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Human Following Smart Shopping Trolley

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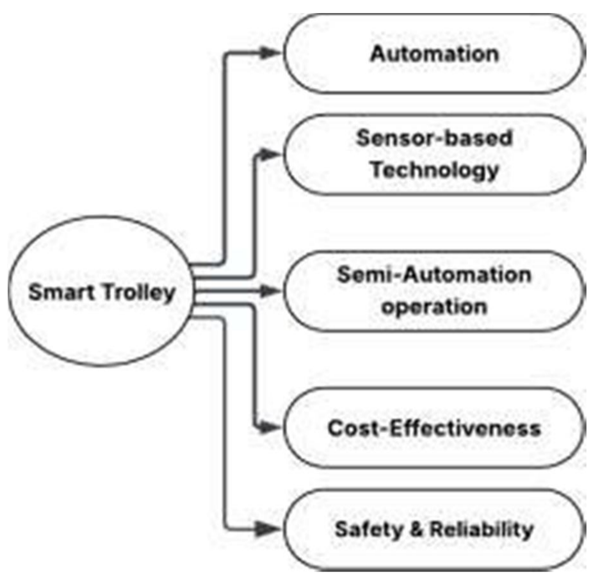
Abstract: Helping people with physical disabilities to move independently is an important part of inclusive technology, but it is still not fully developed, especially for everyday personal use. This study focuses on a detailed design of a Smart Trolley created for users with mobility challenges, combining smart sensor-based systems and automation to reduce physical strain and improve self- reliance. The system is controlled by an Arduino Uno microcontroller, which manages signals from ultrasonic sensors, Bluetooth and IR tracking modules, and the L298N motor driver to enable semi- automatic motion. The trolley can be operated through several modes, such as voice commands, RFID tags, or a mobile application, allowing the user to move it, control its path, or let it follow automatically. Designed mainly for indoor environments like hospitals, shopping malls, and airports, it can detect and avoid obstacles for safety while staying close to the user. This paper explains the system design, working method, and expected benefits, showing how such assistive equipment can be a practical, affordable, and meaningful step toward improving independence and mobility for physically challenged people.

Keywords: [Smart Trolley, Assistive Technology, Arduino Uno, Ultrasonic Sensors, Bluetooth Tracking, L298N Motor Driver, Physical Disability, Obstacle Avoidance]

I. INTRODUCTION

Individuals with restricted mobility often struggle with daily activities that involve lifting or transporting personal items, as regular trolleys and carts depend heavily on continuous manual control and physical strength. The Smart Trolley has been developed to overcome these difficulties by integrating automation with intelligent, sensor-based technology, offering a modern approach that reduces human effort while maintaining safety and ease of use with embedded electronics and control circuits, the trolley operates in a semi-autonomous manner, moving according to user inputs or automatically tracking the user while skill fully avoiding barriers.

The concept of this trolley draws from the fundamentals of autonomous robotics, yet it is specially customized for personal assistance, emphasizing simplicity, low cost, and dependability. The recent growth in microcontroller performance, rechargeable power sources, sensing components, and Bluetooth/IR communication has made it possible to build a practical and economical assistive tool suited for real-life usage. By supporting independence and enhancing mobility, the Smart Trolley stands as an example of human-focused engineering and inclusive technology, offering users a respectful and effective way to manage their daily needs.



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II. LITERATURE REVIEW

The integration of automation, RFID technology, and autonomous navigation has significantly influenced the development of smart shopping and intelligent robotic systems. Several researchers have explored cost- effective designs, efficient navigation, and human-aware interaction to enhance system performance and user experience.

Zhao et al. [1] proposed a low-cost RFID-based smart shopping system aimed at reducing manual billing efforts in retail environments. The system utilizes RFID tags attached to products and an RFID reader integrated into the shopping cart to automatically detect items. The study highlights improvements in checkout efficiency and reduced dependency on barcode scanning, making it suitable for small- and medium-scale retail stores. However, the system primarily focuses on item identification and billing, with limited emphasis on autonomous movement or customer interaction.

Singh and Kumar [2] designed and implemented a smart shopping cart system that integrates RFID technology with a microcontroller-based control unit. Their system enables real-time price calculation and display, helping customers monitor expenses while shopping. The research emphasizes ease of use and affordability but relies heavily on manual cart movement, which restricts scalability and full automation in crowded shopping environments.

