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Zara Tech Trail: Futuristic Autonomous Robocart for Cutting-Edge Multi-Perspective Delivery System

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***Abstract:** The autonomous delivery system presented in this project utilizes a RoboCart equipped with GPS navigation to seamlessly transport products from source to destination. The system, powered by electric charging, ensures timely and secure delivery to end customers, featuring a specialized hand gripper for careful product handling. Designed for diverse applications such as commercial purposes, personal use, and industries including hotels, this fully autonomous cart incorporates a password-enabled security feature to guarantee user verification. Positioned as a cutting-edge technological solution, this project aims to effectively address the last mile delivery challenge, presenting a potential to significantly reduce delivery times and contribute to societal benefits. The success of this initiative holds the promise of substantial positive impacts on the Society.*

***Keywords:** Autonomous, GPS Navigation, electric, Product Handling, Password, last mile, societal Benefits*

I. INTRODUCTION

In the ever-evolving landscape of logistics and delivery systems,the demand for innovative solutions to overcome the challenges of last-mile delivery has intensified. This paper introduces a ground breaking project focused on a Futuristic Autonomous RoboCart, designed to revolutionize the traditional delivery paradigm. Harnessing cutting-edge technology, this autonomous system employs a multifaceted approach to address the complexities of modern delivery networks. The Futuristic Autonomous RoboCart: At the heart of this project lies the Futuristic Autonomous RoboCart, a symbol of technological prowess designed to seamlessly navigate the complexities of last-mile delivery. Equipped with GPS navigation, the RoboCart possesses the intelligence to chart optimal routes, ensuring efficient and precise transportation of products from source to destination [5]. The reliance on electric charging not only aligns with environmental sustainability goals but also enhances the operational endurance of the system [1][10][11][12][13][14][15].

Multifunctional Design and Security Features: The versatility of the Futuristic Autonomous RoboCart is a testament to its multifunctional design. Tailored for diverse applications, including commercial endeavors, personal use, and integration into industries such as hotels, this fully autonomous cart proves its adaptability across a spectrum of scenarios. The incorporation of a specialized hand gripper underscores its commitment to meticulous product handling, promising end-to-end care in the delivery process. In addressing the imperative of security, the system introduces a password-enabled feature, ensuring user verification at each stage of the delivery journey. This not only fortifies the integrity of the delivery process but also aligns with contemporary standards of data privacy and access control [10]. The synthesis of advanced functionalities positions the Futuristic Autonomous RoboCart as a holistic and secure solution for the evolving demands of modern delivery systems.

The Last Mile Delivery Challenge:

A critical aspect that this project aims to confront head-on is the last-mile delivery challenge. Acknowledging the inefficiencies and bottlenecks inherent in traditional delivery approaches, the Futuristic Autonomous RoboCart aspires to be the vanguard in mitigating these issues. By significantly reducing delivery times and enhancing the overall reliability of the process, the system aims to reshape the landscape of last-mile logistics [2][10].

Contributions to Societal Benefits:

Beyond the realm of logistics, the success of this initiative holds the promise of substantial positive impacts on society at large. The potential reduction in delivery times not only enhances customer satisfaction but also contributes to the optimization of urban traffic, reduction in carbon emissions, and increased overall operational efficiency [1][9]. As we delve into the intricacies of this cutting-edge technological solution, the transformative potential of the Futuristic Autonomous RoboCart becomes increasingly apparent, signifying a new era in the evolution of delivery systems.

II. SYSTEM HARDWARE DESIGN

1. Arduino UNO: The Arduino UNO is a popular microcontroller board based on the ATmega328P. It provides a simple and versatile platform for prototyping electronic projects, with digital and Analog input/output pins.
2. Ultrasonic Sensors: Ultrasonic sensors use sound waves to measure distances and detect objects. They emit ultrasonic pulses and measure the time it takes for the echoes to return, allowing for accurate distance calculations.

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Ultrasonic sensors measure distance based on the time taken for sound waves to bounce off an object and return. Distance calculation Formula: Distance = (Speed of Sound * Time) / 2Speed of sound in air at room temperature ≈ 343 meters/second.

