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Development of an Intelligent Human Following Robot as an Automated Shopping Assistant

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Abstract: The human following robot technology presented in this research offers an innovative solution for modern shopping needs. Designed to automatically follow human movement within a distance of 1–15 cm, the robot stops when the distance exceeds this range, ensuring safe operation. As shopping activities in the modern era increasingly demand efficiency and convenience, this robot has strong potential to function as an environmentally friendly personal assistant, helping users carry groceries in supermarkets and malls without relying on plastic bags. The system is built using an Arduino Uno as the central controller, supported by a motor driver, DC motors, wheels, a servo motor, an ultrasonic sensor, and infrared sensors. The ultrasonic sensor measures human distance, while infrared sensors detect the position of objects on the right and left sides. Sensor data is processed to adjust motor direction and speed, enabling the robot to follow users safely. The development of this robot is expected to enhance shopping experiences and support broader applications of robotics in daily life.

Keywords: Arduino Uno, Automation, Human Following, Infrared Sensor, Robot, Robotics, Shopping Assistant, Ultrasonic Sensor.

1. Introduction

In recent years, the rapid advancement of robotics and automation has significantly reshaped various sectors, ranging from industrial manufacturing to personal assistance and service applications. This progress is driven by the increasing need for intelligent systems capable of interacting with dynamic environments while supporting human activities with greater efficiency and precision. The emergence of service robots, particularly human following robots, represents a transformative development in this domain, as these systems bridge the gap between human-centered design and autonomous robotic capabilities [1].

The human following robot exemplifies a new generation of assistive technologies that integrate multi-sensor perception, real-time tracking, and adaptive navigation to support users in everyday tasks. As society transitions into an era where automation becomes deeply embedded in daily routines, the demand for robots that can understand, interpret, and follow human movement patterns continues to rise. This is especially relevant in environments that require mobility assistance, such as supermarkets, malls, airports, hospitals, and warehousing facilities. By enabling robots to operate alongside humans safely and intuitively, researchers can enhance human robot interaction (HRI) and increase the practicality of robotic integration in public spaces [2].

From a technological perspective, the development of human following robots has been facilitated by advancements in microcontroller performance, low-cost sensing devices, and improvements in embedded system design. The use of ultrasonic sensors for distance measurement, coupled with infrared sensors for lateral object detection, allows the robot to track human position with reasonable accuracy even in cluttered environments. Additionally, the incorporation of servo motors enables dynamic sensor orientation, further enhancing the robot's situational awareness. These features, combined with efficient motor driver systems and lightweight chassis construction,

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contribute to the creation of a functional prototype capable of real-world implementation [1].

In the context of modern retail environments, the increasing volume of customers and the growing emphasis on convenience-driven shopping experiences highlight the need for technological innovations that enhance mobility and reduce physical strain. Human following robots can serve as personal shopping assistants that autonomously carry purchased items, navigate store aisles, and maintain an optimal distance from the user. This approach not only improves shopping efficiency but also encourages environmentally friendly behavior by minimizing the use of single-use bags and promoting sustainable retail practices [3].

Beyond retail applications, the broader implications of human following robots extend to other domains such as healthcare where robots can assist nurses or transport medical supplies and military operations, where robots can support personnel by carrying equipment or following designated operators in field missions. These diverse applications underscore the versatility and future potential of human-following technology.

Therefore, the development of a human following robot is not merely a technical endeavor but also a step toward addressing emerging societal needs in mobility assistance, automation, and intelligent service systems. By integrating sensor technology, embedded control, and autonomous decision-making, this research aims to contribute to the advancement of service robotics while providing a scalable, future-oriented solution for improving user convenience, reducing workload, and enhancing overall interaction between humans and robotic platforms [4].

2. Literature Review

2.1 Basic Concept of Human Following Robot

A human following robot is an autonomous machine capable of following a human and providing assistance. This robot follows a person within a specific distance range using various sensors and programmed control logic. In this project, the authors and their team utilize three sensors as the primary input devices, namely two infrared sensors and one HC-SR04 ultrasonic sensor.

