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# IoT-Enabled Autonomous Luggage Robot using Arduino and Ultrasonic Sensors

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**ABSTRACT**

Carrying heavy luggage can be tiring, especially in airports, malls, and travel hubs. This research introduces an autonomous luggage carrier robot that follows the user and avoids obstacles without needing manual control. The robot is built using an Arduino microcontroller and various sensors, like ultrasonic sensors for detecting obstacles and an IR or RFID module to track the user. It moves using motorized wheels and runs on a rechargeable battery. The system is designed to make travel more convenient by reducing human effort.

The most important factor for an autonomous robot is to have a continuous interaction between the person and the robot itself. It uses ultrasonic sensors to locate the person walking in front of it and keeps a constant distance. The robot relates to the person by WiFi model and tracks the location using GPS. However, this study will not only discuss a robot that follows humans but also a robot that will assist humans with an additional feature of following a person according to the detected location, which will be used to pick up the load and move to the desired location of the user. The developed model will help humans in different environments like hospitals, schools, and shopping malls. A unique handmade tag was put on the person the robot was supposed to follow to simplify things. The main hurdle in such a task is that target detection is a sensitive task. The object needs to be unique for the robot to recognize it and accomplish the objective.

Experimental results show that the robot can successfully follow the user indoors and outdoors, effectively avoid obstacles, and carry luggage without losing stability. It performs well on smooth and slightly uneven surfaces, which proves its reliability in real-world conditions. The proposed system enhances travel convenience by reducing the physical effort required to carry luggage, making it a promising innovation for smart mobility solutions.

**Keywords:** human-following, human-tracking, distance tracking, human-robot interaction.

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## 1. INTRODUCTION

With advances in automation and robotics, autonomous luggage transport has gained significant attention as a solution to reduce human effort in lifting heavy loads. Traditional luggage handling relies on manual effort or conveyor belt systems in airports, but these methods can be inconvenient, especially for passengers with disabilities, the elderly, or those carrying multiple bags. A luggage cart that follows a wheelchair using a special color pattern and an optical vision sensor, an automated shopping cart that uses an ultrasonic and infrared sensor [1]. Autonomous luggage carriers aim to bridge this gap by using smart technology to follow users, avoid obstacles, and navigate efficiently in different environments. Several commercial products, such as smart luggage with self-driving capabilities, have emerged, utilizing technologies like computer vision and tracking. However, many existing solutions are costly and require complex infrastructure. The use of Arduino-based autonomous luggage carriers provides a low-cost, efficient alternative, making smart luggage accessible to a wider audience. This research focuses on developing a lightweight, sensor-integrated robotic system to improve travel convenience while maintaining affordability and efficiency [2][3].

The integration of the Internet of Things (IoT) and robotics is revolutionizing the travel industry by enhancing convenience, efficiency, and security. IoT enables seamless connectivity between devices, allowing real-time monitoring, automation, and smart decision-making. For instance, IoT-powered smart luggage comes with GPS tracking, digital locks, and weight sensors, allowing travelers to monitor their bags remotely. Similarly, airports and hotels use IoT for automated check-ins, facial recognition, and smart room controls, making travel smoother and more efficient. On the other hand, robotics plays a vital role in automating luggage handling, assisting travelers, and optimizing logistics. Autonomous robots are now being used in airports and hotels for baggage transport, customer assistance, and even room service. When a person or a person moving their legs is being tracked, the robot will move in lockstep with them, following them forward, left, and right. Robots can locate people by using ultrasonic sensors, which can also access and determine the distance between people and the robot [4].

The scope of this research includes hardware and software integration, motion control optimization, and real-world testing to evaluate the system's performance under various conditions. By providing an affordable and automated luggage-carrying solution, this research contributes to the development of smart mobility systems, benefiting travelers, elderly individuals, and people with mobility challenges. Additionally, the findings from this study can serve as a foundation for further advancements in autonomous transportation and robotic assistance technologies. The robot is intended to track and follow the user, detect obstacles, and navigate safely in dynamic environments such as airports, railway stations, shopping malls, and hotels. The study focuses on utilizing Arduino as the central controller, along with ultrasonic sensors for obstacle detection and modules for user tracking, ensuring efficient and intelligent movement.