3. Infrared Sensors: Infrared sensors detect infrared radiation to identify the presence or absence of objects. They are commonly used in proximity sensing and obstacledetection applications.
4. Gear Motors and Servo Motors: Gear motors are commonly used for driving wheels or other mechanical parts. Servo motors provide precise control of angular position and are often used in robotics for accurate movements.
5. GPS Module-Neo 6M: The Neo 6M GPS module receives signals from satellites to determine its location, speed, and time. It outputs NMEA data, which can be parsed to obtain accurate geographical information [4][5][10].
6. GPS Compass: A GPS compass combines GPS data with a digital compass to provide accurate heading information, allowing for precise navigation [9].
7. OV7670 VGA Camera Module: The OV7670 VGA Camera Module is a compact camera that can capture still images or video. It is commonly used in projects involving image recognition or computer vision applications.
8. ESP32 Module for Micro python: The ESP32 is a powerful Wi-Fi and Bluetooth-enabled microcontroller. When running Micro python firmware, it allows for Python programming, making it easier to develop applications [9].
9. Bluetooth Module for Communication: Bluetooth modules enable wireless communication between devices. They are commonly used for short-range communication in various projects, such as connecting to smartphones or other peripherals.
10. Buzzer: A buzzer is a simple audio signal device that can produce sound when an electrical signal is applied. It is often used for providing audible alerts or feedback.

a) pin: The buzzer pin number.

b) frequency: The desired beep frequency (e.g., 1000 Hz). c)duration: Beep duration in milliseconds. The no Tone(pin) function stops the buzzer after the specified duration.

11. Anti-Theft Tampering Sensors: Tampering sensors detect unauthorized access or manipulation of a device. They are crucial for security applications, triggering alarms or alerts whentampering is detected.
12. 6V Lead Acid Battery: A lead-acid battery is a rechargeable battery commonly used for providing power to electronic devices. It is known for its reliability and ability to deliver a consistent voltage.
13. Hand Gripper: A hand gripper is a mechanical device used for grasping and holding objects. In this context, it may refer to a robotic hand or gripper used for handling products in an autonomous system.
14. Keypad: A keypad is an input device with a set of buttons arranged in a matrix. It is often used for entering numerical or alphanumeric data and is commonly employed for user interaction in various electronic projects. It is used for enable the Password Authentication for users and also for Security Purposes [10].

III. SOFTWARE DEVELOPMENT

Choice of Operating System: The system can be developed on either Windows 10 or macOS. Both platforms support the required software and tools for programming, development, and machine learning.

Integrated Development Environment (IDE):

Utilize the Micro python for developing Micro python scripts on the ESP32 module. This provides an interactive and collaborative environment for code development [4][9].

Programming Languages: Use Python for high-level scripting, machine learning tasks, and Micro python on the ESP32. Arduino IDE can be employed for programming the Arduino UNO.

Python will be the primary language for implementing control algorithms, image processing, and machine learning tasks.

Requirements for Computer Vision: Integrate OpenCV and TensorFlow libraries for computer vision tasks on both the computer and the ESP32. These libraries are essential for image processing, object recognition, and machine learning applications.

Control System Software: Implement PID control algorithms for precise control of gear motors, servo motors, and other actuators. Libraries such as PID in Arduino can be used for easy implementation [10].

Navigation Software: Develop Simultaneous Localization and Mapping (SLAM) algorithms for autonomous navigation. ROS (Robot Operating System) can be used for SLAM implementation. The implementation should involve integrating sensor data (GPS, cameras) to map the environment and localize the system within it [5][10].

Collaboration and Version Control: Utilize version control systems like Git to manage code versions, track changes, and facilitate collaboration between team members.

Testing and Simulation: Employ simulation tools for testing algorithms and code before deployment on the actual hardware. Tools like Gazebo or Pygame can simulate the robotic environment and test navigation algorithms.

Documentation: Maintain comprehensive documentation for all code modules, algorithms, and configurations. Use README files to provide setup instructions, dependencies, and usage guidelines.

User Interface Development: Develop a user interface for interacting with the system. This may include a graphical interface for monitoring the status, controlling the system, and receiving notifications.

Security Implementation: Implement secure coding practices and encryption algorithms, especially when handling sensitive data or communicating over networks.

Error Handling and Logging: Implement robust error handling mechanisms and logging to facilitate debugging and troubleshooting Training and Optimization (Machine Learning): Train machine learning models using TensorFlow for tasks such as object recognition. Optimize models for efficient deployment on the ESP32.