With advancements in robotics, autonomous navigation has gained attention for dynamic and uncertain environments. The study on autonomous navigation and mobile robot control techniques [3] discusses various control algorithms, including sensor-based navigation, obstacle avoidance, and path planning. The authors highlight the importance of adaptability and real-time decision-making in dynamic environments such as malls and warehouses. These techniques provide a foundation for integrating autonomous movement into smart shopping platforms.

Further extending this concept, research on adaptive control and navigation strategies [4] focuses on enhancing robotic autonomy using adaptive algorithms. The study demonstrates how robots can adjust navigation parameters based on environmental changes, improving safety and efficiency. Such strategies are essential for applications where robots interact closely with humans, such as retail and service sectors. Human-centric design has also been explored in autonomous systems. The work on human- aware motion planning and perception [5] emphasizes safe and socially acceptable robot navigation. The study incorporates perception models that allow robots to recognize human presence and adjust their motion accordingly. This approach is particularly relevant for smart shopping systems operating in public spaces, as it improves user trust and reduces collision risks.

Overall, existing literature demonstrates significant progress in RFID-based smart shopping systems and autonomous robotic navigation. However, most smart shopping solutions lack autonomous movement, while many robotic navigation studies do not address retail-specific applications. This research gap highlights the need for an integrated system that combines RFID-based billing, autonomous navigation, adaptive control, and human-aware motion planning to create a fully automated and user-friendly smart shopping experience.

III. METHODOLOGY

The Smart Trolley for Physically Challenged People is designed by integrating hardware, software, and sensor-based control modules to achieve semi-autonomous motion and intelligent navigation. The main aim of this methodology is to allow the trolley to identify, follow, and assist the user safely while operating efficiently in indoor environments such as hospitals, shopping centers, and airports. The overall system framework consists of several interconnected modules, each performing a dedicated role to ensure smooth functionality, safety, and flexibility during use.

A. System Overview

The Smart Trolley works as an intelligent assistive companion that merges various sensors and microcontrollers to perform human-following behavior. It employs ultrasonic sensors for obstacle detection, Bluetooth or IR sensors for user tracking, and multiple control modes such as voice, RFID, and mobile application inputs. All these units are linked to an Arduino Uno microcontroller, which acts as the central processor, handling real-time input data and generating suitable control commands for the motors.

B. Core Components and Operation

1) Input Interface: The input interface provides multiple interaction methods between the user and the trolley.
2) Voice Command Interface: The trolley receives spoken instructions through a Bluetooth-enabled module capable of interpreting commands like “Start,” “Stop,” “Follow,” and “Return,” enabling hands-free operation.

3) RFID Tag Identification: Each individual carries a personal RFID tag that the trolley identifies, ensuring it follows only the assigned user even in crowded places.
4) Mobile Application Control: Through a simple Android-based Bluetooth interface, the user can remotely control the trolley's direction, movement, and speed, or bring it to a complete stop.
5) Processing and Control Unit: The Arduino Uno acts as the main processing controller for the trolley. It gathers data from the ultrasonic, Bluetooth, and IR sensors, processes it through pre-set logical conditions, and transmits control signals to the L298N motor driver. The embedded algorithm ensures obstacle avoidance and maintains safe proximity from the user. The logic mainly relies on if-else decisions and sensor thresholds to determine the trolley's movement relative to the environment.
6) Navigation and Locomotion System: Movement is powered by DC motors driven through the L298N dual H-Bridge driver, enabling two-way motion such as forward, backward, left, and right turns. Wheel encoders are attached to measure motor speed and ensure smoother motion and directional accuracy. The motor driver provides steady current and voltage supply, maintaining reliable motion even with variable load conditions.
7) Tracking and Following Mechanism: The trolley's ability to follow the user is based on Bluetooth or IR-based tracking. The Bluetooth module calculates signal strength (RSSI) to estimate the distance between the user's phone and the trolley. Depending on this data, the Arduino adjusts speed and direction to keep a safe gap (generally 0.5 to 1.5 meters). In the IR-based system, reflective sensors identify the user's presence and align the trolley's path accordingly.
8) Obstacle Detection and Avoidance: Ultrasonic sensors are positioned at the front and sides to detect nearby barriers. These continuously emit ultrasonic waves and measure the echo time to calculate distance. When an object is detected within the safety range (around 30 cm), the Arduino stops or reroutes the trolley automatically. This setup enables reliable operation in narrow or crowded areas, preventing unwanted collisions.
9) Power Supply Management: Power is supplied by a 12V rechargeable lithium-ion battery, ensuring long-duration use with minimal upkeep. A voltage regulator maintains consistent voltage for the Arduino and sensors, while the motor driver draws power directly from the battery. A solar charging feature may be added in future versions to improve runtime and energy efficiency.
10) Communication and Synchronization: The interaction between modules such as input, control, and motion is managed through serial communication protocols. Bluetooth and RFID communicate wirelessly with the Arduino, while PWM signals control the motors. The system ensures real-time data exchange and instant response, allowing smooth switching between manual and autonomous functions.