The ultrasonic sensor functions to measure the distance between an object and the sensor [5]. As long as the detected object remains within a distance range of 1–15 cm, the robot moves forward. In addition, the two infrared (IR) sensors are used to detect the presence of a human, which is indicated by the reflection of infrared light emitted toward the human body. When the infrared light is reflected back to the sensor, it signifies that an object is present near the sensor. This signal is then processed, resulting in the activation of the motor driver and the display of status information on the serial monitor [6].

The two infrared sensors are positioned on the right and left sides of the ultrasonic sensor. When the right infrared sensor detects reflected light, it sends an electrical signal to the motor driver, and according to the programmed logic, the left DC motor moves forward while the right DC motor moves backward. Conversely, when the left infrared sensor detects reflected light, the right DC motor moves forward and the left DC motor moves backward. The right DC motor is connected to pin M3, while the left DC motor is connected to pin M1 of the motor driver.

Below the three sensors, a servo motor is installed to control the orientation of the sensor assembly. The three integrated sensors are mounted on a supporting structure, which is mechanically connected to the servo motor, allowing dynamic adjustment of the sensor direction [7].

2.2 Human Following Robot Mechanisms

The functional workflow of this robot is based on real-time data processing to ensure precise navigation and responsive movement. The core mechanism is described as follows:

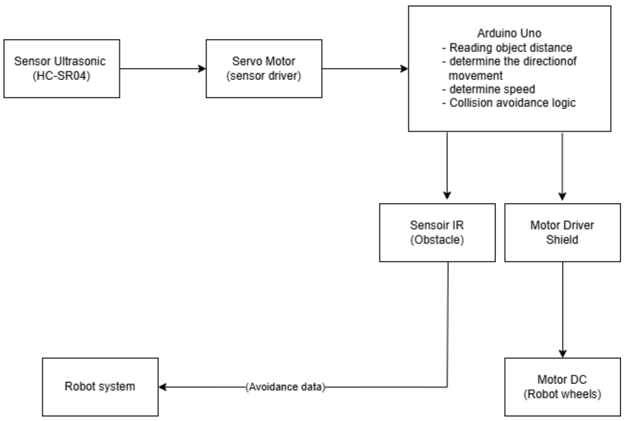

Figure 1. System Block Diagram

The human following robot system operates by initially measuring the distance between the robot and the target using an ultrasonic sensor (HC-SR04),

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which enables the determination of appropriate movement direction and velocity. The ultrasonic sensor is mounted on a servo motor that continuously rotates to scan the surrounding area, allowing real-time environmental monitoring. The data obtained from this scanning process are transmitted to the Arduino Uno, which functions as the central processing unit. The Arduino processes inputs from both the ultrasonic and infrared (IR) sensors to assess object distance, detect obstacles on the right and left sides, and execute movement decisions, including direction control, speed adjustment, and collision avoidance logic. Based on these processed decisions, the motor driver shield controls the DC motors responsible for driving the robot's wheels. The resulting wheel movements serve as the system's response in maintaining a safe following distance and avoiding obstacles. Overall, the integration of ultrasonic sensors, infrared sensors, a servo motor, and a motor driver enables the robot to operate safely and responsively. Despite its functional advantages, the system presents certain limitations, such as the ultrasonic sensor's reduced accuracy when detecting transparent or sound-absorptive surfaces and the infrared sensor's susceptibility to interference in highly illuminated environments [2].