## 2. LITERATURE REVIEW

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Traditional luggage handling relies on manual transportation using trolleys, conveyor belts, and baggage carts, which often require human intervention. In large-scale systems like airports, automated baggage handling systems are used, consisting of conveyor belts, barcode/RFID scanners, and sorting mechanisms to streamline luggage movement from check-in to boarding areas.The basic concept of the arrangement of the ultrasonic sensor where the human legs are being sensed within the area of interception. There are two situations in the sensors placement, the first is when there is an intercept signal between sensor 1 and sensor 2, the systems inform the robot that it senses the human's left leg, while when there is an intercept signal between sensor 2 and sensor 3, the system is sensing the right leg [5][6].

When we speak about humans following robots, the cardinal issue that needs to be taken care of is the direction finding of the robot. The direction-finding should be such that the robot follows the designated subject only, and it should not deviate from its path. Technological advancements have engendered many methods that aim to tackle this issue with maximum possible accuracy. The human following the shopping cart has a similar aim. The robot only detects the target due to the tag that is placed on the person who needs to be pursued [1].

However, these solutions remain expensive and are not widely accessible. The growing interest in autonomous luggage carrier robots aims to bridge the gap between traditional manual handling and costly automated systems by offering an affordable, portable, and user-friendly alternative. Now in this changing world, people have started to live with robot-like humans following robots for their luxurious lives. This project is called a human-following robot because it can follow humans with the help of IR sensors and can co-exist with humans and help humans in any kind of work with more accuracy and in less time[7].

In hospitals, robots with IoT can assist in surgeries, help patients, and monitor health conditions in real time. In smart homes, IoT-powered robots, like vacuum cleaners, security bots, and voice assistants, make daily tasks easier. In farming, IoT robots can water crops, harvest food, and protect plants from pests, reducing the need for human labor. As technology improves, IoT will continue to make robots more helpful in many areas of life, making work easier, faster, and more efficient. The robot, however, is unable to track and find an object on its own. Therefore, the robot needs a mechanism that can make decisions so that it can act appropriately and complete the task [4].

## 3. SYSTEM ARCHITECTURE AND DESIGN

The autonomous luggage carrier robot is built using several key hardware components that work together to ensure smooth and efficient operation. At the core of the system is the Arduino microcontroller, which acts as the brain of the robot, processing sensor inputs and sending signals to various components to control movement and navigation. For obstacle detection and avoidance, the system is equipped with ultrasonic sensors, which continuously scan the surroundings and help the robot navigate safely without colliding with objects. The movement mechanism consists of motor drivers and wheels, which allow the robot to move smoothly in different environments, ensuring stability even while carrying luggage.

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To power the system, the robot uses a rechargeable battery with an efficient power management system, ensuring that all components receive a stable power supply for extended operation. This setup allows the robot to function autonomously without frequent recharging. Additionally, a wireless communication module such as Wi-Fi enables remote control and monitoring, allowing users to interact with the robot through a smartphone or other smart devices. Some advanced models may also include GPS modules for location tracking, further improving the robot's usability.

### 3.1 Components of the Robot

**(i)Arduino Uno-** The ATmega328P microcontroller is the heart of the Arduino Uno and comes with 32KB of flash memory, 2KB of SRAM, and a 16MHz clock speed. It's well-suited for controlling real-time systems, reading sensor data, and executing programmed logic. Arduino Uno is shown in Figure 1.

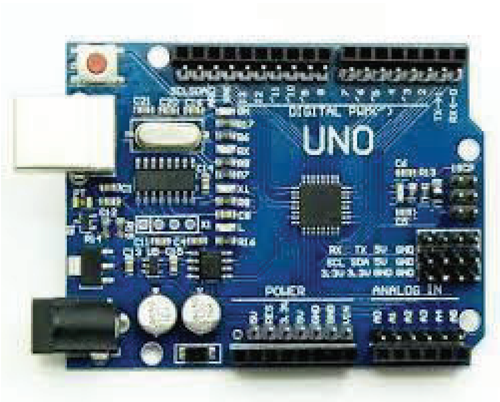


**Figure 1. Arduino Uno**

**(ii)Ultrasonic sensor-** An ultrasonic sensor is an electronic device that measures distance by emitting ultrasonic sound waves and detecting their echo when they bounce back from an object. It typically consists of a transmitter and a receiver, working together to calculate the time taken for the sound to return. An ultrasonic sensor is shown in Figure 2.