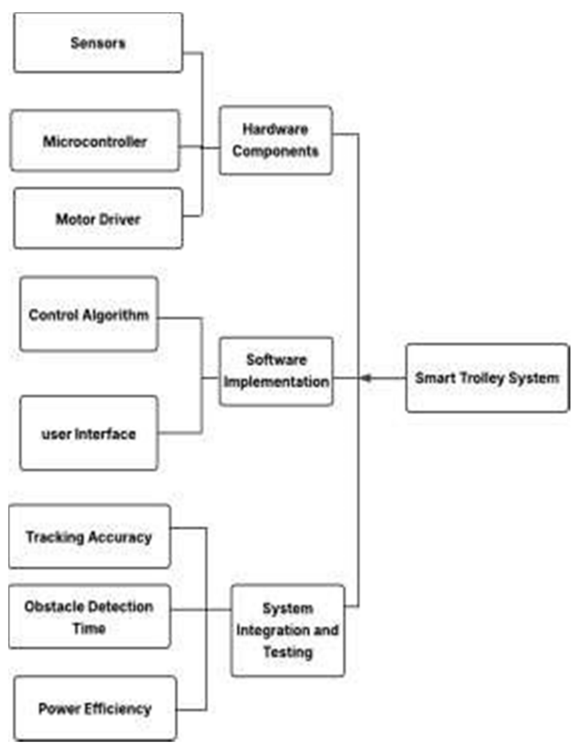


Fig. 3.2 System Architecture

C. System Integration and Testing

All hardware units were installed on a strong chassis capable of carrying loads up to 10 kilograms. Initial testing was conducted indoors under controlled conditions. Performance was assessed using three key factors:

1) Tracking Accuracy: The steady distance maintained between the user and the trolley.
2) Obstacle Detection Time: The reaction time taken to identify and avoid obstacles.
3) Power Efficiency: The average duration of operation per single battery charge.

Experimental results showed that the trolley could consistently follow the user, efficiently detect and avoid obstacles, and deliver dependable performance within the desired operating limits.

IV. SYSTEM ARCHITECTURE

The system architecture of the Smart Trolley for Physically Challenged People is structured to achieve autonomous navigation, obstacle detection, user communication, and effective load management through the coordinated use of both hardware and software modules. The overall design is divided into four major layers the Input Layer (Sensing Unit), Processing Layer (Control Unit), Output Layer (Actuation Unit), and Communication Layer (User Interface and Tracking System). These interconnected layers together ensure smooth interaction between the user and the robotic trolley, allowing efficient performance and intelligent behavior in real-world conditions.

A. Input Layer (Sensing Unit)

The sensing layer functions as the sensory system of the smart trolley, gathering information from the surroundings and receiving user-related signals necessary for proper operation.

1) Ultrasonic Sensors: Installed at the front and sides of the trolley to detect obstacles, calculate distance, and maintain safe movement even in busy environments.
2) Infrared Sensors (IR): Used for short-distance object detection and for accurate alignment while following or docking near the user.
3) RFID Reader Module: Enables the trolley to recognize and verify items placed inside it, supporting automatic billing and item management functions.
4) Load Sensor (Weight Sensor): Monitors the total load inside the trolley to avoid overloading and adjusts motor speed based on the weight being carried.
5) Bluetooth/Smartphone Connectivity Sensor: Allows users to connect wirelessly using a mobile application or remote system for easy control and summoning.
6) Battery Voltage Sensor**:** Continuously checks the battery's charge level and alerts the user or system when it needs recharging.

B. Processing Layer (Control Unit)

This layer represents the central intelligence of the system, managing all the information received from sensors and executing programmed decisions.

