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Tracing Luggage Carrier Robot Vehicle: Design and implement an accurate self-control robot system

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ABSTRACT

Nowadays, travelers have been faced with a common problem when carrying heavy luggage, especially when airports do not meet the passengers' needs to some extent. Thus, the need to reduce the luggage carried is one of the obstacles that the traveler faces due to the lack necessitated by the fact that the vehicles provided by the airports. Therefore, to overcome this issue, several luggage carrier robots have been developed to provide user convenience and automation, which significant advancement in introducing mobility. Carrying luggage, following users, and elimination, common challenges faced by travelers. Therefore, a self-controlled luggage carrier robot is proposed to provide enhanced mobility, follow the user, avoid obstacles, and carry luggage effectively. A tracing person algorithm-based self-control robot and an ultrasonic sensor (HC-SR04) based avoiding obstacle avoidance, respectively. The simulation results have shown that the proposed system achieved in effectively demonstrates its ability to switch between tracing, stop, and collision avoidance modes autonomously by achieving a Mean absolute error (MAE) of 3.88 cm in distance tracking. Besides, it provides accurate logical tracking under different loads which is best for light-to-medium luggage loads (4-5 kg approximately) to maintaining optimal walking of 0.36 m/s.

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1. Introduction

The robot tracking cart is able to carry the luggage of a specific person and follow him by using sensing procedures. New technologies such as the Internet of things [1] and robots will overcome difficulties in many facilities in our life [2]. For example, in factories, factory workers need to make strenuous efforts to transport products from one place to another, and at the airport that considers one of the most crowded places and one of the transitional stations for many people whether for a business trip, a training course or a tourist trip where the airport workers need more time and efforts to transport and manage these parcels [3]. Recent methods focus on overcoming the problems by proposing different schemes for design tracing luggage carrier controlled by its users [5], [10], [11].

Different studies and articles on robot tracking and following. One of the studies clarifies the need for building a luggage carrier and the manufacturing steps taken to produce a working prototype. The scaled initially model that is developed in their work performs the primary functions of the actual proposed design [4], [12]. They successfully built the luggage carrier prototype that can be controlled by phone and is able of moving in all directions and is also able to avoid crashes by detecting the obstacle in the pathway. And the main aim of another study is to build a luggage cart that being controlled by the owner by using a remote control [5], [13]. In particular, it aims the following: to construct a luggage cart that can carry less than or equal to 5.6 kilograms weight of luggage; to

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wirelessly control the luggage cart using two Arduino Microcontrollers, two Zigbee modules, a direction/tilt sensor; and to navigate the wheels of the luggage cart using a relay, dc motor and servo motor. This luggage cart is limited to stop, forward, left and right directions, as well as limited turning. It has its own specific frequency dedicated to follow its owner [5]. The researchers conclude that the electronics design prototype is working. All of the objectives were met. They were able to create a luggage cart with two wheels at the back being controlled by the DC motor and two wheels in front being controlled by the servo motor. The two Zigbee modules and the two Arduino Mega microcontrollers were properly programmed and were able to give data.

One of the primary benefits of this design is a luggage carrier robot follows the direction of the owner's action using sensing procedures. The contributions of this work are presented as follows:

(1) To design a luggage carrier robots can carry several kilograms weight of luggage.

(2) To self-control the luggage robot using Arduino and Ultrasonic sensor.

(3) Dc motor to navigate the wheels of the luggage cart.

2. Methodology

This Section explains the methodology used in this paper and discusses the electronic circuit architecture elements and explains them clearly, software and hardware component, and device control implementation. Table 1 presents the hardware component of the design.

Table 1 Hardware component of the design.

Hardware Name	**Arduino Uno**	**L298 module**	**Capacitor**	**Bread Boards**	**Servo motor**	**Wires**
Figures						

In this system, the control system used is Arduino Uno. It is a microcontroller board that is open-source, it the most widely used in the Arduino family the type of controller used is ATMEGA328P. It has 14 digital inputs and output pins (6 of them acts as PWM pin), 6 analog pins, a reset button, and USB power input. Besides, L298 module is used to control DC motor and the movement of wheels. HR-SC04 ultrasonic sensor: in this paper HR-SC04 ultrasonic sensor used to detect and observe the obstacle to avoid it. The principle of its work by sending and receiving sound waves and calculating the distance through the time period it takes to go and return the waves [6].