Networking and Communication: Implement communication protocols between components using Bluetooth and Wi-Fi. Ensure secure data transmission and handle potential communication errors.

Integration Testing: Conduct thorough integration testing to ensure seamless communication and functionality between all hardware components and software modules.

GPS PERFORMANCE:

Table 1

Parameter	Specifications	Neo 6m
Receiver type	50 Channels GPS L1 frequency, C/ACode SBAS: WAAS, EGNOS, MSAS	
Sensitivity	Tracking & Navigation Reacquisition, Cold Start, HotStart	-162 dBm, -160 dbm, -148 dbm ,-157dBm
Time-To-First-Fix	Cold Start, WarmStart, Hot Start, Aided Starts	27s, 27s, 1s, <3s
Configurable Timepulse frequency range		0.25 Hz to 1 kHz
Maximum Navigation update rate		5Hz
Operational Limits	Dynamics, Altitude, Velocity	4g, 50,000 m , 500 m/s
Heading accuracy		0.5 degrees
Accuracy for Timepulse signal	RMS ,99%, Granularity, Compensated	30 ns ,<60 ns, 21 ns, 15 ns
Velocity accuracy6		0.1m/s
Horizontal position accuracy	GPS, SBAS,SBAS + PPP ,SBAS + PPP	2.5 m, 2.0 m , < 1 m (2D, R50) , < 2 m (3D, R50)
Power Save mode & Voltage	Available	1.75 V (min), 1.8 (type), 1.95 V (max)
Active Antenna Recommendations	Minimum gain, Maximum gain, Maximum noisefigure	15 dB (to compensate signal loss in RF cable), 50 dB, 1.5 dB

A. Extracting GPS Data:

1. Read the File**:** First, make sure you have a file named "gps_data.txt" with the relevant GPS data. You can create this filemanually or obtain it from your NEO-6M module.
2. **Parse NMEA Sentences**: NMEA sentences are typically comma- separated strings.
3. **Extract Latitude and Longitude**: Look for lines starting with "$GPGGA" (which is a common NMEA sentence for GPS data). Extract the latitude (usually the third field) and longitude (usually the fifth field) from these lines.
4. **Convert to Decimal Degrees**: The extracted latitude and longitude are usually in degrees, minutes, and seconds format. You'll need to convert them to decimal degrees (e.g., 40.12345°).
5. **Store the Data**: Store the extracted latitude and longitude values in lists or any other data structure for further processing [6][10].

A complete $GPGGA sentence looks like this- $GPGGA,123429, 12.853372, N, 80.171469 ,E,1,11,0.9,530.4,M, 46.9,M,,*47

Table 2

Parameter	Value
UTC Time	12:34:29
Latitude	12.853372 N
Longitude	80.171469 E
Fix Quality	1 (GPS fix)
Satellites Used	11
HDOP	0.9
Altitude	530.4 M
Geoid Height	46.9 M

B. Reading Digital Compass:

i. Calculate Pitch and Roll:

We'll use an accelerometer (usually integrated with the magnetometer) to measure pitch and roll angles [8][10].

The accelerometer provides normalized values for acceleration along the X, Y, and Z axes (accXnorm, accYnorm, accZnorm). The pitch angle (θ) is calculated as asin(accXnorm).

The compensated X component (magXcomp) is calculated as:

magXcomp = mag_raw[0] * cos(θ) + mag_raw[2] * sin(ϕ)

The compensated Y component (magYcomp) is calculated as:

magYcomp = mag_raw[0] * sin(θ) * sin(ϕ) + mag_raw[1] * cos(ϕ) - mag_raw[2] * sin(θ) * cos(ϕ)

ii. Calculate Heading with Tilt Compensation: Finally, the heading (H) is calculated as:

heading = 180 * atan2(magYcomp, magXcomp) / π

C. Keypad Interfacing:

We have used the Keypad.h library [12] to interface the 4×3 keypad and the Servo.h library to control the servo motor.The delivery product is kept safe in a container which remains locked with a four digit password. When the robotreaches to its destination, it stops and waits for the customer to enter the four digit password that hasbeen sent to thecustomer's cell phone along with the order confirmation. Thisfour digit password would be preset by the vendor in theprogram. If the input password does notmatch, the buzzer beeps three times and the customer needs toretype the input password [10]. The roll angle (ϕ) is calculated as asin(accYnorm / cos(θ)).

i. Calculate Compensated Magnetometer Values:

We'll use the raw magnetometer readings (mag_raw) along the X,Y, and Z axes.