1) Microcontroller (Arduino Uno / ESP32 / Raspberry Pi) :- Acts as the main processing hub that runs algorithms and coordinates all modules.
2) Data Processing Algorithms :- Responsible for analysing sensor signals, adjusting motor speed, and guiding path control.
3) Human Following Algorithm :- Uses Bluetooth or IR data to follow a specific user while maintaining a fixed and safe distance.
4) Obstacle Avoidance Algorithm :- Operates on threshold distance logic to identify and bypass obstacles using real-time sensor feedback.
5) Power Management Unit :- Distributes voltage efficiently across all components to extend the system's operational duration.

C. Output Layer (Actuation Unit)

This layer converts control signals into actual mechanical responses and system feedback.

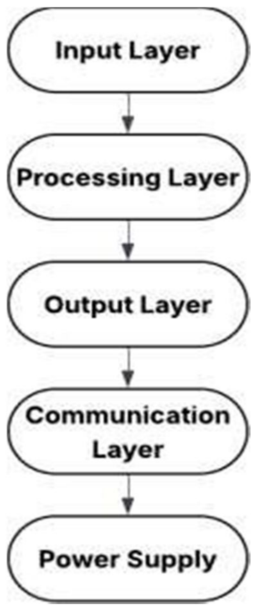
1) DC Motors with L298N Motor Driver :- Control the trolley's wheel operations, including forward, backward, and directional turns.
2) Servo Motors :- Provide fine angular adjustments for navigation or lifting mechanisms.
3) Buzzer and LED Indicators :- Offer audible and visual alerts for situations like obstacle detection, battery warnings, or system errors.
4) Display Unit (LCD/OLED) :- Presents useful data such as total billing amount, current battery percentage, and system activity status.

D. Communication and User Interface Layer

The communication layer ensures effective coordination between the user and the trolley through wireless connectivity and interface systems.

1) Bluetooth Communication Module (HC-05):- Provides wireless communication and device pairing with smartphones for control and updates.
2) RFID-Based Billing System :- Each item includes an RFID tag, which is scanned automatically to update total billing in real time and generate a digital invoice.
3) Mobile Application Interface :- A dedicated app allows the user to track, summon, and control the trolley remotely, while also viewing item details and past transactions.
4) Voice Assistance Integration (Optional):- Offers hands-free control for users with disabilities, enabling simple voice-based commands for motion and billing operations.

E. Smart trolley System Architecture



F. Power Supply and Energy Management

The power unit ensures uninterrupted operation while optimizing power use and energy distribution.

1) Rechargeable Li-ion Battery Pack :- Serves as the primary power source, rechargeable through a standard 5V or 12V supply.
2) Solar Charging Unit (Optional Upgrade):- Provides sustainable backup power to extend the battery's operational time.
3) Voltage Regulation **Circuit :-** Delivers consistent voltage to delicate modules like sensors and controllers, ensuring stable performance.

V. EXPECTED OUTCOMES

The Smart Trolley for Physically Challenged People project is anticipated to deliver multiple beneficial outcomes across the areas of technical functionality, user experience, cost efficiency, and community impact. The following subsections highlight the key results that this innovation aims to achieve upon successful implementation.

A. Technical Outcomes

Efficient Autonomous Navigation: The trolley is designed to perform smooth and self-directed motion by processing real-time data gathered from ultrasonic, infrared, and Bluetooth sensors. It will provide accurate direction handling, effective obstacle avoidance, and adaptive navigation in both narrow and crowded locations.

High Obstacle Detection Accuracy: With several ultrasonic sensors positioned at strategic angles, the system can identify obstacles with exceptional precision and react instantly by slowing down, halting, or altering its path, thus minimizing any possibility of collision.

B. User-Centric and Social Outcomes Enhanced User Independence

This system will help elderly or physically challenged individuals move freely with their belongings, allowing them to perform everyday tasks confidently and independently, reinforcing personal dignity.

Improved Safety and Comfort: Through automated obstacle detection and controlled movement, the system reduces potential hazards, ensuring safety and comfort, particularly in public or high-traffic environments such as hospitals or malls.

C. Economic and Practical Outcomes Cost-Effective Design

By utilizing low-cost modules like Arduino Uno, motor drivers, and ultrasonic sensors, the trolley remains financially feasible. Its overall development cost is much lower than that of other commercial assistive systems.

Ease of Maintenance and Scalability:- A modular hardware setup makes it easy to maintain, upgrade, or replace parts such as motors and sensors without major redesigning, ensuring long-term usability.

D. Research and Technological Outcomes Academic Contribution

The system provides a framework for academic research in robotics, embedded technology, and automation systems, offering a solid reference point for further development.