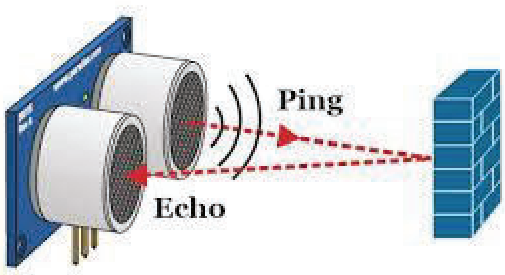


**Figure 2. Ultrasonic sensor**

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**(iii)L293D Motor Shield-** It can drive up to 4 DC motors **or** 2 stepper motors simultaneously, with individual speed and direction control using PWM signals. This shield connects directly to the Arduino Uno and simplifies motor wiring, handling the high current needed to power the motors. The L293D Motor Shield is shown in Figure 3.

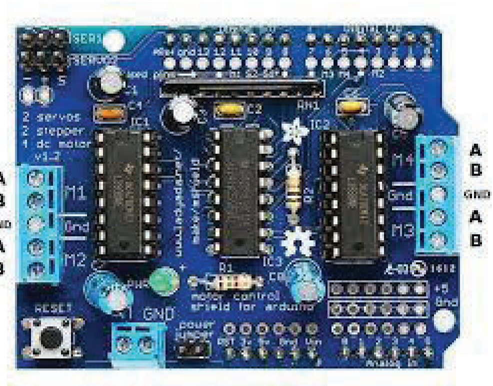


**Figure 3. L293D Motor Shield**

(**iv) WiFi Module -** ESP-01 is a compact and cost-effective WiFi module based on the ESP8266 chip, widely used in IoT projects due to its wireless communication capabilities. Despite its small size, it provides robust connectivity and supports standard TCP/IP protocols, making it suitable for connecting microcontrollers like the Arduino Uno to the internet. The ESP-01 is shown in Figure 4.

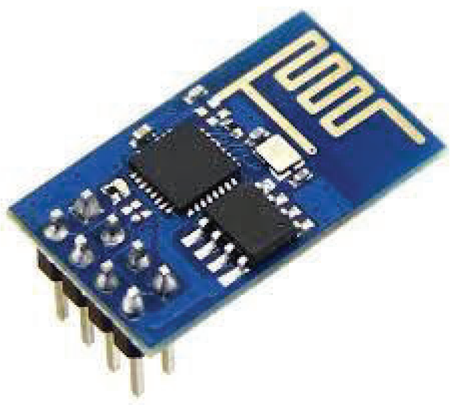

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**Figure 4. ESP-01**

**(v) Battery-operated gear motors-** Battery-operated gear motors are very useful for an IoT-based Luggage Robot because they provide the necessary power and torque to move the robot smoothly and efficiently. These motors are equipped with internal gears that reduce speed and increase torque, making them ideal for carrying loads like a luggage bag. The Battery-operated gear motors is shown in Figure 5.

**Figure 5. Battery-operated gear motors**

(vi) **IR sensor -**An infrared (IR) sensor is an electronic device that detects infrared radiation emitted or reflected by objects. It typically consists of an infrared LED (which emits infrared light) and a photodiode or phototransistor (which receives the reflected infrared light). When an object is present in front of the sensor, the emitted IR light is reflected back and detected by the receiver, generating a change in output. This output can be either digital or analog depending on the sensor design, and it is commonly used for proximity detection. The IR sensor is shown in Figure 6.

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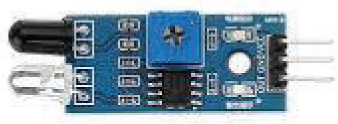

**Figure 6. IR sensor**

## 4. THEORETICAL BACKGROUND

The IoT-based luggage robot will undergo rigorous testing in controlled real-world environments**,** including airports, hotels, and train stations, to evaluate its adaptability under different conditions. These locations were chosen to simulate common travel scenarios, such as navigating crowded spaces, avoiding dynamic obstacles, and handling varying floor surfaces (e.g., carpets, tiles, and ramps). The robot will rely on ultrasonic sensors for obstacle detection and balance, while Wi-Fi/Bluetooth-enabled microcontrollers will facilitate IoT connectivity for real-time tracking.