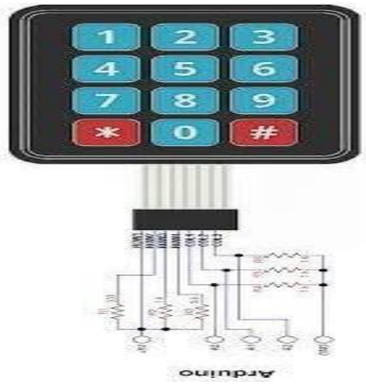

Fig 1: Keypad

IV. WORKING PRINCIPLE

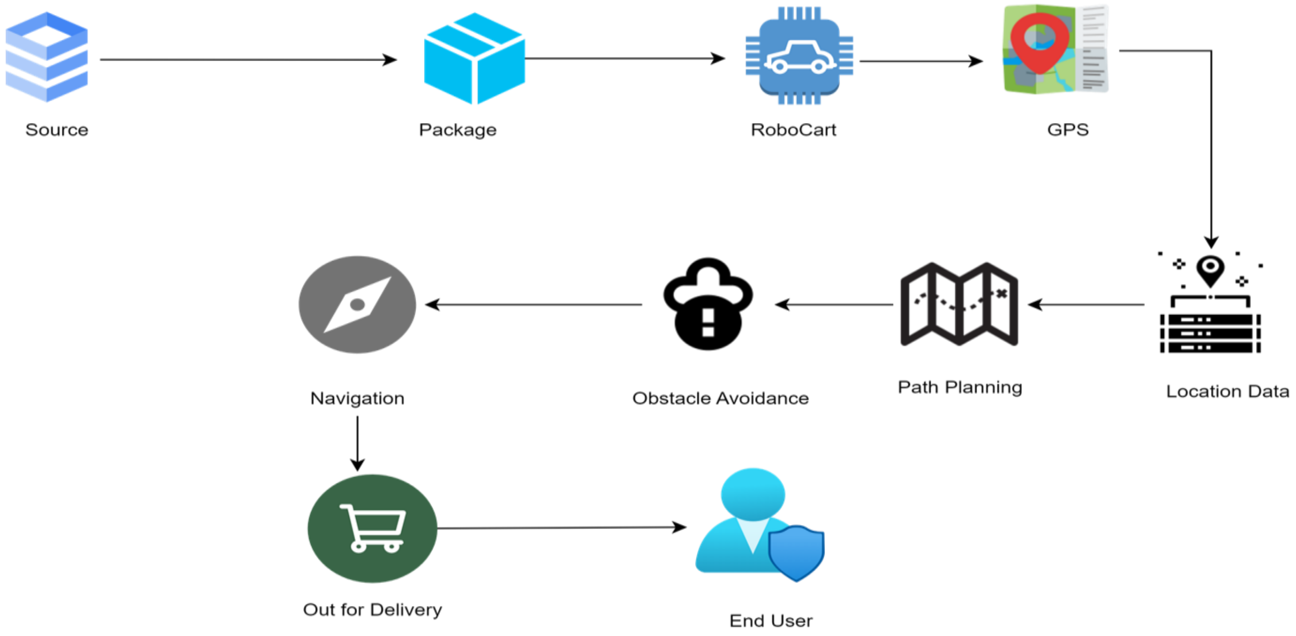

Fig 2: System Architecture of Autonomous Delivery

Source: The source refers to the origin of information or data that feeds into the robot's decision-making process.The autonomous delivery robot, the source could include various inputs such as user requests, package details, and environmental data.

Package: Represents the item being delivered. It includes information about the package size, weight, destination, and any special handling instructions. The robot needs to interact with this package efficiently during pickup, transport, and delivery.

Robocart: The robocart is the physical platform of the delivery robot. It houses all the necessary hardware components, including sensors, actuators, and communication modules. The robocart's design influences its mobility, stability, and payload capacity.