2.3 Flowchart

The system flowchart outlines the core workflow of the human following robot, beginning with initialization and continuing to real-time decisions based on sensor input

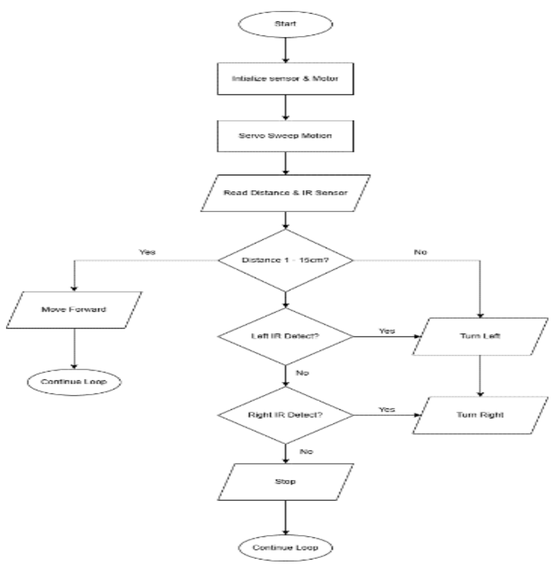

Figure 2. Flowchart

The flowchart represents the decision-making process of a human-following robot that uses ultrasonic and infrared sensors to control its movement. The system begins with initialization of the servo, motors, and IR sensors, followed by reading distance data from the ultrasonic sensor and obstacle information from the IR sensors. If the detected distance falls between 1–15 cm, the robot moves forward to follow the user. If the distance is outside this range, the system evaluates the IR sensors: when the left sensor detects an obstacle, the robot turns left, and when the right sensor detects an obstacle, it turns right to maintain alignment. If neither sensor detects a valid path and the distance is greater than 15 cm, the robot stops. After executing the required movement, the system returns to the main loop, continuously repeating the sensing and decision-making cycle to ensure real-time responsiveness and stable human-following behavior.

3. Related Work

Previous studies on human-following robots primarily focus on improving sensor accuracy, navigation, and human tracking. Most works utilize ultrasonic sensors, infrared sensors, and microcontrollers as the core components, forming the foundation for the system developed in this research.

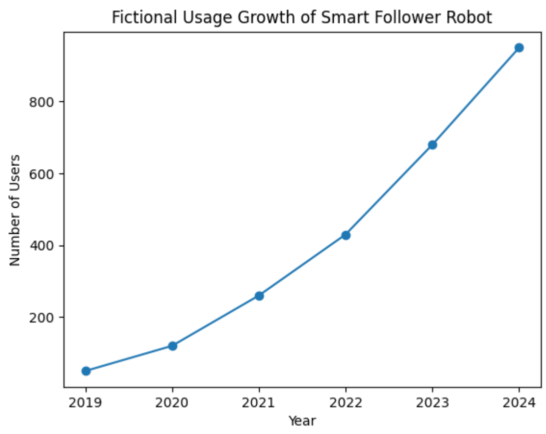

Figure 3. Graph of Increasing Use of Robots

The use of smart follower robots has increased steadily over the years along with technological advancements. Initially, these robots were mainly used for research and educational purposes. As sensor accuracy, control systems, and motor performance improved, they began to be applied in

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practical tasks such as assisting with carrying items and supporting service environments. In recent years, smart follower robots have been more widely adopted due to their reliability, efficiency, and the growing demand for automation.

3.1 Human Following Robot and Navigation

In the human-following robot system, every component works together to support smooth and autonomous operation. Each part has a specific function that enables the robot to follow a target and respond to its surroundings effectively.

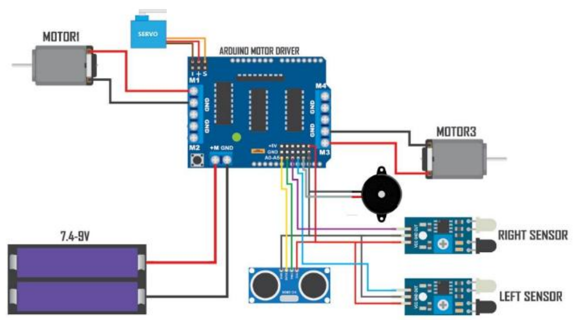

Figure 4. System Design

Arduino Uno functions as the main controller (the brain) of the robot, managing all components and making decisions based on sensor data. The motor driver shield is used to control the direction and speed of the TT gear motors that drive the robot's wheels, allowing the robot to move according to commands from the Arduino Uno. The TT gear motors and wheels enable the robot to move in the specified direction, while the servo motor is used to rotate the ultrasonic sensor so that it can detect objects or humans from different directions. The ultrasonic sensor measures the distance between the robot and the target being followed, whereas the infrared sensors are used to detect lines or obstacles around the robot. All sensor data are processed by the Arduino Uno to ensure the robot can automatically follow the target while avoiding collisions [8].