### A. Obstacle Detection Efficiency

The basic concept of the arrangement of the ultrasonic sensor is where the human legs are being sensed within the area of interception. There are two situations in the sensor placement, the first is when there is an intercept signal between sensor 1 and sensor 2, the systems inform the robot that it senses the human's left leg, while when there is an intercept signal between sensor 2 and sensor 3, the system is sensing the right leg.[5][8]

### B. Response Time and Navigation Accuracy

The microcontroller part software takes all data from all sensors and saves it to the correct path. According to the data input, the microcontroller parts give the necessary input for the motor control section to guide and run the motor for working. Since we are using an Arduino microcontroller, we have to use Arduino IDE software to write and upload a program in the microcontroller [7].

The system design consists of a separate processing and control unit. The processing unit only makes use of a sensor and is linked to the control unit. The control unit is serially linked with the processor, and it makes use of several sensors and modules, i.e., an ultrasonic sensor and infrared

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sensors. The above sensors work in unison with each other and help the robot in its operation and to navigate its path by avoiding the obstacles and maintaining a specific distance from the object. The decision is made based on information obtained from all the above sensors[9].

### C. Power Consumption and Battery Life

Battery efficiency is critical for prolonged operation. Tests will measure power drain (mAh/hr) in idle mode and active mode (moving with luggage). By implementing low-power sleep modes and PWM-based motor control, the robot should achieve 6–8 hours of continuous operation on a 10,000mAh Li-ion battery. Recharge time will be optimized to under 3 hours to ensure practicality for travelers. Data logging will track energy usage patterns, helping identify further optimization opportunities. Hence robot must be powered by some type of power source. Battery, solar power, and electrical line power may be used to power the robot for its functioning.[10] [9].

## 4. MODEL DEVELOPMENT & IMPLEMENTATION

The structure of a human following robot is quite different from the other Arduino car because we have to include some more sensors (like an ultrasonic sensor, an IR sensor) in our car. Also, the placement of the sensors is quite different from the other Arduino project, so we have to pay more attention while building a human-like robot. The first important thing is to fix the DC geared motor to the chassis of the car. Take the four DC geared motors and then fix them on the bottom side of the chassis. The development of the autonomous luggage carrier robot follows a structured methodology, focusing on robot navigation, IoT-enabled features, and prototype development to ensure efficient and reliable operation. The robot navigation mechanism is designed using ultrasonic sensor-based distance measurement, which continuously scans the environment to detect nearby objects. These sensors help the robot measure distances accurately and avoid collisions through an autonomous obstacle detection and avoidance system. There are four DC motors used in the development of the mechanical assembly of this rover, each of which operates individually. Motors are the final control elements that control the position and direction of movement of the robot. Arduino board sends the PWM signals to the L298N bridge module, which finally empowers the signal so that it can drive the motors.

By processing real-time data from the sensors, the robot adjusts its path dynamically to navigate safely around obstacles. Additionally, a path-following algorithm is implemented to ensure the robot can track and follow the user while maintaining a safe and stable movement pattern. To enhance user convenience, the system integrates several IoT-enabled features. The robot is equipped with GPS-based location tracking, allowing users to monitor its position in real-time. Through a mobile application, users can remotely control the robot, access location data, and receive important system updates. The system also provides smart notifications and alerts, such

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as low battery warnings, status updates, and movement alerts, ensuring that users always stay informed about the robot's operation. The workflow diagram of the developed system is shown in Figure 7.

