iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IV **Month of publication:** April 2025

DOI: https://doi.org/10.22214/ijraset.2025.69859

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

Gesture Controlled Robot for Elderly Assistance

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Abstract: ***"The most effective technology is the one that disappears into the background allowing people to accomplish more with less." Inspired by this, we suggest a gesture-activated robotic assistant to aid senior citizens with daily tasks. Age-related mobility problems can make seemingly simple tasks challenging and dangerous. Our technology detects hand gestures—wirelessly sent to a four-wheeled mobile robot—using a glove with flex sensors and an MPU6050 accelerometer. Driven by Bluetooth and an Arduino microcontroller, the robot reads gestures as movement directions, therefore allowing safe and autonomous interaction. In gesture recognition with real-time response, the system attained a 95% accuracy rate. By offering a reasonably priced, scalable solution, this work advances the more general objective of human-centered robots beyond only satisfying pragmatic demands. Its modular architecture lets future modifications like robotic arms or obstacle detection possible, therefore allowing it to be flexible in changing user needs.***

Index terms: Arduino, Assistive Robot, Bluetooth, Elderly Assistance, Flex Sensors, Gesture Control, MPU6050.

I. INTRODUCTION

As the world's aged population grows, guaranteeing a safe and independent living for senior individuals has become an increasingly pressing issue. Conditions such arthritis, limited flexibility, or chronic pain can make many older persons less mobile. Simple chores like bending down to get an object can become difficult or even dangerous, thus depending more on caretakers or running the danger of harm.

We propose a gesture-activated robotic assistant that responds to natural hand motions in order to close this distance and provide a more user-friendly and simpler solution. Our technology captures hand motions with a wearable glove with flex sensors and an MPU6050 accelerometer. Bluetooth allows these motions to be wirelessly sent to a four-wheeled robot that navigates accordingly. Through direct motion control, the technology helps elderly people to simplify interaction, enabling them to engage in daily activities more independently and safely, fostering autonomy and confidence in their daily life.

II. LITERATURE SURVEY

Particularly in the domain of assistive robotics and human-robot interaction (HRI), gesture-based control systems have attracted a lot of interest recently. This part provides a complete review of past studies influencing gesture-activated systems.

Marc Peral et al. (2022) presented a deep learning gesture in real time system to help humans and robots communicate. They first extracted 2D hand landmarks using MediaPipe then followed with a neural network classifier with 10 FPS accuracy of 87.5%. Although the model exceeded traditional optical flow techniques, its reliance on vision-based input made it vulnerable to lighting conditions and occlusions, which can greatly restrict its performance in surroundings not under computer control.

Building a 3D-printed soft robotic hand coupled with embedded sensors and pneumatic actuation, Hao Zhou et al. (2022) enabled gesture recognition and adaptive grasping. Their work displayed improved real-time adaptability to object forms and sizes and variety. But the lack of strong structural support limited its application for heavy objects or in circumstances needing stability—especially problematic in assistive settings where dependability is essential.

Christopher R. Walker et al., 2023 presented a sensor-based gesture recognition glove for diver-robot communication. By use of dielectric elastomer stretch sensors and IMUs, the glove supported multiple gestures and attained an accuracy of up to 98% in dry conditions. But underwater performance suffered with decreasing buoyancy control and hand motion complexity. Their technology is designed for aquatic environments and not best for terrestrial, elderly-assistive circumstances even if it shows great accuracy in controlled environments.

Using machine learning, Stefan E. Khan and Zachary C. Danziger (2024) investigated continuous gesture control mapping hand gestures to robotic arm motions. Strong performance over several control systems was shown by the system using several gesture-to-----motion mapping approaches. A big drawback, though, was the lack of dual-system integration—that is, sensor-based adjustments or combining gesture control with environmental feedback.

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2013 saw Z. Ren et al. create a strong part-based gesture recognition system leveraging Kinect sensor depth data. The model was heavily dependent on external hardware and spatial configuration, so it was inappropriate for small or personal situations like homes even if it exhibited great accuracy in structured settings.