Table 1. System Description Robot

No	Caption
1	Arduino Uno
2	Adafruit Motor Shield L239D
3	Infrared Sensor
4	Ultrasonic HCSR04 Sensor
5	Servo Motor
6	Two DC Geared Motors
7	Two Wheels
8	Robot Chasis
9	Jumper Wires

3.2 Seamless Shopping

The robot automatically follows the shopping direction of the human by adjusting its speed and direction to maintain an optimal distance. This ensures a smooth and more efficient shopping experience, allowing customers to focus on selecting items while the robot follows them from behind without requiring any manual effort [2].

Figure 5. Hardware Placement

The human following robot based on Arduino Uno works like an intelligent system that can safely and efficiently follow a person. At the heart of the robot is the Arduino Uno, which serves as the robot's "brain". The Arduino receives information from various sensors and processes it according to the uploaded program. All decisions moving forward, backward, turning, or stopping come from this central controller.

To drive the wheels, the robot uses TT Gear Motors. However, these motors are not directly controlled by the Arduino they are managed through a motor driver shield. The motor driver acts as a bridge, controlling the rotation direction and speed of the wheels so the robot can move according to the Arduino's commands. With this combination, the robot can smoothly follow a person.

To allow the robot to "see" objects or people around it, it uses an ultrasonic sensor. This sensor acts like the robot's eyes, measuring the distance between the robot and its target. To increase its field of view,

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the ultrasonic sensor is mounted on a servo motor, which can tilt the sensor in various directions. This enables the robot to detect objects both in front and to the sides.

Additionally, the robot is equipped with infrared sensors, which detect lines or obstacles. These sensors help the robot avoid collisions and stay on the correct path. Information from the infrared sensors is also sent to the Arduino, allowing the robot to make real-time decisions [9].

With this combination of components Arduino Uno as the brain, motors and motor driver for movement, servo motor to direct the sensor, and ultrasonic and infrared sensors to "see" and detect the environment the robot can intelligently and responsively follow a person while avoiding obstacles along its path.

3.3 Advanced Navigation and Object Detection

Using advanced technologies such as ultrasonic sensors, infrared sensors, and computer vision, the cart is capable of detecting and avoiding obstacles, navigating through crowded aisles, and dynamically adjusting its path based on the shopper's movements. It can maintain a safe distance from both people and objects while ensuring smooth and responsive motion, even in complex or busy retail environments.

By continuously analyzing its surroundings and the shopper's behavior, the cart provides a seamless, convenient, and efficient shopping experience, reducing the effort required by the user and enhancing overall safety and comfort during shopping [2].

Figure 6. Illustration of a Robot Using AI

The image illustrates the working principle of a human following robot, a system designed to autonomously track and follow a person using a combination of sensors, actuators, and an embedded controller. At the core of the system is the Arduino Uno, which functions as the main processing unit responsible for interpreting sensor data and executing control algorithms. The program embedded in the Arduino enables the robot to make decisions in real time, allowing it to react dynamically to changes in the user's movement and to the surrounding environment.

To achieve mobility, the robot uses two TT gear motors connected to a pair of wheels, with their motion controlled through a motor driver shield. This shield regulates motor speed and direction based on commands issued by the Arduino. As seen in the image, the motor driver enables the robot to move forward, turn, or stop depending on the distance and position of the person in front of it. This ensures that the robot can maintain a consistent tracking behavior while ensuring smooth and stable motion.

A key feature of the system is the servo motor that supports the ultrasonic sensor. The servo motor rotates the sensor to scan the environment, allowing the robot to detect the position of the user as well as identify potential obstacles. In the image, the ultrasonic sensor emits waves toward the person, enabling the robot to measure distance accurately. This continuous scanning allows the robot to maintain optimal spacing, ensuring that it follows the user without lagging behind or approaching too closely.