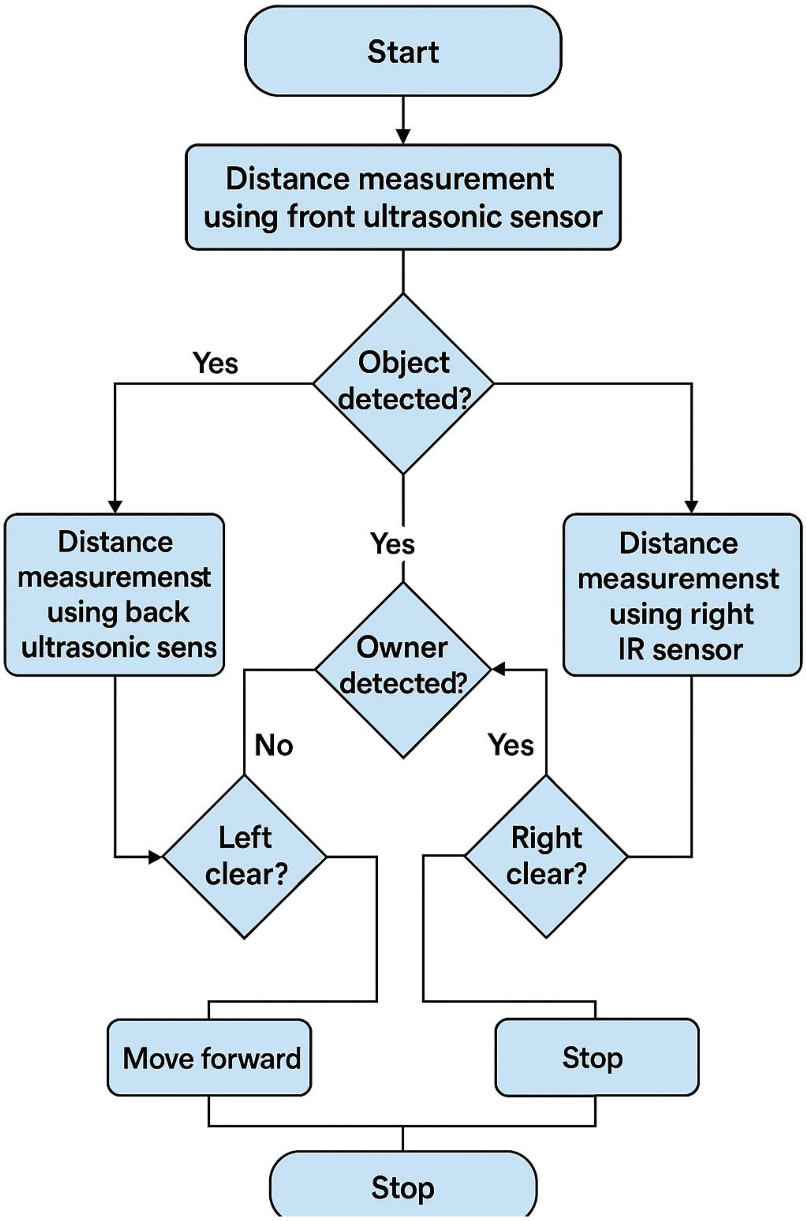


**Figure 7. The Workflow of the Developed System**

Step 1: Once the system is active, the robot starts by measuring the distance ahead using the front ultrasonic sensor. This sensor constantly checks for obstacles in the robot's path. If an obstacle is detected within a specific range, such as less than 30 cm, the robot needs to determine whether this obstacle is the luggage owner or something else.

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Step 2: To identify the owner, the robot uses the back ultrasonic sensor. This sensor measures the distance between the robot and the person behind it. If it detects the owner within a predefined following distance, it confirms the presence of the person the robot is meant to follow.

Step 3: If the owner is detected, the robot then checks if the path is clear on the right side using the right IR sensor. If this side is free of obstacles, the robot is allowed to move forward or steer slightly to the right to maintain its path. If the right side is not clear, the robot stops to avoid a collision.

Step 4: If the back ultrasonic sensor does not detect the owner, the robot checks the left side using the left IR sensor. If the left side is clear, the robot may try to adjust its path to the left. If the left is also blocked, the robot stops entirely, assuming it cannot safely navigate forward or sideways, and that it has lost track of its target.

The Circuit diagram of the developed system is shown in Figure 8.