While gesture recognition and robotic control have evolved, many early studies concentrated on stationary environments, rigid interaction models, or context-specific applications like industrial automation or submarine navigation. Often using camera-based inputs or predefined gesture mappings inappropriate for senior home users' evolving demands, these systems

This draws attention to a significant discrepancy in present research: few models are developed for geriatric assistive purposes even while many models effectively address gesture-based control or robotic manipulation. Most past solutions rely on predefined motions, inflexible interfaces, or external hardware configurations—which do not fit the actual restrictions or ease-of-use of senior assistance.

To get beyond these constraints, our wearable, sensor-based system stresses low-cost technology, natural contact, and real-time responsiveness. Our method translates simple hand gestures into wireless robot commands therefore enabling safe, autonomous object retrieval. Its modular design lets future additions like robotic arms and obstacle detection, therefore enabling the system to be flexible enough to meet changing user needs and technological requirements.

TABLE 1: Gesture Recognition And Robot Action Results

Aspect	Existing Systems	Proposed System
Control Method	Joystick / App / Voice	Wearable gesture glove
Ease for Elderly	Low to Moderate	High
Hardware Requirement	Smartphone / Controllers	Flex sensors, MPU6050, Arduino
Environmental Constraints	Noise (voice), screen access (app)	Minimal (indoor Bluetooth range)
Response Time	Moderate to Fast	Fast (150 ms)
Cost	Moderate to High	Low
Customization	Limited	Easily extendable

III. PROPOSED METHOD

The suggested system aims to provide older people with a simple and quick way of object retrieval by means of a robotic platform under gesture-operated control. Three main subsystems—gesture recognition using a wearable glove, wireless data transfer, and robot navigation and control—make up the answer; they run in real time. Perfect for homes, the whole arrangement is built with user comfort, simplicity, and economy in mind.

A. Gesture Recognition System

The system's core consists in a glove with flex sensors and an MPU6050 accelerometer. The flex sensors detect digit bending; the MPU6050 records motion and orientation depending on pitch and roll values. These elements together help one to identify motions, including hand forward, backward, left, or right angling and fist forming. Every motion relates to a command the automaton will receive.

Attached to the glove is an Arduino Nano which gathers and analyzes sensor data. This microcontroller reads the analog and digital signals from the sensors and maps them to certain movement commands—that is, stop, forward, backward, left, or right.

B. Bluetooth Communication

Using HC-05 Bluetooth modules, the glove wirelessly signals the robot to guarantee simplicity of usage and prevent physical limitations. On the glove, the Arduino Nano sends the interpreted command signals to the Arduino UNO attached on the robot. Bluetooth was chosen because of its low power consumption, enough within range, and convenience of integration with microcontroller platforms.

The communication protocol is meant to be light-weight and responsive as well. The "forward" instruction might be shown by the "F" character, for example; the "backward," "left," "right," and "stop" commands are shown by the "B," "L," "R," and "S" characters, respectively.

C. Robotic Platform

Comprising a four-wheeled chassis driven by DC motors and under control by an L298N motor driver module, the robot is Reaching the Bluetooth signals, the Arduino UNO analyzes them and adjusts the actuators. Independent of the speed of command changes, the motor driver guarantees safe operation and smooth transitions. The robot runs on a bank of 18650 small, rechargeable, compact lithium-ion batteries suitable for the voltage needs of the actuators and control board.

D. System Movement

The user wears the glove then makes a gesture.The MPU6050's flex sensors and signal detection identify and interpret the motion. The Arduino Nano characterizes the gesture as a command. Bluetooth carries the command to the automaton. Receiving the signal, the robot analyzes it and moves in the intended path. Real time persistence of this loop guarantees a responsive and interactive experience. This system is highly scalable due to its modular design, which enables the integration of additional features, such as robotic limbs or voice input.