In automation technology, the servo motor is one of the famous that is used in a different application. This is an electrical tool that is self-contained and rotates electronic components with high performance and high accuracy [7]. It has advantages that are unique to regular engines, as it controls precise angular position and speed. It utilizes a normal motor and integrates it with a sensor for guidance on the position. The working principle of a servo motor is Pulse Width Modulation (PWM) [8]. That means its rotation angle is regulated by the pulse period added to its PIN control [9]. In this project, it is connected with the sensor to help it discover what is around and avoid obstacles, and it is controlled by the microcontroller.

3. Implementation of the suggested robot system

The purpose of this system is to provide the most complete control of the robot over its movement without user intervention. Arduino board which is a microcontroller of robot represents its core and its brain, which make all the Decisions. The Arduino processes and analyzes the data read by the ultrasonic sensor, which represents the distance between the robot and the objects, to make the appropriate decision to operate the motors and move the robot in any direction it is heading. The ultrasonic sensor is linked to the servo motor, which in turn helps the sensor to rotate and discover its surroundings to avoid obstacles and barriers and choose the appropriate path. The motor is controlled by a microcontroller for clockwise and counter clockwise rotation.

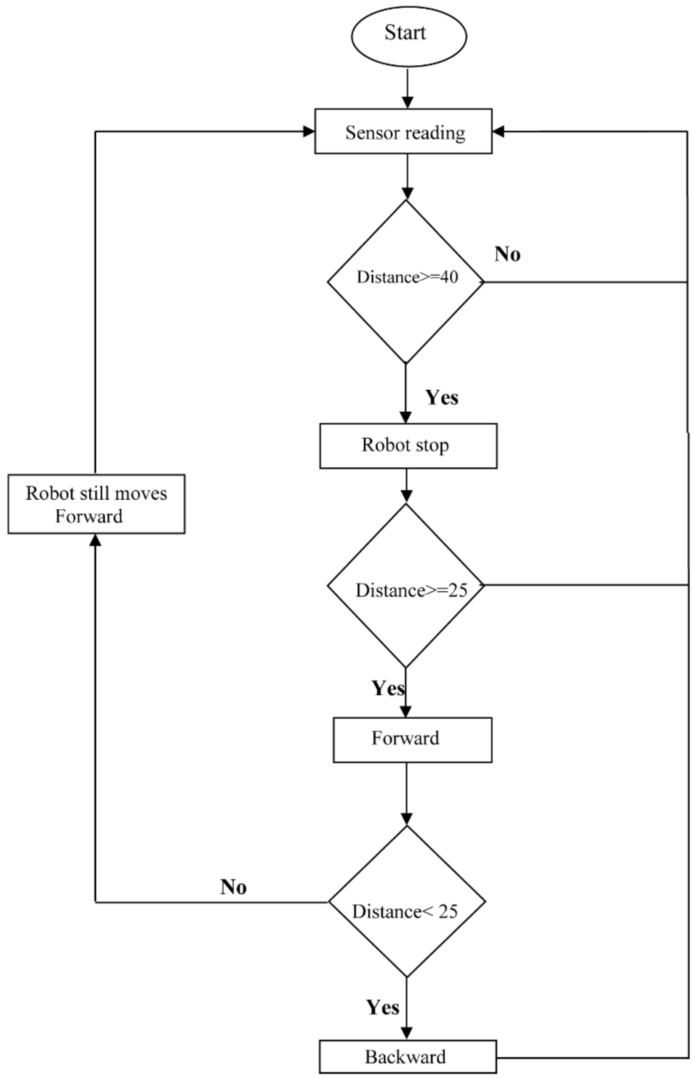

Figure 1 Flowchart of the code

The main goal of this research is the total reliance on determining the pathway that falls on the shoulders of the robot through a specific algorithm shown as in the Fig. 1.