Integration of Embedded Systems and AI: This design highlights the synergy between sensors, microcontrollers, and algorithmic intelligence, showing how such integration can deliver efficient, human-focused automation.

E. Societal Impact Promoting Social Inclusion

The Smart Trolley supports individuals with disabilities in performing routine activities independently, encouraging social participation and inclusivity.

Encouraging Innovation in Assistive Robotics: This project shows how low-cost automation can provide meaningful solutions for accessibility issues, inspiring further creativity in assistive device design.

VI. IMPLICATIONS

A. Improved Mobility and Independence

The Smart Trolley system greatly improves the mobility and independence of physically challenged individuals. It allows users to move their belongings without requiring assistance from others, which promotes personal freedom and self-reliance in daily routines. By minimizing the physical effort involved in carrying or lifting items, the trolley encourages confidence and helps users participate more actively in personal and public environments. This independence not only enhances convenience but also restores a sense of dignity, enabling users to manage tasks with pride and assurance.

B. Assistive Technology Advancement

This project represents a major step forward in the field of assistive technology. It demonstrates how inexpensive sensors, microcontrollers, and automation circuits can be used to design practical, real-life solutions for people with mobility difficulties. The Smart Trolley bridges the gap between robotic automation and human-centered design by combining intelligent control with ease of use. The system serves as a foundation for future innovations in assistive robotics and can inspire the development of other personal mobility devices that integrate similar smart functions at low cost.

C. Safety and Accessibility Enhancement

Safety and accessibility are core aspects of the Smart Trolley's design. Equipped with ultrasonic sensors for obstacle detection and avoidance, the trolley ensures smooth movement even in crowded or narrow spaces such as hospitals, malls, and airports. These features help prevent accidents and provide reassurance to the user while operating in public areas. Furthermore, the integration of multiple control modes such as voice command, RFID tagging, and mobile app connectivity makes the trolley accessible to users with different physical abilities, ensuring inclusive operation for all.

D. Economic and Practical Benefits

From an economic perspective, the Smart Trolley offers a highly cost-effective and practical solution. It uses affordable and easily available components such as the Arduino Uno, L298N motor driver, and ultrasonic sensors, significantly reducing the total cost of production.

The modular design also allows for convenient maintenance, repair, and future upgrades without major redesign. Because of its low manufacturing cost and simple structure, the system has potential for large-scale production and implementation in healthcare facilities, shopping malls, and transportation centers, making it an economically viable assistive tool.

E. Educational and Research Impact

The project provides valuable educational and research opportunities in the fields of embedded systems, robotics, and IoT-based automation. It serves as a hands-on model for students and engineers to understand real-time sensor integration, motor control, and human-tracking systems. Moreover, it encourages further experimentation with artificial intelligence or machine learning for future path-optimization and smart decision-making. The Smart Trolley thus acts as a learning platform for academic projects and inspires innovation in assistive robotics research.

F. Social and Inclusive Impact

Socially, the Smart Trolley contributes to inclusion and empowerment by supporting differently-abled users in performing tasks independently. By reducing reliance on caregivers, it helps individuals regain confidence and participate more freely in social and public spaces. The project directly aligns with the principles of equality and accessibility, addressing real-world challenges faced by people with disabilities. It also contributes to the United Nations Sustainable Development Goals particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 10 (Reduced Inequalities) by promoting inclusive innovation and reducing barriers to mobility.

G. Sustainability Implications

The design of the Smart Trolley also reflects environmental awareness and sustainable engineering. The optional solar charging feature supports renewable energy use, reducing dependence on conventional power sources and minimizing battery waste. By automating the transport of goods and materials, the trolley also decreases manual labor and physical strain, leading to better energy efficiency and optimized human effort. This sustainable approach aligns with modern eco-friendly design principles and encourages responsible technology development.

H. Future Application Scope

The Smart Trolley has broad potential for future applications and scalability. Beyond personal use for physically challenged individuals, the same technology can be adapted for elderly care, hospital logistics, warehouse automation, and shopping assistance. Its intelligent navigation and modular control structure make it suitable for customization according to different environments. The system's framework can also serve as the foundation for developing fully autonomous wheelchairs, delivery robots, or robotic companions in the future. Thus, the Smart Trolley not only solves present challenges but also opens the door to next-generation assistive robotics and mobility solutions.