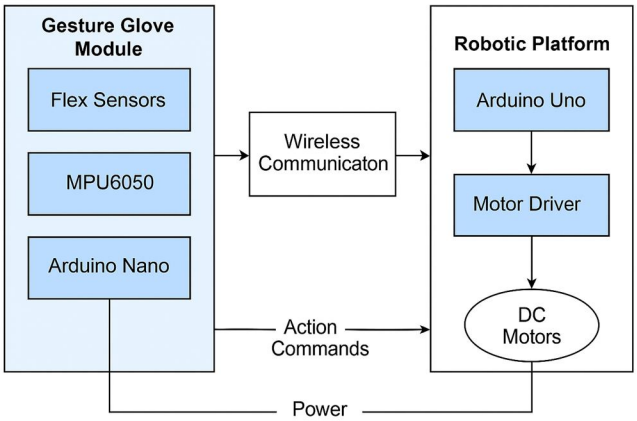


Fig 1. Block Diagram

IV. DESIGN AND IMPLEMENTATION

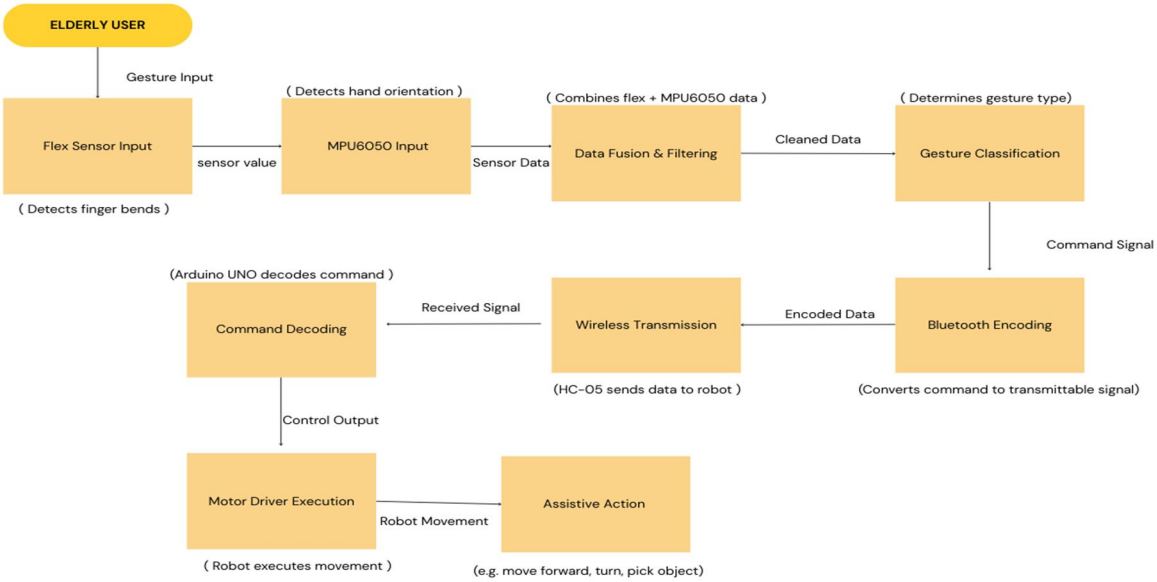


Fig 2. Flow diagram

Designed to be an assistance tool for senior citizens, the proposed gesture-activated robot let users use simple hand gestures to accomplish object retrieval chores. Integrating embedded technology, sensor-based motion capture, wireless communication, and electromechanical control inside a seamless and user-friendly design, the system was painstakingly developed to be adaptable, responsive, and economical. A gesture acquisition glove, a wireless communication link, a mobile robotic platform, and the embedded control logic controlling their interaction makes up the whole configuration. Low power consumption, portability, and simplicity of use for household environments define the design.

Three main subsystems characterize the system architecture: the robot control platform, the communication interface, and the gesture recognition unit. Embedded in a wearable glove with several flex sensors and an inertial measurement unit (IMU), more especially the MPU6050, which combines an accelerometer and a gyroscope to detect direction and angular motion, is the gesture recognition unit An Arduino Nano microcontroller drives this machine using real-time sensor reading processing. Once the gesture is recognized, the Arduino Nano uses an HC-05 Bluetooth module to wirelessly send the result into a particular instruction to the robotic platform. From the receiving side, an Arduino UNO microcontroller decodes the command and forwards it to the L298N motor driver, therefore activating the DC motors regulating the robot's movement.