3.1. Software circuit design

Fig. 2 represents the basic distance test for sensor circuits by using an ultrasonic sensor, Arduino and, buzzer. By programming this circuit, conditions have been set.

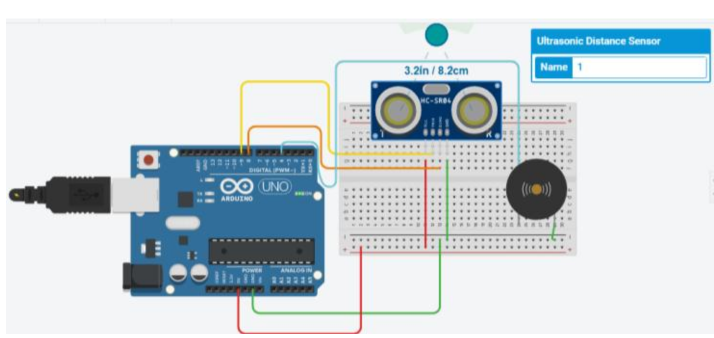

Figure 2 The measurement when distance is less than 25 cm

- First, if the distance is greater than 25 the robot will keep moving.
- The second case when the distance is less than 25 which means the robot is facing an obstacle the buzzer will be turned on.

3.2. Hardware circuit design

Fig 3 describes the connection of the drive system circuit

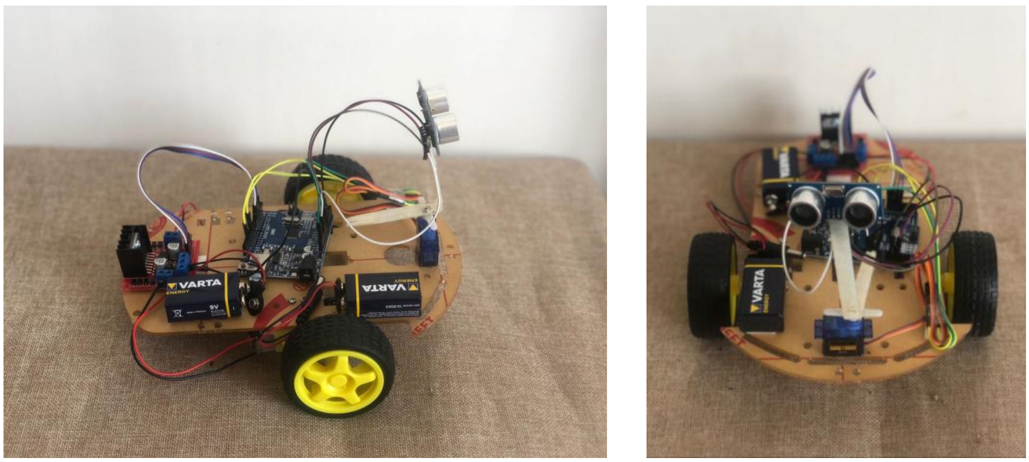

Figure 3 The circuit connection on drive system

4. Simulation Results and Discussion

We should mention the most important findings that we design to control the tracing machine using microcontroller and ultrasonic sensor. According to the output read of sensor represent the observed distance which is calculated within a time interval. The robot will start move forward and followed the user according to the distance between the user and vehicle, if the range of distance between (25 – 39 cm) robot will keep moving. When the distance between followed person and robot become less than 25 cm the robot moves backward to avoid collision. If distance between the tracked robot and the person is equal or larger than 40 cm it decides to send the motors instructions to stop.