GPS: Provides accurate location information to the robot. It enables the robot to determine its position relative to the deliverydestination. The robot uses GPS data for navigation, route planning, and real-time position updates. May involve algorithms such as A* (A-star) or Dijkstra's algorithm for pathfinding [5][7].

Navigation: Component handles the robot's movement from thesource to the destination. It involves path planning, obstacle avoidance, and localization. Path planning algorithms consider factors like road conditions, traffic, and terrain to find an optimal route. Obstacle avoidance ensures that the robot avoids collisions with static and dynamic obstacles.

Obstacle Avoidance: The robot's sensors (such as LiDAR, cameras, and ultrasonic sensors) detect obstacles in its vicinity. Algorithms analyze sensor data to adjust the robot's trajectory and avoid collisions. Employ local planning algorithms like the Velocity Obstacle method or Reciprocal Velocity Obstacle method [4].

Path Planning: Path planning determines the best route from the source to the destination. It considers factors like road networks, traffic rules, and environmental conditions. Algorithms optimize the path based on criteria such as distance, time, and energy efficiency [5][8].

Location Data: Location data includes real-time information about the robot's position, nearby landmarks, and obstacles.The robot continuously updates its location using GPS and other localization techniques.Location data feeds into the navigation and path planning modules [3][5].

Out for Delivery: It is an exciting stage in the shipping process! It means that your package is currently on the Robocart and en route to your destination**.** The shipment has left the local shipping facility and is now making its way to you via a delivery route.

End-User: The end user interacts with the autonomous delivery robot. The end user initiates delivery requests, tracks the package, and receives notifications.

V. TESTS AND RESULTS

Operations: They can operate efficiently, reducing labor expenses. Optimizing They can navigate traffic and congestion more effectively. Reducing. By using electric power, they contribute to sustainability [2].

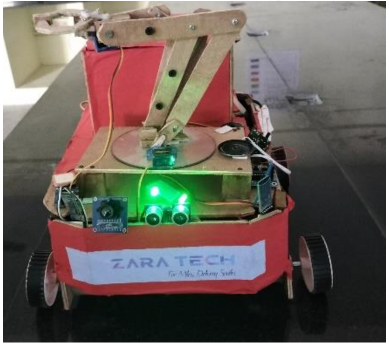

Fig 3: Autonomous Delivery Robot

Infrastructure: A network of charging points is essential. Safe. Dedicated lanes or pedestrian-friendly routes. Storage Lockers for secure parcel drop-offs.

Regulations: Currently, regulations for ADRs (Autonomous Delivery Robot) are not well-established. Clarity is needed regarding safety, liability, and operational guidelines.

Acceptance: Novelty that People are still getting accustomed to this technology. Building trust and confidence in ADRs' reliability and safety.

Promising Results: Existing studies highlight the potential of ADRs. However, real-world case studies and implementations are crucial for practical insights.

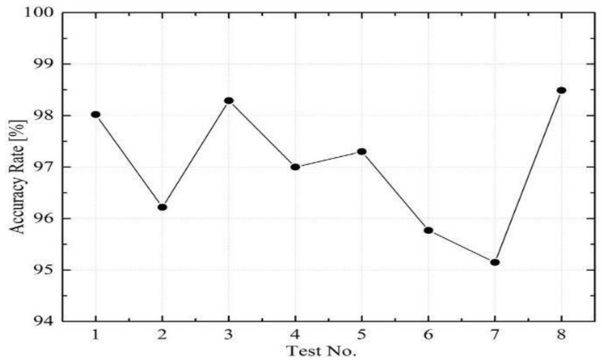

Fig 4: Accuracy Rate for Heading Angle Movement

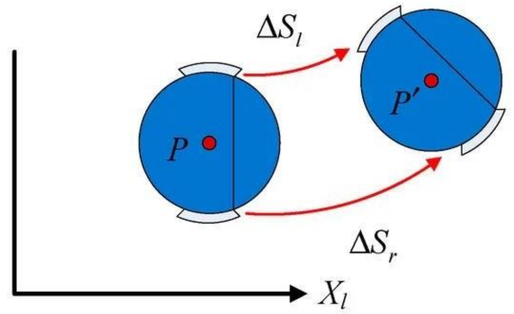

Fig 5: Movement Track Diagram of the Robot

This is a low-cost design. It is assumed that the trajectory of the food delivery robot is a segment of an arc Assume that the -wheel distance ofthe food delivery robot is $4L$ and the center of its movement mechanism(the center of the two rounds of connection) is point p.

