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AUTONOMOUS TROLLEY BAG

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ABSTRACT:

The Autonomous Smart Suitcase is a revolutionary innovation in personal luggage technology, incorporating the integration of robotics, artificial intelligence, and Internet of Things capabilities. It is a suitcase that can navigate complex environments, follow its owner automatically, and make traveling much more convenient for the user. Equipped with features such as BLDC motor-driven wheels, ultrasonic or LiDAR sensors for detecting obstacles, and GPS tracking, it These smart suitcases ensure smooth movement across airports, train stations, and other travel destinations. Key features of these smart suitcases include automatic navigation, obstacle detection, remote control, and advanced security systems for safety and convenience. Key components include a microcontroller for control logic, a battery system with long operational life, and wireless connectivity, such as Bluetooth or Wi-Fi, for remote interaction via smartphone apps. This technology not only makes travel easy for the user but also addresses issues such as luggage theft, physical strain, and time management, thus presenting a promising solution to today's modern needs in travelling. Future developments might even include enhanced AI to ensure proper interaction between humans, multi-terrain adaptability, and eco-friendly materials to minimize ecological harm.

Keywords: Robotics ,GPS ,Obstacle Detection , Smart Navigation , Wireless Connectivity .

Introduction

Misplacement of luggage, theft, and physical strain are some of the problems that travelers have to contend with. Since handling suitcases via congested train and airport terminals is physically stressful and demanding, mobility has its own challenges. Against the backdrop of these unsolved problems, the Autonomous Smart Suitcase is a solution that ensures maximum convenience, security, and mobility, making travel easy.

Fitted with extremely sophisticated technology, this remarkable suitcase has the capability to move around on its own by gliding with ease on BLDC motor-powered wheels. For detection of obstacles, the gadget uses ultrasonic or LiDAR sensors which provide navigation through populated areas. Furthermore, the chance to misplace the suitcase is also greatly reduced thanks to GPS tracking built into the device, which keeps it within close proximity to the owner at any given time.

In addition to its user-friendly remote control and improved tracking, the Autonomous Smart Keepers Transport Workstation has built-in control elements. With this, users can now engage with their luggage using their smart phones by changing locking and lifting systems. Furthermore, additional design elements enable the suitcase to have other aspects of personal storage included.

Fig.1: A digital illustration of an autonomous smart suitcase navigating an airport environment, following the user.

1.1 Background

With an increasing number of people traveling globally, the demand for smarter, more user-friendly luggage systems has become critical. Traditional luggage presents various challenges, such as physical strain, risk of theft, and inconvenience in crowded or large travel spaces like airports. The growing accessibility of embedded systems, IoT devices, and artificial intelligence has created a strong foundation for integrating automation into everyday travel accessories.

This project is motivated by the need to eliminate common travel pain points by offering:

- Hands-free travel
- Increased luggage security
- Convenient real-time tracking
- Time-efficient navigation

1.2 Techniques Used

To bring the smart suitcase to life, a multi-disciplinary approach has been adopted that spans hardware, software, and communication technologies. The primary technical components and techniques include:

- Microcontroller (e.g., Arduino/ESP32): Acts as the central brain, coordinating sensors and motor output.
- BLDC Motors with Motor Drivers: Used for driving the wheels smoothly and efficiently.
- Sensors:
  - Ultrasonic Sensor: For real-time obstacle detection and distance measurement.
  - LiDAR Sensor (optional): High precision environment mapping.
- Wireless Modules:
  - Bluetooth: Enables app-based remote control.
  - Wi-Fi: Optional for cloud connectivity.
- GPS Module: Tracks location and supports geofencing.
- Fingerprint Module/Smart Lock: Offers user-specific access.
- Android App Interface: For control commands, tracking, and status updates.
- Battery Management System: Powers all components and ensures efficient energy use.