Table 2 The result over several distance

Distance	Action
Distance = (25 – 39) cm	Robot move forward and tracing person
Distance < 25 cm	Robot move backward
Distance >= 40 cm	Robot stop

The advantage of this system it's provide self-control to choose the appropriate path and not the user is control, thus we gained the time was it takes to alert the user about an obstacle and direct the robot to the best route. This is

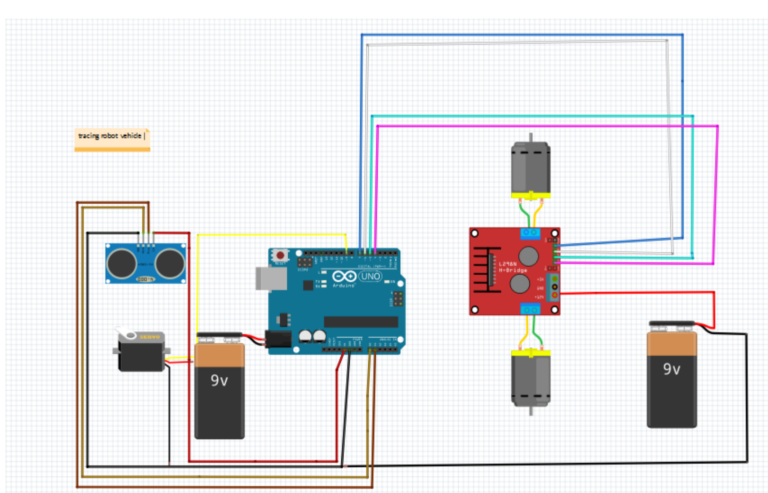

Figure 4 describes the connection between all devices in this project

what distinguishes this robot for which is designed in [4] and [5]. Look for circuit diagram in Fig. 4.

For the tracing person algorithm evaluation, a simulation is carried out with 1000 times steps to evaluate the effectiveness of the proposed system. The simulation conducted to test the capability of the robot to maintain the target distance, its response time, and the impact of varying luggage loads on system performance.

4.1. Accuracy of tracing system

The logic of the robot's movement has a specific distance threshold as we are mentioned in Table 2. The results of the simulation shown that the proposing system achieves its zones successfully. Fig 5 demonstrates the performance graph for the robot system.

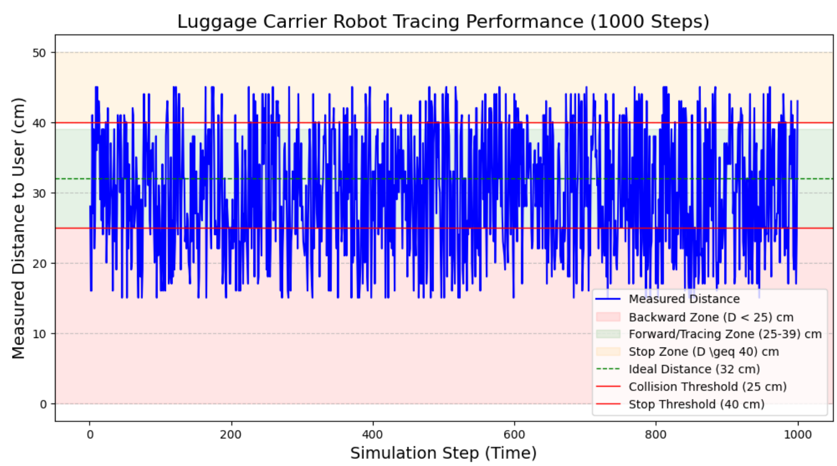

Figure 5 Demonstrate the performance of measuring target distance maintaining over 1000 steps of the robot system

Based on Fig 5, the proposed robot has corrected its position actively to stay in its forward/tracing zone according to the records that shown the measured distance to user fluctuating between stop threshold (40 cm) and collision threshold (25 cm) to achieve behavioral dynamics feature. On the other hand, the proposed system produced a marginal low error by achieving of 3.88 cm (MAE) as a tracing accuracy and 4.97 cm as an overall tracking RMSE respectively. The registered error confirm that the ultrasonic sensor keeps the robot within the desired path range belong to the user effectively. Further, the robot provides a high – frequency between optimal tracking among collision avoidance switching by registered error rate of 0.526 which reflect the reactive nature of the presented system. The low error rate demonstrated the optimal band of frequently exits to correct either overshooting or lagging.