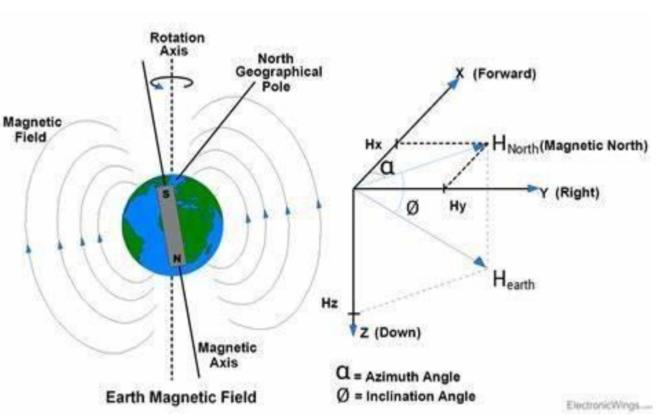

Fig 6: Heading Angle Changes Measured by HMC 5883L

It can be used for low-cost compassing and magnetometry. It has 12-bit ADC and compass heading accuracy is up to 1° to 2°. It has Anisotropic Magneto Resistive (AMR) technology which provides precision in axis sensitivity and linearity. It uses I2C communication protocol to communicate with microcontrollers. **HMC5883L** uses magneto resistive sensor arranged in a bridge circuit, which is made of nickel-iron (Ni-Fe magnetic film) material.

This change in voltages is used to get the magnetic field direction in space .The components of Earth Magnetic Field (Hx, Hy) are parallel to the earth's surface and are used in determining the compass direction. Only the X and Y components of the earth's field are used in determining the azimuth angle, or the compass direction [10].

Base: The foundation on which the catapult rests.

Launching Arm: The elongated wooden arm that holds the projectile(such as Package items) and is used to launch it.

Mechanical Components: Wires, pulleys, or other mechanisms that contribute to the catapult's functionality.

Degrees of Freedom: The robotic arm offers **four joints**, allowing forprecise and flexible movement.

Servo Motors: The kit includes four high-quality servo motors, pre-assembled and calibrated for seamless integration with the robotic arm.These servo motors provide reliable and precise control over each joint's movement.

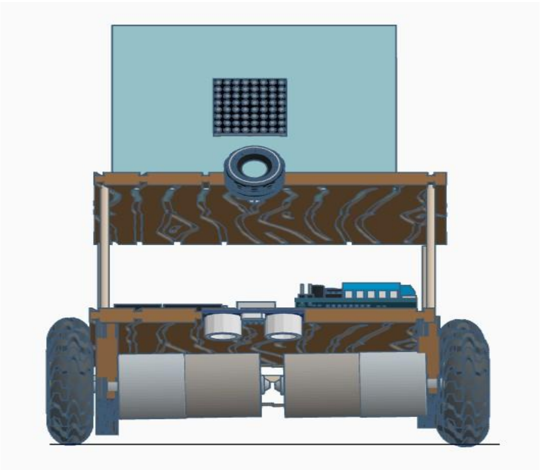

Fig 7: Robocart Design Using Autodesk

Fig 8: 4 DOF-Hand Gripper

Gripper Attachment: The robotic arm comes equipped with a gripper, enhancing its capability to interact with and manipulate objects. The gripper is designed for a secure and efficient grasp, making it ideal for tasks that require object manipulation.

Easy Assembly: Designed for easy assembly, this kit allows users to quickly set up the robotic arm without extensive technical expertise. Clear instructions guide users through the assembly process.

Compatibility: The robotic arm is compatible with popular microcontrollers such as **Arduino** and **Raspberry Pi**. This compatibility opens up opportunities for programming and customization, enabling users to implement various control algorithmsand applications.

Versatile Applications: Suitable for a wide range of applications, including educational projects, research, and prototyping. Its versatility makes it an excellent choice for learning and experimentation in the fields of robotics and automation.

Quality Construction: The components are made from durable materials, ensuring the longevity and reliability of the robotic arm. Thesturdy construction allows for repeated use and experimentation.