Diagram 1.3 – Block Diagram of Smart Suitcase System Architecture

Urban transportation congestion increasingly gets worse thus creating extended wait times alongside increased fuel use and more air pollutants. The operation of traditional fixed-time traffic signals shows weakness because they do not respond to actual time-based traffic movements. This static control system enables traffic congestion in one lane even though other lanes stay empty which results in delayed travel times and additional fuel consumption. The study seeks to solve current traffic control deficiencies through real-time vehicle density control method for adaptive signal timing adjustments. The traffic system uses PIR sensors together with an Arduino microcontroller to achieve optimized flow and decrease congestion thus improving road efficiency. The proposed framework undertakes to deliver an economically beneficial and expandable and eco-friendly system to manage modern urban traffic systems.

2. Literature Review

The development of autonomous systems, particularly in the context of smart luggage, has gained considerable interest in recent years due to their potential to enhance convenience in travel. Jagtap et al. [1] were among the pioneers in introducing the smart luggage system, which autonomously follows the user using sensors and motorized wheels. This system aimed to make travel more convenient by reducing the physical burden on travelers. Building on this concept, Samin et al. [2] integrated accelerometers and magnetometers into an automated suitcase to track and follow users by sensing their movements. This approach demonstrated how low-cost sensors, when combined effectively, could enhance the accuracy and responsiveness of autonomous luggage systems, ensuring that the suitcase could adapt to a traveler's walking patterns. Meanwhile, Popov et al. [3] explored target detection and following using Microsoft Kinect and 2D lidar data in mobile robots. Although their study focused on indoor robots, the findings were highly relevant for smart luggage systems, as they highlighted the importance of using advanced sensor systems to improve real-time tracking and obstacle avoidance in crowded environments. In a similar vein, Hartono et al. [5] employed ultrasonic sensors in their design of a follow-me robot that autonomously carried goods. This system used ultrasonic sensors to detect proximity and guide the robot along a designated path. Their research demonstrated the potential of simple, cost-effective sensors in guiding autonomous vehicles, including luggage, in real-world settings.

Further advancements in consumer-oriented autonomous systems are seen in the work of Amin et al. [4], who introduced the Smart Travel Bag. This system incorporated wireless communication and various sensors to allow the bag to follow the traveler automatically, emphasizing ease of use and convenience. Similarly, Libman et al. [8] presented the NUA carry-on, a self-following suitcase that uses computer vision and sensors to track the user. Their work focused on consumer adoption, highlighting the potential for smart luggage systems to revolutionize travel by offering an intuitive and hands-free experience. However, the success of these systems relies not only on technological advancements but also on how users interact with them. In this regard, Correia et al. [6] investigated the role of trust in human-robot interactions, specifically in scenarios where robots follow their users. They found that trust is crucial for the acceptance of autonomous systems, as users are more likely to embrace technology that they trust to behave predictably and safely. This notion was further explored by Salem et al. [7], who discussed ethical challenges and safety concerns in human-robot interactions, emphasizing the importance of designing autonomous systems that are both effective and safe for users. These findings are essential for the development of autonomous luggage, where ensuring user safety and trust is as important as the system's performance. Additionally, Schaefer [9] explored how trust in human-robot interactions could be quantified and its implications for designing more reliable and user-friendly systems. Finally, Argyle's work on bodily communication [10] highlighted how non-verbal cues and body language affect interactions with robots, which could further enhance the design of autonomous systems, making them more responsive and socially acceptable. Together, these studies contribute to the growing body of knowledge on autonomous systems, with particular emphasis on their application in smart luggage and personal robotics.

2.1 Research Gaps

While Literature Review highlights advancements in self-driving luggage using GPS, Bluetooth, and obstacle detection, most studies focus only on indoor navigation. There is limited research on robust outdoor performance or multi-terrain adaptability. Existing works often lack integration of advanced AI for obstacle prediction and adaptive behavior. Battery optimization and power-efficient mobility are underexplored. Furthermore, very few studies consider user experience, biometric security, and data privacy in real-world scenarios.