Capturing the intention of the user depends critically on the gesture glove. It detects bending motions by use of three flex sensors placed deliberately across the fingers, therefore enabling the identification of hand postures including a closed fist. Measuring pitch and roll angles, the MPU6050—mounted close to the wrist—offers real-time orientation data. These sensors taken together let the system differentiate between several gesture kinds, including tilting the hand forward, backward, left, or right. From the sensors, the Arduino Nano constantly receives the digital and analog values, evaluates them against calibrated threshold values, and decides the matching motion. Every acknowledged motion corresponds to a distinct character command: forward with "F," backward with "B," left with "L," right with "R," and stop with "S." The robotic platform receives these character-based signals then via a serial Bluetooth link.

Comprising a four-wheeled chassis coupled with DC motors, the robotic platform offers stability and multidirectional movement. The major processing unit on the robot is the Arduino UNO installed on it. The glove commands translate into an instruction that energizes the relevant motor channels across the L298N motor driver. This arrangement allows the robot to move as intended practically immediately. Driving all motors in the same direction helps one achieve the forward movement; turns are carried out by stopping one set of wheels and turning the other set. The stop instruction causes the supply of current to the motors to stop, hence instant rest of the robot. 18650 lithium-ion batteries provide both the glove's and the robotic platform's power. Portable embedded systems would find these batteries appropriate since they have high energy density, rechargeability, and small form factor. Whereas the robotic unit uses a sequence of cells to meet the current needs of the motors and controller, the glove is driven by a single cell controlled through a voltage module. Operating wirelessly, the system provides complete user freedom of movement free from connected connections. One important stage in execution was sensor calibration. Digital Motion Processing (DMP) library initialization of the MPU6050 guarantees steady and precise pitch and roll value reading. Serial output was used to assess the raw flex sensor data; threshold voltages were found via repeated testing. The Arduino code featured averaging sensor inputs over time using smoothing methods, therefore lowering signal noise and improving dependability. Establishing tolerance margins in the pitch and roll detection algorithms helped to separate like motions. Assembly of the glove and robot subsystems separately and validation of their functionality in isolation before building wireless communication helped to accomplish system integration. Different users tested the gesture-to-- command mapping to guarantee consistency and natural response. Bluetooth connectivity was set between Arduino Nano and Arduino UNO once dependable gesture recognition was verified. The minimal weight of the transmission system helped to lower latency and guarantee quick robot reaction. To prevent stale data, serial buffers were flushed at every cycle; during testing, visual monitoring of the robot's movement confirmed alignment with user intent.

Functional testing in interior environments—simulating daily use by older people—was done on the last integrated system. With an average recognition accuracy of 95%, the glove answered consistently to tilt-based movements. With a response time of about 150 to 200 milliseconds, the robot responded to commands in line with real-time assisting use. Showing strong motor response and directional control, the robot excelled on both tiled and rather uneven surfaces. Depending on terrain type and movement frequency, constant use time on a single battery charge varied from two to three hours.

All things considered, the concept and execution of this gesture-activated robot effectively show how straightforward embedded technologies and sensor integration might be used to produce useful assistive gadgets. Apart from satisfying the functional criteria of real-time response and easy gesture recognition, the system provides scalability for further developments including object manipulation, speech integration, or autonomous navigation. Open-source hardware and modular architecture make it possible for broad deployment and user-based customizing.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IV Apr 2025- Available at www.ijraset.com