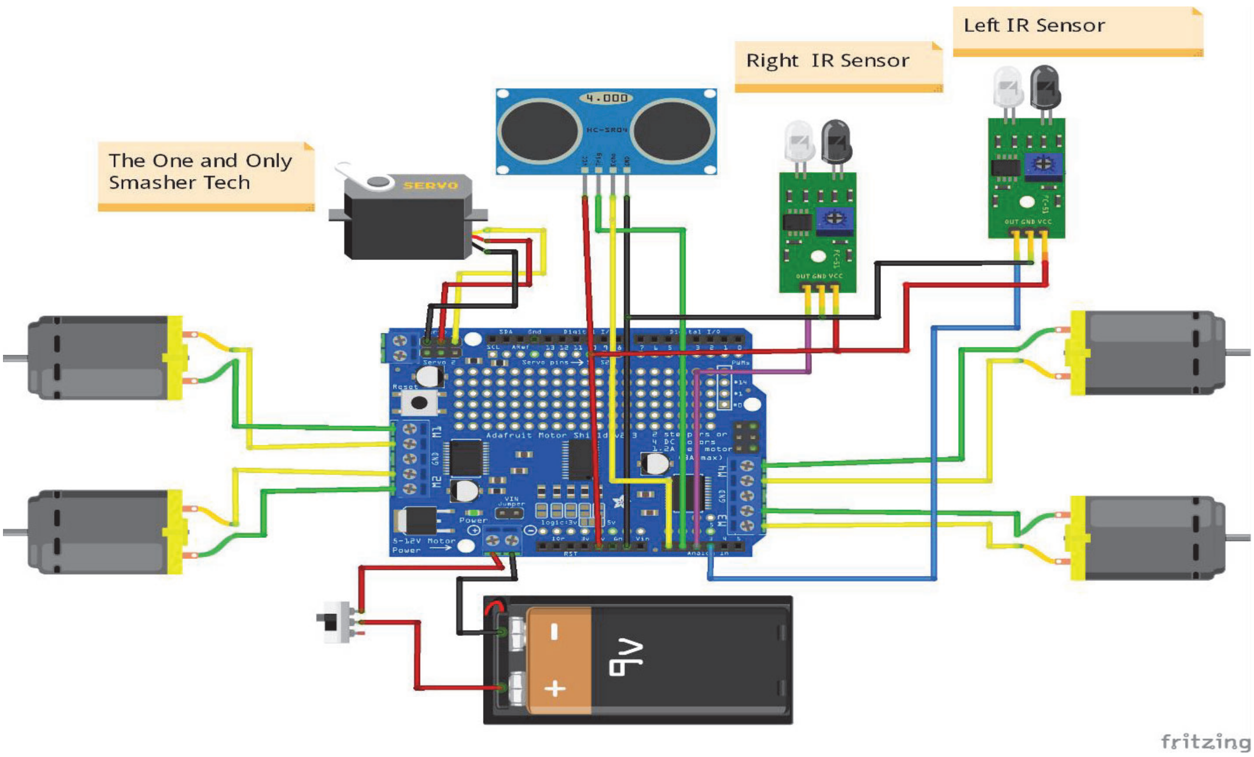


**Figure 8. The Circuit Diagram of the Developed Model**

The detailed information of the circuit diagram is mentioned below.

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a. When you come near to the robot starts to follow you. there are 4 wheels in the robot. and 4 motors attached to the chassis. now there are three sensors on the robot, one is an ultrasonic sensor and two IR sensors, which are arranged like two sensors left and right to the ultrasonic sensor. and when you put your hand near the ultrasonic sensor, the robot will start moving forward.
b. If you turn your hand to the left side, the Arduino robot moves on the left side, and if you put your hand to the right, the robot will move in the right direction. so, how the whole system works, we will talk about this.
c. c. When you put your hand in front of the ultrasonic sensor, the sensor detects you and sends this information to the Arduino. The Arduino has a distance prefix, so if your hand is away from the sensor, it will not read that, and if your hand is near the sensor, it will read it.
d. Now that Arduino knows that something is in front of the sensor, Arduino sends some instructions to the motor driver, and the motor driver triggers the motors. When the Arduino robot starts to move forward, we need to run all the motors forward.
e. Now, what about the sensors? An infrared sensor works on infrared light which can also detect objects near to it. so there is two IR sensor one is at the left side of ultrasonic sensor, and other is at the right side of the ultrasonic sensor. when anything comes near to the left sensor Arduino got the information that there is something is near to the left sensors and according to the code, the robot will turn to the left. and the same process for the right sensor. so this is how the human following robot works.

## 6. CHALLENGES AND LIMITATIONS

One of the primary challenges for IoT-based human luggage robots is sensor accuracy in dynamic environments. These robots rely on cameras, LiDAR, and ultrasonic sensors to navigate crowded spaces such as airports, hotels, or train stations. However, sudden movements, changing conditions, and unexpected obstacles (such as people or vehicles) can lead to misidentification or delayed responses, increasing the risk of collisions [5] . The biggest challenge with luggage-carrying robots is low battery life and power management. Since these robots need to operate for long periods, their batteries face three main challenges including rapid power consumption from heavy loads, energy consumption from constant Wi-Fi connections, and additional power usage from real-time data processing (cameras, sensors, etc.).These cause the battery to drain quickly[11].