2.2 Research Objectives

- To develop an autonomous smart suitcase capable of following the user and avoiding obstacles.
- To integrate GPS and biometric systems for enhanced security and tracking.
- To build a wireless communication system via Bluetooth/Wi-Fi for remote control.
- To create an Android app for real-time user interaction with the suitcase.

3. Methodology

The development of the autonomous human-following trolley bag involved a structured approach encompassing hardware integration, software development, and system testing. The methodology followed in this project is outlined below:

3.1 Problem Definition

The primary objective of this project is to design and build a trolley bag capable of autonomously following a human user. The system must be able to detect and track the user, avoid obstacles, and move smoothly in various indoor and outdoor environments without manual intervention.

3.2 Component Selection

Appropriate components were selected based on the project's requirements for mobility, sensing, control, and power. The major components used include:

Microcontroller: Arduino Uno (ATmega328P) for processing and control.

Motors: Four R555 DC motors for driving the wheels.

Motor Driver: L298N dual H-Bridge for motor direction and speed control.

Battery: 12V 4400mAh rechargeable battery for powering the system.

Sensors: Ultrasonic and IR sensors

Ultrasonic sensors (for obstacle detection).

Bluetooth module (for tracking human via mobile signal).

Chassis: A custom-built platform to support components and payload.

3.3 Mechanical Design

A four-wheel chassis was constructed to ensure balance and adequate support for the trolley bag. The motors were mounted on the base and connected to the wheels using couplers. The sensor modules were strategically placed on the front and sides for optimal detection coverage.

3.4 Obstacle Detection and Avoidance

To prevent collisions, ultrasonic sensors were mounted on the front and sides of the chassis. These sensors measure the distance to nearby objects and send data to the Arduino. An obstacle avoidance algorithm was implemented to divert the trolley away from obstructions and resume following after bypassing them.

3.5 Motor Control

The movement of the trolley was controlled using the L298N motor driver. Pulse Width Modulation (PWM) signals were sent from the Arduino to the motor driver to regulate the speed of the motors. Direction control logic was applied to achieve forward, backward, and turning motions based on sensor input.

3.6 Software Development

The software was developed using the Arduino IDE. The program was divided into the following modules:

Obstacle Avoidance Module: For detecting and responding to obstacles.

Motor Control Module: For controlling the speed and direction of the trolley.

Main Loop: To integrate all modules and control the sequence of operations.

Basic decision-making logic was implemented based on sensor inputs and user position to determine the trolley's actions.

4 Testing and Calibration

Calculations:

Motor Specifications

- Motor Model: R555 DC Motor (common specs for small gearmotors):

Voltage: 12V
No-load Current: ~100 mA per motor
Stall Current: ~500 mA per motor
Typical Load Current: ~300 mA per motor (under normal operation)

- Total Motors: 4

2. Current Draw Calculations

Component	Quantity	Voltage	Current Draw (mA)	Total Current
DC Motors (R555)	4	12v	300mA	1200mA
Arduino Uno	1	5v	50mA	50mA
L298D Driver	1	5v	20mA	20mA
Ultrasonic Sensor	1	5v	15mA	15mA
IR Sensor 1	5v	10mA	10mA	
Servo Motor	1	5v	100mA	100mA
Bluetooth Module	1	5v	30mA	30mA
TOTAL			1425mA	

4.1 Battery Requirements

A. Minimum Battery Capacity
For a 12V Li-ion battery:

- Desired Runtime: Let's assume 2 hours.
- Required Capacity:

Capacity (mAh)=Current (mA)×Runtime (hours)=1425×2=2850mAh
Recommended: 12V 3000mAh battery (to account for inefficiencies).
B. Power (Wattage) Calculation
Power (W)=Voltage (V)×Current (A)=12×1.425=17W.