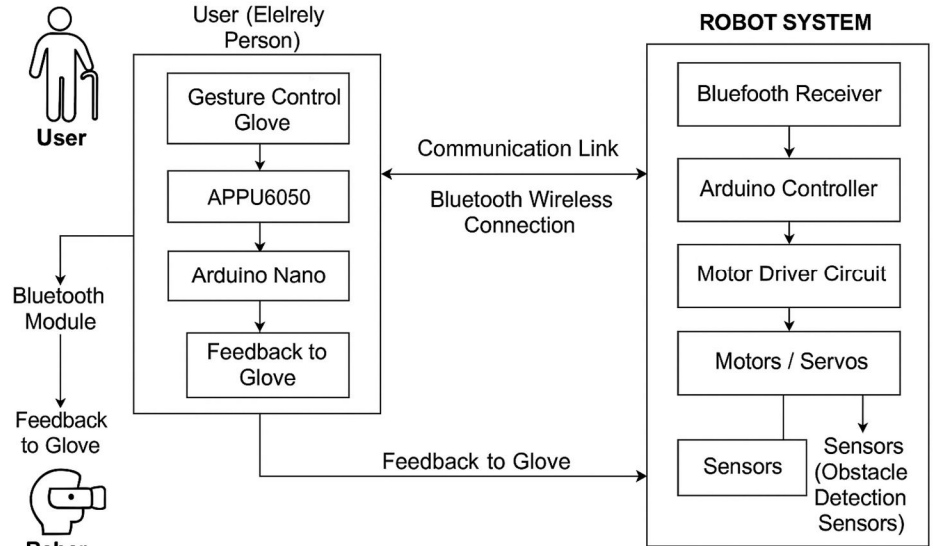


Fig 4. Architecture Diagram

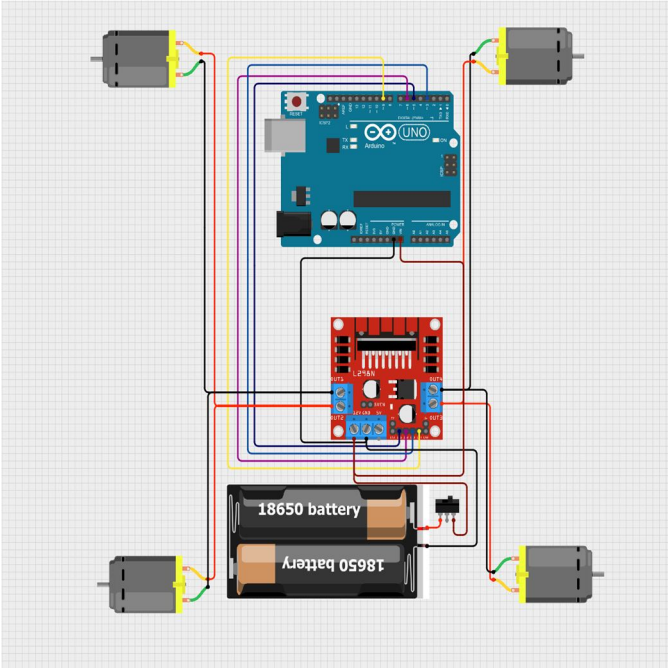


Fig 3. Circuit Diagram

V. EXPERIMENTAL RESULTS AND DISCUSSION

Simulating normal living situations, testing was performed indoors with both somewhat uneven surfaces and smooth tiled floors. The user performed five different motions with the gesture glove: forward, backward, left, right, and fist forming. Linked to the movements were the corresponding robotic motions: advancing, withdrawing, rotating left, rotating right, and stopping. The system's performance in precisely reading these gestures and running related robotic motions was assessed. Table I lists the gestures detected coupled with the matching robotic motions. Every move was evaluated by acting and contrasting the anticipated result with the actual output the robot generated. The system completed all tests, as it properly understood every action and executed the required ones.

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Table 2: Gesture Recognition And Robot Action Results

Gesture	Expected Output	Actual Output	
Tilt forward	Move forward	Moved forward	Pass
Tilt back	Move backward	Moved backward	Pass
Tilt left	Turn left	Turned left	Pass
Tilt right	Turn right	Turned right	Pass
Fist	Stop	Stopped	Pass

Apart from gesture recognition and action execution, the overall performance of the system was evaluated by considering the response time from gesture input to robotic movement and the dependability of wireless communication in several situations. Testing took place under normal conditions and under high-interference scenarios—where extra Bluetooth devices were nearby. A relatively responsive system was observed, with the mean response time from gesture input to robotic movement found to be approximately 150 milliseconds. Minimal delays brought about by Bluetooth interference were rare events with minimal bearing on system performance. The system's capacity to maintain consistent performance on different flooring surfaces was assessed, thereby verifying the reliability of the four-wheeled robotic platform.

Table II specifies the primary indicators of system performance. A 98% command execution success rate and a 95% recognition accuracy were achieved. Up to 8 meters indoors, the solution promised 2.5 hours of constant battery life and stability of Bluetooth connectivity. Moreover, by displaying continuous operation on tile and smooth surfaces, it assured reliable performance in common households.