Specifications: Material: MR Grade Plywood (5 mm Thickness)Weight: Approximately 0.15 kg Dimensions: 32 cm (length) × 3 cm (width) × 12 cm (height).

VI. CONCLUSION

Healthcare (Hospitals): Surgical Assistance: Medical robots have revolutionized surgeries by providing precise assistance to surgeons. They enhance patient outcomes and reduce risks.

Clinical Support: Beyond the operating room, robots assist healthcare workers in clinical settings. During the COVID-19 pandemic, they helped reduce exposure to pathogens by handling tasks like supply delivery and disinfection.

Hospitality: Room Service: Delivery robots can efficiently deliveritems to hotel rooms, enhancing guest experience.

Contactless Service: In a post-pandemic world, robots minimizeperson-to-person contact during room service and housekeeping. Concierge Services: Robots can provide information, guide guests,and even offer entertainment.

Industrial Settings: Warehouse Logistics: Autonomous robots streamline inventory management, order picking, and materialhandling.

Manufacturing: Collaborative robots (cobots) work alongside humans, improving production efficiency. Safety and Inspection: Robots inspect hazardous environments, reducing risks for workers.

Personal Use: Home Assistance: Personal delivery robots can handle tasks like grocery delivery, mail collection, and even walking pets.

Last-Mile Delivery: In urban areas, robots can deliver packages tohomes, reducing traffic congestion.

Elderly Care: Robots provide companionship, monitor health, andassist with daily activities.

VII. FUTURE ENHANCEMENTS

Autonomy and Navigation: Improve obstacle detection and path planning algorithms for seamless navigation. Enhance localization accuracy using advanced sensors and machine learning.4Human- Robot Interaction: Develop natural language processing (NLP) capabilities for better communication. Ensure user-friendly interfaces for intuitive interaction Safety and Reliability: Implement fail-safe mechanisms to prevent accidents. Regular maintenance and self-diagnosis features. Customization: Modular designs to adapt to different environments (e.g., hospitals vs. hotels). Swappable components for specific tasks. Energy **Efficiency:** Optimize power consumption for extended operation. Explore renewable energy sources (solar, kinetic) for charging.

Security and Privacy: Protect sensitive data (e.g., patient records) during robot interactions. Secure communication protocols.

DECLARATION STATEMENT

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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AUTHORS PROFILE

PL Palaniappan holds a B.Tech (Artificial Intelligence and Data Science) degree from Prince Dr.K Vasudevan College of Engineering and Technology, with expertise in Robotics Embedded Development, Software Development, Computer Vision, and Image Processing. As a professional skilled in Robotics and Automation, I lead the development of innovative projects. I am an aspiring professional adept at AI and software development, data science, and engineering, with strengths in analytical thinking, problem solving, creativity, and innovation. I specialize in designing and implementing robust solutions, leveraging machine learning and deep learning technologies. I am excited about the potential of emerging technologies to shape the future and am eager to contribute my expertise to projects that push the boundaries of innovation and creativity.

M Devendran is a highly motivated individual with a B.Tech degree in Artificial Intelligence and Data Science from Prince Dr. K Vasudevan College of Engineering and Technology. Aspiring Professional in AI, Machine learning and designing. My technical skills include proficiency in Autodesk, Python, and CAD software design. I am passionate about tackling complex engineering challenges and thrive in environments that demand creativity and innovation. With a keen eye for detail and a knack for problem-solving, I am committed to driving positive change through technology. Driven by a passion for creativity and a desire to make a positive impact, I am excited about the endless possibilities that AI, data science, and design hold for transforming industries and improving lives.

Shanmuga Priya R, equipped with a B.Tech in Information Technology and an M.E in Engineering, is currently immersed in her Ph.D. studies. Her academic trajectory embodies a fusion of theoretical understanding and practical application, indicative of a holistic approach to problem-solving. With a background spanning IT and engineering, her research pursuits likely delve into the intersections of these fields, aiming to uncover novel solutions and advancements. Shanmuga Priya's journey as a scholar underscores a profound commitment to knowledge acquisition and dissemination. Her academic endeavors are driven by a passion for exploring the frontiers of technology and engineering, with the ultimate goal of contributing meaningfully to her field. As an emerging researcher, she is positioned to make significant contributions through her innovative insights and research findings, poised to enrich the scholarly discourse within her area of expertise.