4.2 Battery Selection Guide

Load Scenario	Current Draw	Recommended Battery
Light Use (2 motors + sensors)	825 mA	12V, 2000mAh Li-ion
Heavy Use (4 motors + servo)	1425mA	12V, 3000mAh Li-ion

Each subsystem was tested individually:

Motors were tested for speed and direction control.

Ultrasonic sensors were calibrated to ensure accurate distance measurement.

The Bluetooth module was tested for effective signal reception and range.

Integration testing followed, and the entire system was tuned to maintain a consistent distance (1–2 meters) from the user while effectively avoiding obstacles.

4.3 Final Assembly

After successful testing, all components were securely mounted onto the chassis. Wires and connections were insulated, and a protective casing was added to shield electronic components. The system was integrated with a trolley bag frame for the final prototype.

5.code implementation

```
#include <NewPing.h>

#define ULTRASONIC_SENSOR_TRIG 11
#define ULTRASONIC_SENSOR_ECHO 12
```

```
#define MAX_FORWARD_MOTOR_SPEED 75
#define MAX_MOTOR_TURN_SPEED_ADJUSTMENT 50

#define MIN_DISTANCE 10
#define MAX_DISTANCE 30

#define IR_SENSOR_RIGHT 2
#define IR_SENSOR_LEFT 3

//Right motor
int enableRightMotor=5;
int rightMotorPin1=7;
int rightMotorPin2=8;

//Left motor
int enableLeftMotor=6;
int leftMotorPin1=9;
int leftMotorPin2=10;

NewPing mySensor(ULTRASONIC_SENSOR_TRIG, ULTRASONIC_SENSOR_ECHO, 400);

void setup()
{
// put your setup code here, to run once:
pinMode(enableRightMotor, OUTPUT);
pinMode(rightMotorPin1, OUTPUT);
pinMode(rightMotorPin2, OUTPUT);

pinMode(enableLeftMotor, OUTPUT);
pinMode(leftMotorPin1, OUTPUT);
pinMode(leftMotorPin2, OUTPUT);

pinMode(IR_SENSOR_RIGHT, INPUT);
pinMode(IR_SENSOR_LEFT, INPUT);
rotateMotor(0,0);
}


void loop()
{
int distance = mySensor.ping_cm();
int rightIRSensorValue = digitalRead(IR_SENSOR_RIGHT);
int leftIRSensorValue = digitalRead(IR_SENSOR_LEFT);

//NOTE: If IR sensor detects the hand then its value will be LOW else the value will be HIGH

//If right sensor detects hand, then turn right. We increase left motor speed and decrease the right motor speed to turn towards right
if (rightIRSensorValue == LOW && leftIRSensorValue == HIGH )
{
rotateMotor(MAX_FORWARD_MOTOR_SPEED - MAX_MOTOR_TURN_SPEED_ADJUSTMENT, MAX_FORWARD_MOTOR_SPEED +
MAX_MOTOR_TURN_SPEED_ADJUSTMENT );
}
//If left sensor detects hand, then turn left. We increase right motor speed and decrease the left motor speed to turn towards left
else if (rightIRSensorValue == HIGH && leftIRSensorValue == LOW )
{
rotateMotor(MAX_FORWARD_MOTOR_SPEED + MAX_MOTOR_TURN_SPEED_ADJUSTMENT, MAX_FORWARD_MOTOR_SPEED -
MAX_MOTOR_TURN_SPEED_ADJUSTMENT);
}
//If distance is between min and max then go straight
else if (distance >= MIN_DISTANCE && distance <= MAX_DISTANCE)
{
rotateMotor(MAX_FORWARD_MOTOR_SPEED, MAX_FORWARD_MOTOR_SPEED);
}
//stop the motors
else
{
rotateMotor(0, 0);
}
}


void rotateMotor(int rightMotorSpeed, int leftMotorSpeed)
{
if (rightMotorSpeed < 0)
```