The robot is also equipped with infrared (IR) sensors placed at strategic points to enhance obstacle detection. These sensors detect objects or boundaries around the robot, serving as an additional safety mechanism that prevents collisions. The combination of ultrasonic and IR sensing allows the robot to differentiate between a moving target (the human) and stationary obstacles, improving its overall navigation performance.

Overall, the image visualization aligns with the robot's operational workflow: the ultrasonic sensor identifies the user's distance and direction, the servo motor adjusts its orientation for continuous monitoring, the IR sensors detect nearby obstacles, and the motor driver actuates the wheels based on processed data in the Arduino Uno. This integrated system enables the human following robot to

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effectively track a person while maintaining safety, stability, and situational awareness [10].

4. Result and Discussion

Human following robots, also known as human follower robots, are designed to automatically follow a human or a specific object. The general working principle of a human following robot can be explained through the following steps using the components that have been mentioned, namely Arduino Uno, motor driver shield, wheels, TT gear motors, servo motor, ultrasonic sensor, and infrared sensors.

a. Arduino Uno

Arduino Uno functions as the brain of the robot, controlling all other components. The program uploaded to the Arduino Uno allows the robot to execute specific commands and make decisions based on sensor input [11].

b. Motor driver shield

The motor driver shield is used to control the TT gear motors that drive the robot’s wheels. The motor driver shield is responsible for controlling the direction and speed of the motors so the robot can move according to the commands given by the Arduino Uno.

c. TT gear motor and wheels

The TT gear motors drive the robot’s wheels. The motor driver shield controls the rotation and direction of the wheels to ensure the robot can move as desired and in the specified direction [8].

d. Servo motor

The servo motor is used to move the ultrasonic sensor. By tilting this sensor in various directions, the robot can detect objects or humans around it. The position of the servo motor is controlled by the Arduino Uno.

e. Ultrasonic sensor

The ultrasonic sensor is used to detect the distance between the robot and the objects or humans around it. With this information, the robot can adjust its speed and direction to keep following the object it is meant to follow.

f. Infrared sensor

Infrared sensors are used to detect lines or obstacles around the robot. This helps the robot avoid collisions or maintain its movement path. The information from these sensors is also used in the decision-making process by the Arduino Uno.

4.1 General Working Process

a. The robot starts by measuring distance using the ultrasonic sensor and decides its direction and speed based on the position of the object being followed.
b. The infrared sensors and ultrasonic sensor help in avoiding collisions.
c. The motor driver shield drives the wheels according to the decisions made by the Arduino Uno.
d. The servo motor moves the ultrasonic sensor so it can continuously monitor its surroundings.

The design of this shopping robot is highly flexible for future integration with various advanced technologies (Fig. 6, Fig. 7, Fig. 8, Fig. 9), including improved human tracking, enhanced interaction, and autonomous routing in specific store areas. This adaptability enables the system to incorporate new innovations without major structural changes, with potential upgrades such as advanced sensor fusion, faster real-time processing, and connectivity to smart retail infrastructure.

Figure 7. Physical form of the robot

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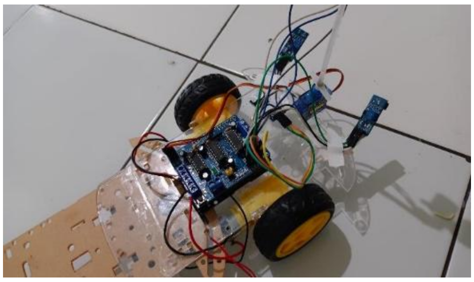