Fast charging or extra batteries can help, but frequent charging is still inconvenient. If the robot operates in very hot or cold weather, the battery performance decreases even more. A good cooling/heating system is therefore essential. Another limitation for luggage robots is connectivity issues in large or crowded spaces, as it relies on stable Wi-Fi connections for cloud processing, remote control, and real-time information. In areas with large terminals or poor network coverage, latency or signal drops can cause functionality and delays in performing any

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tasks. Dead network zones can force the robot to go into limited offline mode, reducing its smart features; this can be mitigated by implementing edge computing or mesh networking, but this increases complexity and cost. Weight capacity is another limitation, which restricts the robot's functionality, while it must carry luggage efficiently, adding heavy batteries, motors, and structural components reduces the available payload capacity. Exceeding the weight limit impairs mobility, increases energy consumption, and may violate transport regulations.

## 7. FUTURE ENHANCEMENTS

In the future, IoT-based luggage robots can be significantly improved through AI-powered object recognition; integrating a combination of computer vision, LiDAR, and edge AI processing would be optimal for smart and safe navigation. Additionally, Intel RealSense depth sensors or thermal cameras can improve obstacle detection in poor lighting conditions, while ultrasonic sensors serve as a fail-safe to avoid close ranges. There are many interesting applications of this research in different fields, whether military or medical. A wireless communication functionality can be added to the robot to make it more versatile and control it from a long distance. This capability of a robot could also be used for military purposes. By mounting a real-time video recorder on top of the camera, we can monitor the surroundings by just sitting in our room[11].

Combining this with LiDAR and SLAM algorithms ensures accurate navigation in complex environments such as airports, enabling the robot to create dynamic maps and avoid collisions. For user interaction, offline voice recognition (Picovoice) and gesture control (Edge Impulse) allow operators to operate the robot hands-free. By using these technologies together, a robust AI recognition system can be created that ensures smooth, autonomous operation in real-world travel scenarios. Another major upgrade could be a solar-powered or energy-efficient design, allowing the robot to recharge itself using a built-in solar panel or regenerative braking (for wheeled models). This will increase battery life, especially in outdoor environments, reduce reliance on frequent charging, and improve the robot's performance. Additionally, enhanced security features such as RFID scanning or fingerprint authentication will prevent theft and ensure only authorized users can access luggage[12].

These upgrades will make luggage robots more autonomous, efficient, and safe, making them essential travel companions. We can also add some modifications to the algorithm and the structure as well to fit it for any other purpose. Similarly, it can assist the public in shopping malls. So there it can act as a luggage carrier, hence no need to carry the weights or to pull that. Similarly, an ample amount of modifications could be done to this prototype for far and wide applications[11][13].

## 8. CONCLUSION

The IoT-based luggage robot represents a transformational advancement in smart travel and logistics, combining cutting-edge technologies to address real-world challenges. By integrating AI-powered navigation with computer vision and LiDAR-SLAM, energy-efficient edge computing, and intuitive voice/gesture control, this solution demonstrates practical autonomy in dynamic environments such as airports, stations, hotels, etc. Key innovations include reliable obstacle avoidance, extended battery life through optimized power systems, and secure user authentication – all achieved while maintaining offline functionality for consistent performance. Beyond personal luggage transport, this technology has promising applications in hotel concierge services, airport assistance for passengers with reduced mobility, and urban last-mile delivery systems. In the future, we can make these smart luggage robots even better. They can work together like a team (swarm robotics) to handle multiple bags efficiently. We can also connect them to smart city systems, allowing them to navigate public spaces more intelligently. With emotional AI, robots can understand and respond to users' emotions, making interactions more natural. These improvements will bring our luggage robot to the forefront of smart transportation services, changing the way we travel and carry luggage in cities. This project not only solves immediate travel inconveniences but also establishes a foundation for more sophisticated autonomous systems in urban environments, an important step toward a seamless, intelligent transportation ecosystem.

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