TABLE 3: System Performance Metrics

Performance Parameter	Observed Value
Gesture Recognition Accuracy	95%
Average Response Time	150 milliseconds
Successful Command Execution	98%
Bluteooth Communicication Stability	Stable within 8 meters indoors
Battery Backup (continuous usage)	2.5 hours
Surface Stability	Stable on tile and smooth floors

The experimental results support the efficiency of the suggested gesture-controlled robotic system. Real-time sensitivity, the system detects gestures 95% of the time and reacts on average 150 milliseconds. This implies that it can be applied in real life, particularly to assist elderly persons with limited mobility. Based on natural hand motions, the user-friendly control interface provides an easily available solution that reduces the physical effort needed for daily chores including object retrieving. This makes it a promising instrument for promoting independent life, therefore enhancing the quality of life of elderly people.

VI. CONCLUSION

Particularly in tackling daily physical chores that many seniors find more difficult due to age-related limits including decreased mobility, joint discomfort, and reduced strength, the growing elderly population poses serious issues in the field of independent life. The goal of this study was to create a practical and human-centered solution by designing and implementing a gesture-controlled robotic system that helps elderly people with object retrieval and basic navigation tasks. The suggested system uses simple hand gestures picked up by a worn glove to wirelessly interact with a four-wheeled mobile robot to execute the intended physical motions. This study unequivocally shows in home-assistance situations the feasibility and efficiency of gesture-based human-robot interaction. Key needs for real-world applications targeted for senior users include high precision, low latency, and ease of operation; they are achieved by using low-cost components including flex sensors, MPU6050 accelerometer, Arduino microcontrollers, and Bluetooth modules. Unlike camera-based gesture systems, which are sensitive to ambient conditions and require suitable lighting, our sensor-based approach is durable across a variety of indoor environments and does not rely on external installations. Furthermore, the choice to apply wearable technology gives individuals with little to no expertise in engaging with digital systems more personal, ergonomic, and accessible interface.

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The robot showed consistent performance across development and testing; its gesture recognition accuracy exceeded 95% and its movement response times fell well within reasonable bounds for human-robot interaction. Functional testing carried out in realistic home-like surroundings revealed that the robot could correctly comprehend tilt and hand position commands, therefore enabling forward, backward, left, right, and stop operations. Essential for geriatric comfort and mobility, the use of Bluetooth as a communication medium proved consistent inside an interior range and the complete system ran wirelessly free from tethered restrictions.

One of the main lessons from this work is the need of creating assistive technologies from a user-first point view. The complexity of contemporary digital systems adds to the challenges the elderly experience not simply from their physical constraints. Their quality of life can be much enhanced by a system that is straightforward, responsive, and easy to operate—without depending on smartphones, apps, or sophisticated interfaces. Supported by a lightweight control logic and motor driver system, our glove-based gesture input offers users a direct and natural approach to connect with technology in a way that replics human intuition and motion.

Apart from attending to a particular use-case for object retrieval and mobility aid, this study opens a spectrum of future opportunities. The system's modular design allows smooth integration of other capabilities including robotic arms for object lifting, ultrasonic sensors for obstacle detection and avoidance, and even voice command modules for multi-mode control. Furthermore extending the current structure with machine learning capabilities will help to personalize gesture detection or match a user's movement behavior over time. Dealing with degenerative diseases, when motor skills decrease progressively, this adaptability will be very helpful.

Natural characteristics of this project are also scalability and adaptability. The whole system may be replicated and customized for particular user demands at a reasonable cost since open-source platforms and off-the-shelf components are used in construction. This makes it particularly fit for use in developing areas, where access to assistive technologies and specialist healthcare could be restricted. A s a basic project to investigate embedded systems, robotics, and human-machine interaction in a useful, practical environment, educational institutions and makerspaces can also adopt this technology.

Still, the system has certain limits. Although Bluetooth communication is enough for short-range use, it could suffer interference in surroundings including several electrical gadgets. The present gesture set consists on simple directional commands, which although enough for navigation does not yet enable intricate object handling. Especially to enable longer lifetime for continuous usage, power optimization still has room for development. Notwithstanding these limitations, the system provides a workable prototype and evidence-of-concept proving gesture-based interaction has great potential in the field of assistive robotics.