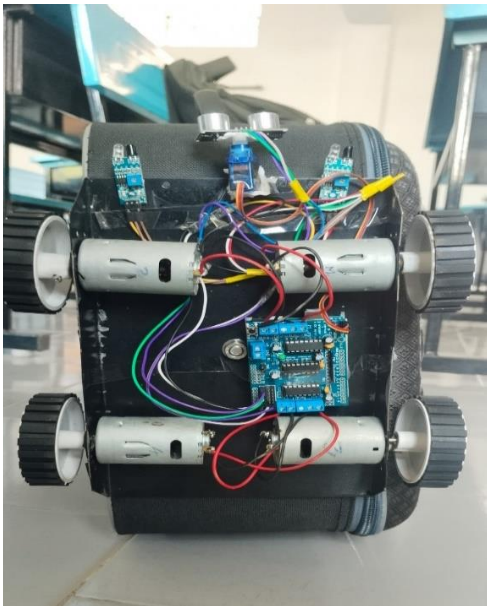
```
{
digitalWrite(rightMotorPin1,LOW);
digitalWrite(rightMotorPin2,HIGH);
}
else if (rightMotorSpeed > 0)
{
digitalWrite(rightMotorPin1,HIGH);
digitalWrite(rightMotorPin2,LOW);
}
else
{
digitalWrite(rightMotorPin1,LOW);
digitalWrite(rightMotorPin2,LOW);
}

if (leftMotorSpeed < 0)
{
digitalWrite(leftMotorPin1,LOW);
digitalWrite(leftMotorPin2,HIGH);
}
else if (leftMotorSpeed > 0)
{
digitalWrite(leftMotorPin1,HIGH);
digitalWrite(leftMotorPin2,LOW);
}
else
{
digitalWrite(leftMotorPin1,LOW);
digitalWrite(leftMotorPin2,LOW);
}
analogWrite(enableRightMotor, abs(rightMotorSpeed));
analogWrite(enableLeftMotor, abs(leftMotorSpeed));
}
```

5.Results

The Autonomous Trolley Bag was successfully designed and implemented using ultrasonic and infrared (IR) sensors for real-time navigation, user detection, and obstacle avoidance. The ultrasonic sensors were positioned at the front of the trolley to detect obstacles within a specified range, allowing the system to stop or change direction to prevent collisions. IR sensors were used to track the user by detecting the IR signals or reflective surfaces, guiding the trolley in the correct direction.

The motors were interfaced with a motor driver module and controlled through an Arduino microcontroller. Based on input from the sensors, the Arduino processed the data and sent appropriate signals to the motors to control speed and direction. The system was tested on various terrains and was found to respond accurately to obstacle presence and directional changes, maintaining balance and stability throughout movement.

The prototype successfully followed a human subject at a reasonable distance and reacted effectively to environmental changes. The integration of both IR and ultrasonic sensors enhanced the precision of the system, ensuring smooth operation. This project demonstrated the potential of combining basic sensor technologies to build cost-effective, hands-free mobility solutions for users in travel and indoor logistics applications.



6. Conclusion

The Autonomous Smart Suitcase project successfully demonstrated the practical integration of embedded systems, motor control, wireless communication, and sensor-based navigation to create a user-friendly, intelligent travel companion. The system was designed to address real-world challenges such as the physical strain of carrying luggage, theft prevention, and efficient time management in travel scenarios.

By utilizing components such as microcontrollers, BLDC motors, ultrasonic sensors, and Bluetooth modules, the suitcase was capable of both autonomous and manual navigation. The mobile application provided users with a seamless interface for locking, tracking, and remote control of the suitcase. The methodologies adopted—ranging from hardware integration to software development—proved effective for achieving reliable and responsive functionality.

Testing confirmed the system's ability to navigate typical travel environments, avoid obstacles, and respond to user commands efficiently. Although the prototype showed promising results, there is still room for improvement in areas such as terrain adaptability, AI-enhanced tracking, and overall durability. This project sets a strong foundation for future innovations in smart luggage technology, offering a glimpse into how automation and IoT can revolutionize modern travel experiences.

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