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# Design and Simulation of a Smart Luggage Bag with Integrated Tracking and Security Features

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***Abstract* - The increasing demand for intelligent travel solutions has led to the development of smart luggage systems that enhance security, tracking, and user convenience. This paper presents the design and simulation of a smart luggage bag integrating obstacle avoidance, GPS–GSM communication, theft detection, and a keypad-based password locking mechanism. Ultrasonic sensors are used for obstacle detection to provide collision avoidance and ensure safe movement, while a GPS module enables real-time location tracking and a GSM module supports remote alert transmission during unauthorized movement or security breaches. Theft detection is achieved by monitoring abnormal luggage motion when the system is in a locked state, triggering instant alerts to the user. The proposed system is validated through simulation to evaluate functional accuracy, response time, and reliability under various operating conditions. Simulation results demonstrate that the integrated system significantly improves luggage security, situational awareness, and user assistance, providing a reliable foundation for future smart luggage solutions with potential IoT-based enhancements.**

***Keywords:*** Smart Luggage, Obstacle Avoidance, GPS, GSM, Theft Detection, Password Lock, Simulation.

## I. INTRODUCTION

With the rapid growth of global travel and increasing concerns related to luggage safety, theft, and user convenience, traditional luggage systems are no longer sufficient to meet modern travel demands. Travelers frequently face challenges such as misplaced baggage, unauthorized access, and difficulty in maneuvering luggage in crowded environments. Advances in embedded systems, sensor technology, and wireless communication have enabled the development of smart luggage solutions that offer enhanced security, real-time tracking, and intelligent assistance. Integrating features such as obstacle avoidance, location monitoring, and automated alert systems can significantly improve both safety and user experience. In this context, this research focuses on the design and simulation of a smart luggage system that combines ultrasonic-based obstacle detection, GPS–GSM communication for real-time tracking and alerts, motion-based theft detection, and a keypad-controlled password locking mechanism. By validating the system through simulation, this study aims to assess its functional performance, reliability, and effectiveness, while establishing a scalable foundation for future smart luggage systems with advanced IoT and automation capabilities.

## II. LITERATURE REVIEW

Sutar et al. proposed a smart bag with theft prevention and real-time tracking using GPS and GSM modules. The system sends alert messages and location details to the user during unauthorized movement of the luggage. Although the design provides effective tracking functionality, it does not include obstacle avoidance, password-based access control, or intelligent theft detection logic. The proposed paper improves this work by integrating ultrasonic-based obstacle avoidance, keypad-controlled locking, and motion-based theft detection for enhanced security and usability. [1]

Talib et al. developed an IoT-based smart bag using Arduino Uno, integrating GPS, GSM, and motion sensors to provide real-time luggage tracking and alert notifications. While the system enhances luggage monitoring, it relies on basic motion sensing and lacks secure access mechanisms, which can lead to false alerts. The proposed system improves upon this by implementing password-based locking and activating theft detection only during abnormal motion in the locked state. [2]

Sharma et al. presented an IoT-based luggage security system focusing on GPS tracking and GSM-based alert transmission. The system effectively addresses luggage loss and theft through location monitoring but does not include physical access security or obstacle avoidance features. The proposed work overcomes these limitations by incorporating a keypad-controlled password locking mechanism and ultrasonic sensors for obstacle detection. [3]

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Amin et al. designed a smart travel bag equipped with GPS, GSM, and sensor modules to improve traveler convenience and luggage safety. Although the system supports tracking and alert generation, it lacks intelligent theft detection and collision avoidance mechanisms. The proposed paper enhances this work by adding obstacle avoidance and motion-based theft detection during locked conditions. [4]

Abhang et al. proposed a smart bag system integrating GPS, GSM, and alert mechanisms for traveler safety. The system mainly focuses on communication and tracking features and does not include access control or intelligent motion analysis. The proposed system improves this by introducing keypad-based password protection and intelligent theft detection logic. [5]

Patil et al. developed an automatic luggage follower system with obstacle detection using ultrasonic sensors to assist users in crowded environments. While the system improves mobility and obstacle avoidance, it does not provide tracking, theft detection, or access security. The proposed work integrates obstacle avoidance with GPS–GSM communication and security mechanisms, offering a more comprehensive smart luggage solution. [6]

## III. SYSTEM ARCHITECTURE

The proposed system architecture is centered on the Arduino Uno R3, which acts as the main control unit and interfaces with multiple sensors and modules. An MPU6050 accelerometer detects abnormal movement for theft detection, while an HC-SR04 ultrasonic sensor provides obstacle detection. A matrix keypad enables password-based locking, supported by a buzzer and SG90 servo motor for alerting and mechanical actuation. GPS NEO-6M provides real-time location data, and the SIM800L GSM module sends alerts and location updates to the user. An ESP32 module supports extended communication and processing tasks. Power management is handled using a 230 VAC to 12 VDC converter, LM2596 buck converter, and TP4056 charging module. Motor control is achieved through an L298N motor driver, ensuring smooth and controlled luggage movement.

The circuit diagram illustrates the hardware implementation of the smart luggage system centered around an Arduino Uno R3 microcontroller. The Arduino interfaces with multiple peripherals, including an HC-SR04 ultrasonic sensor for obstacle detection, an MPU6050 accelerometer for motion and theft detection, and a 4×4 matrix keypad for password-based access control. A servo motor (SG90) is used to actuate the locking mechanism, while an L298N motor driver controls the drive motors for luggage movement.

