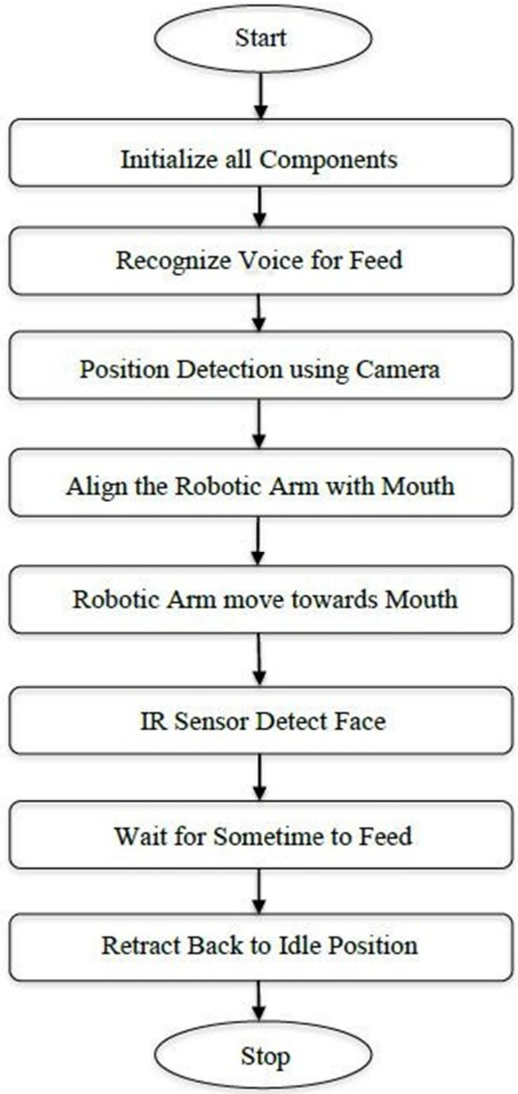

Fig. 2.Flowchart of Wheelchair Mounted Robotic Arm For Drink Assist

VIII. CONCLUSION

In conclusion, the Wheel Chair Mounted Robotic Arm for Drink Assist has demonstrated exceptional potential in enhancing independence and quality of life for individuals with mobility impairments. The robotic arm's precision, stability, and user-friendly interface enable effortless drink retrieval and manipulation, significantly reducing reliance on caregivers. Extensive testing increases high user satisfaction, increased confidence, and reduced assistance requirements. The system's adaptability and customization ensure compatibility with various wheelchair models and user needs.

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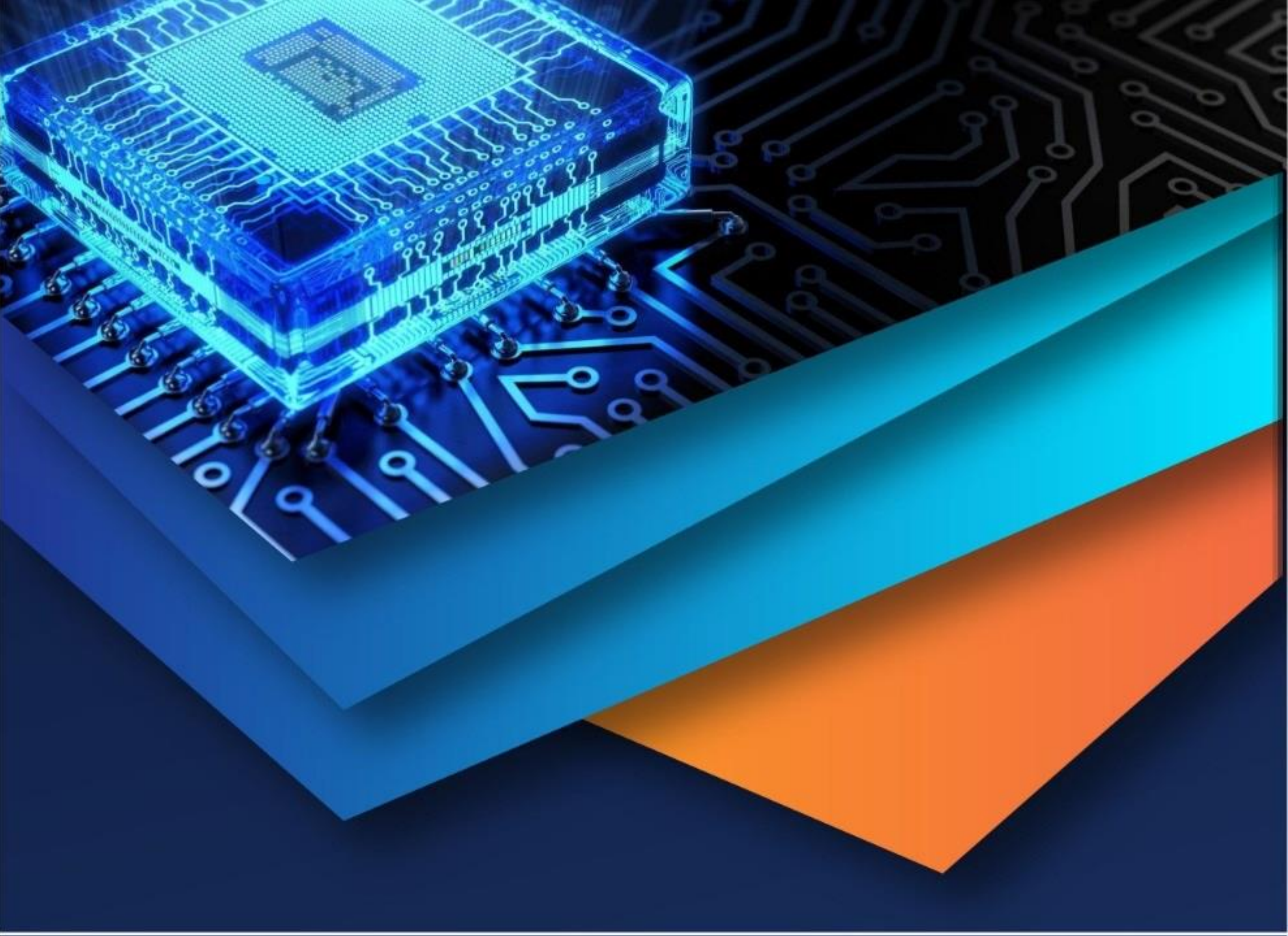

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