Figure 8. Physical form of the robot from above

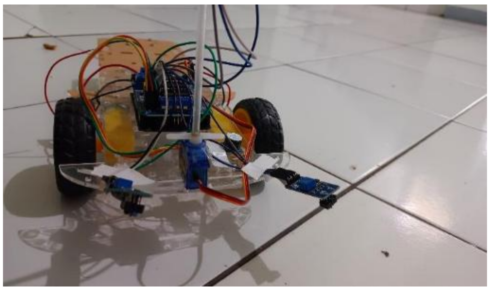

Figure 9. physical form of the robot seen from the front

4.2 Testing Process

The testing process begins with a hardware setup test, which involves powering on the system and inspecting all connections, including the Arduino, sensors, motors, and infrared modules. At this stage, each sensor's functionality is verified to ensure accurate distance measurements and proper response behavior. Once the hardware is confirmed to operate correctly, the procedure continues with the human following test. In this phase, a person moves in front of the robot to evaluate its ability to adjust its speed according to human movement. Additionally, obstacle detection and avoidance tests are conducted to assess the robot's capability to respond effectively to real-world environmental conditions.

The next phase involves the cart stop test, which ensures that the robot is able to stop following once the shopping process is completed and is able to remain idle while awaiting further instructions. Testing then proceeds with the power and battery test, which includes evaluating the system's operating duration and its ability to recover from power interruptions or losses. The final stage is the end-to-end test, which simulates the complete shopping workflow—from following the user, performing scanning tasks, to navigating based on given commands. This comprehensive evaluation aims to assess the system's overall performance under normal operating conditions. At the end of the process, the robot is disengaged from follow mode after all shopping activities have concluded and, optionally, can send a signal indicating that the robot has finished being used [2].

Table 2. Tool Accuracy Testing

Distance	Surrounding Conditions	Caption
1-3 cm	An obstacle is detected	detects
1-6 cm	An obstacle is detected	detects
1-9 cm	An obstacle is detected	detects
1-12 cm	An obstacle is detected	detects
1-15 cm	An obstacle is detected	detects
1-18 cm	no obstacle is detected	does not detect
1-21 cm	no obstacle is detected	does not detect

Table 3. System Condition

Condition	Distance/Sensor	Robot actions
Following human	1-15cm	Proceed
Human are far away	>15cm	Stop
Right IR is active	Right = 0, Left =1	Turn left
Left IR active	Right=1, Left= 0	Turn right

Overall, the working principle of the human following robot shows how each component is interconnected and works together to achieve its main goal: automatically and safely following a human or a specific object. Through the combination of sensors, actuators, and data processing by the microcontroller, the robot can make the right decisions in various situations. By understanding this workflow, we can see how the system is able to operate efficiently and can be further developed in the future for various needs and more complex applications [12].

5. Conclusion

The human following robot developed in this study demonstrates how robotics technology can be effectively integrated with sensor-based automation to support practical human needs, particularly in

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modern shopping environments. By utilizing Arduino Uno as the central controller, along with ultrasonic and infrared sensors for distance measurement and object detection, the robot is able to follow a human within a defined range while maintaining stable and safe movement. The motor driver, DC motors, and servo motor work cohesively to execute precise navigation based on real-time sensor data.

Testing results confirm that the robot can reliably detect obstacles within a distance of 1–15 cm, adjust its movement according to human position, avoid collisions, and stop automatically when the human moves beyond the detectable range. End-to-end evaluations also show that the robot can successfully simulate a complete shopping process, demonstrating responsiveness and consistent system performance under normal conditions.

Overall, this human following robot presents a promising solution for enhancing convenience and efficiency in shopping activities by serving as a hands-free shopping assistant. Furthermore, the system offers strong potential for future development, including integration with advanced navigation, improved human tracking, and broader applications in fields such as healthcare, logistics, and military operations. Continued innovation in this area is expected to contribute significantly to improving everyday life through smart, autonomous robotic assistance.

Conflics of Interest

The authors declare that there is no conflict of interest regarding the publication of this article. All research activities, analyses, and findings presented in this study were conducted independently and are not influenced by any personal, financial, or institutional interests.

Author Contributions

The first author formulated the research concept and developed the main ideas presented in this article. All authors contributed to the preparation of the theoretical framework, the execution of calculations, the validation of the analytical methods, and the development of the interpretation of the results. Each author was also involved in reviewing, editing, and refining the manuscript until it was ready for publication.

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