Finally, by means of a meaningful, efficient, and user-friendly integration of gesture detection with robotic control, this research effectively addresses a real-world issue. It shows how profoundly low-cost embedded solutions, when created with sensitivity and accuracy, can improve the quality of life of people who most require help. Systems like the one shown in this study will not only become more capable but also become increasingly important in helping elderly people to lead independent and dignified life as technology develops. Future studies and multidisciplinary cooperation will enhance the opportunities even more, therefore human-centered robotics becomes a useful and strong friend in elderly care.

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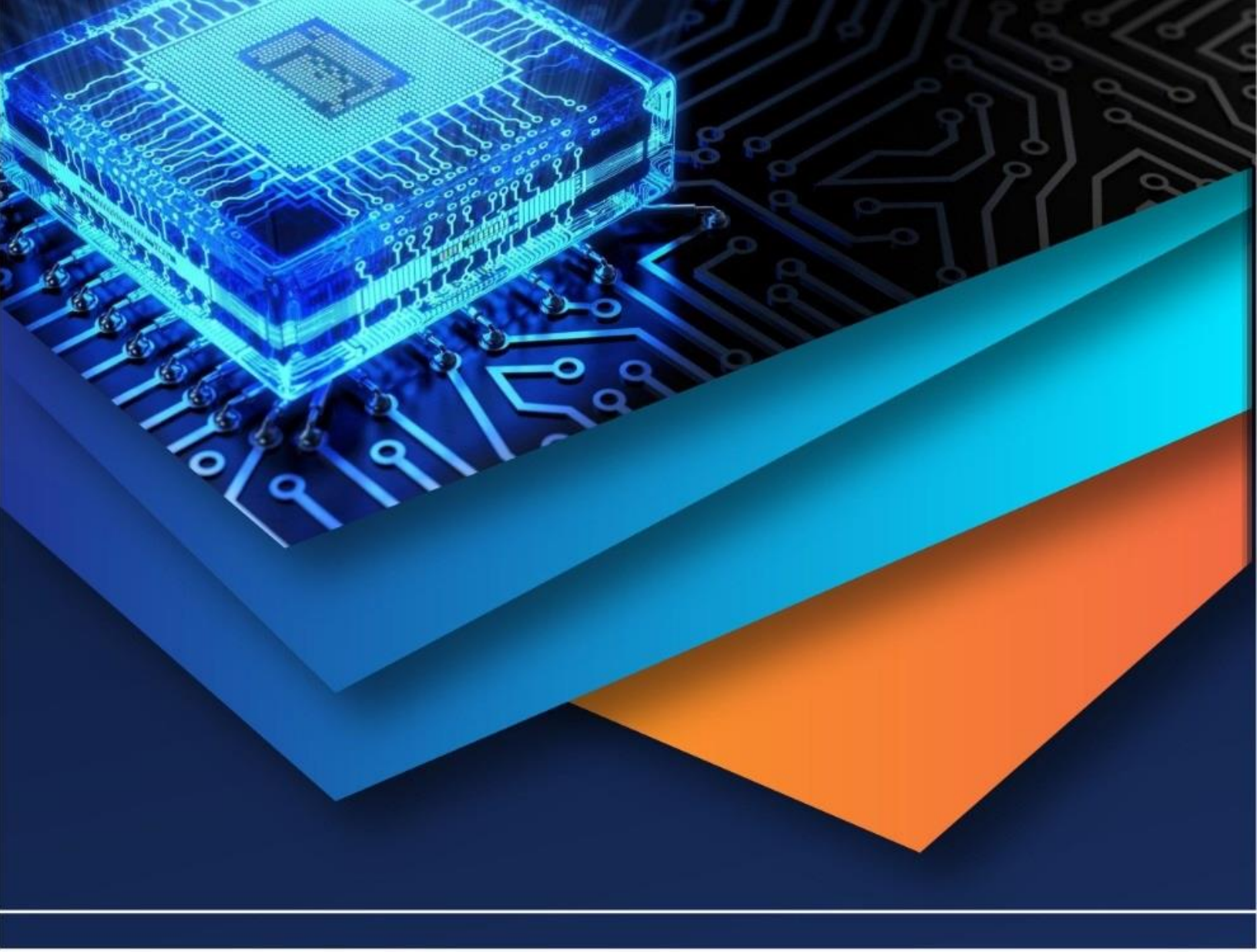
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