VII. CONCLUSION

The Smart Trolley marks a significant step forward in the domain of assistive technologies. Through the integration of automated motion control, intelligent sensing, and human- tracking mechanisms, it successfully minimizes physical strain while maintaining safety, comfort, and ease of use. The system's adaptable and modular framework also makes it open to future upgrades and improvements, laying the groundwork for next-generation mobility assistance solutions. With continued research, testing, and optimization, the Smart Trolley can evolve into a reliable, cost- effective, and life-enhancing device that empowers individuals with physical challenges to move through their everyday environments with improved freedom, confidence, and independence.

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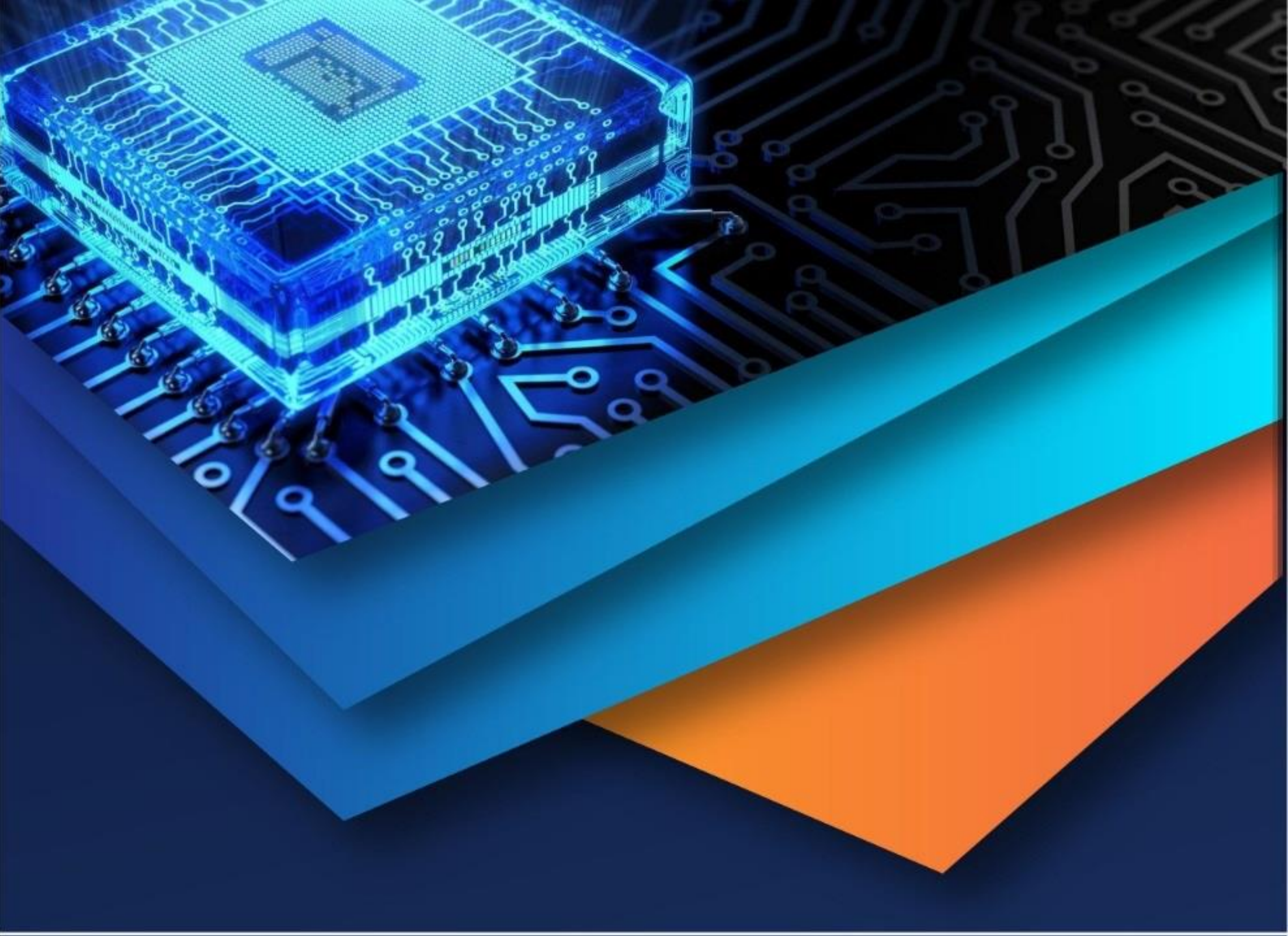

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