4.2. Impact of load capacity

To verified the limitation of the selected hardware in the proposed tracing luggage carrier implementation, different weights are carried out that include 1,4, and 7 kg respectively. Table 3 presents the results of various load capacity by calculating the average of speed, response time, tracking RMSE accordingly.

Table 3 simulation results of various load capacities

Load capacity (kg)	Ang Speed (m/s)	Avg Response Time (s)	Tracking RMSE (cm)
1 kg	0.54	0.44	4.97
4 kg	0.36	0.67	4.97
7 kg	0.18	1.33	4.97

Based on Table 3 results, the system achieved its capability in keeping up with navigating user diminishes significantly that confirms the system successful carry out heavier loads. These speed degradations have shown the inverse relationship between load and speed by dropping the average speed significantly from 0.54 m/s at 1 kg to 0.18 m/s at 7 kg as the load approaches the motor's limits. For the response latency, the execution of the order is delayed as an inertia when the heavy load carries out in forward/backward commands in the Arduino's that increase the latency drastically with weight tripling from 0.44s (1 kg) to 1.33s (7 kg). On the other hand, the simulation results have shown a constant of tracking RMSE at 4.97 cm across all loads that indicates the robustness of the sensor logic and decision-making algorithm with mechanical actuation affecting when weight is increased. Fig.

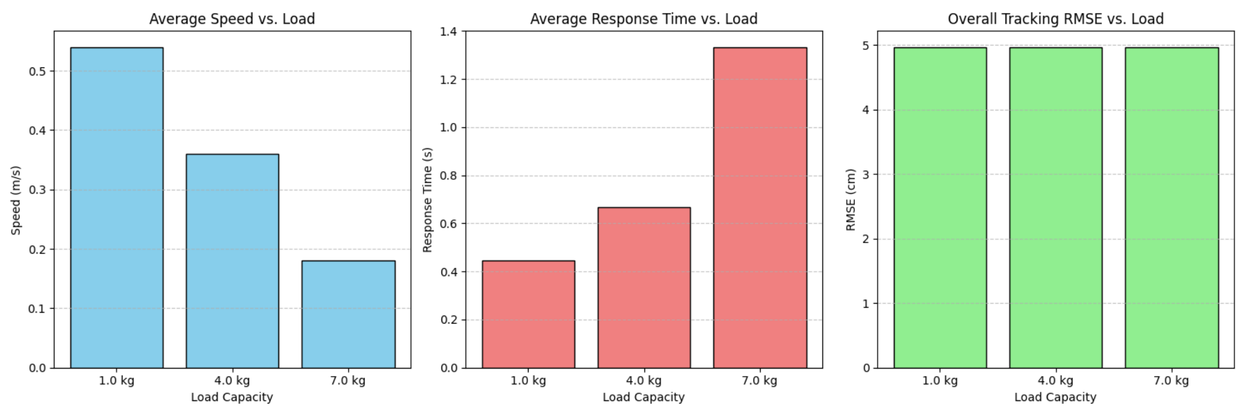

Figure 6 Performance analysis of speed, response time, and RMSE across different luggage loads

6 display the different luggage loads respecting to speed, response time, and RMSE.

5. Conclusion and Future Work

To eliminate the crucial challenges that travelers faced concerning heavy luggage and mobility, this study, a self-controlled luggage carrier robot is designed and implemented that capable of tracing a specific user using ultrasonic sensing mechanisms. The proposed user navigator robot which integrated ultrasonic sensors, DC motors, and Arduino Uno to tracing travelers based on user distance. The simulation results have been validated the control algorithm, that achieving a Mean Absolute Error (MAE) of just 3.88 cm in distance tracking. Thus, the proposed system is capable of switching between tracing, stop, collision avoidance modes autonomously effectively. Moreover, system successfully achieved accurate logical tracking under different loads to maintain optimal navigating speed of 0.36 m/s which is best suited for light-to-medium luggage loads (4-5 kg approximately). For future work, replacing the DC motors by gearbox to improve the luggage carrier's performance in addition to we intend to integrate a computer vision like camera and algorithms to track user's face to avoided wrong target in crowded airport.

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