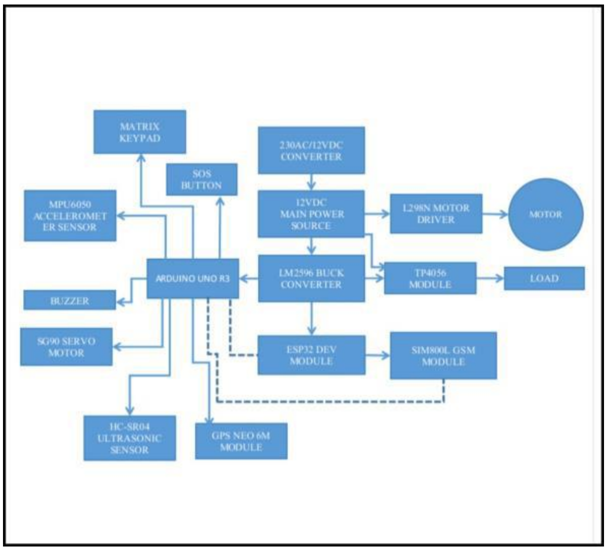


**Figure 1: Block Diagram**

A Neo-6M GPS module provides real-time location data, and alert functions are supported through a buzzer and push buttons for SOS and system control. All sensors and modules operate on regulated 5 V power, ensuring stable operation. The integrated circuit enables coordinated sensing, secure access, movement control, and communication, forming a reliable hardware platform for the smart luggage system.

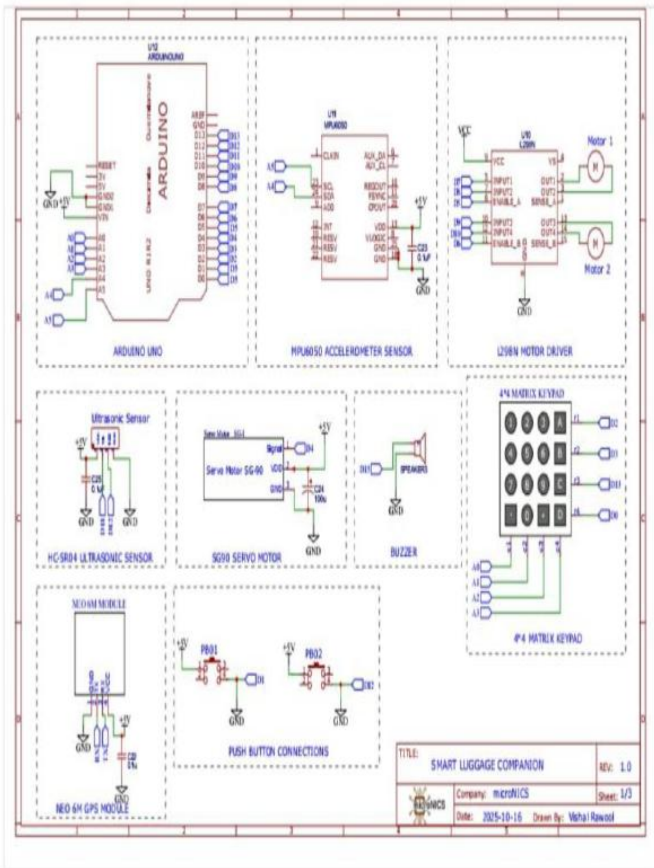


**Figure 2: Circuit Diagram**

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## IV. WORKING

The Smart Luggage System is powered by a 12 V Li-ion battery with a protection module. Buck converters regulate the voltage to 5 V for the Arduino Uno R3, sensors, and servo motor, and 4 V for the SIM800L GSM module. When powered ON, the Arduino and ESP32 initialize all connected modules.

The system operates in two modes: Travel Mode and Alert Mode. In Travel Mode, activated via Google Voice commands through the ESP32, the HC-SR04 ultrasonic sensor measures the distance between the user and the luggage. Based on this data, the Arduino controls the DC motors via the L298N motor driver, enabling the luggage to follow the user. In Alert Mode, the MPU6050 accelerometer continuously monitors movement and tilt. Any unauthorized motion triggers the buzzer alarm, which can be stopped using a push button.

Location tracking is achieved using the Neo-6M GPS module, while the SIM800L GSM module enables SMS alerts, location sharing, and two-way communication. Security is enhanced using a 4×4 keypad and servo-based locking mechanism, allowing access only with a correct password. The integrated coordination of sensors, communication modules, and controllers ensures reliable operation, enhanced security, and user convenience.

## V. SIMULATION RESULT

**Simulation for Motion Detection Working:**

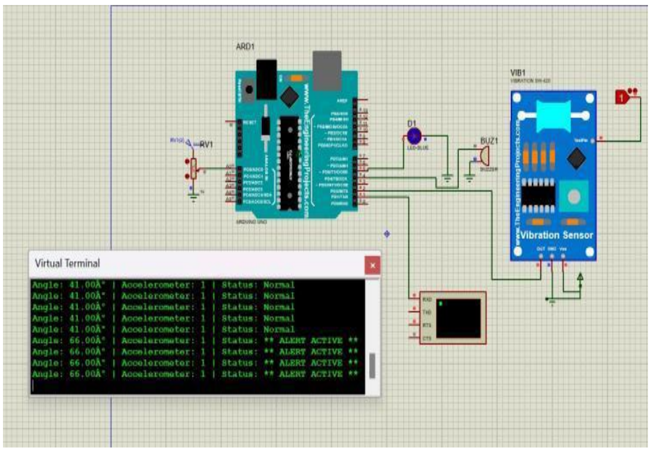


**Figure 3: Simulation for Motion Detection**

When the bag experiences any unwanted movement (i.e., movement beyond the set threshold angle), the accelerometer sensor detects this motion. Upon detection, the blue LED starts blinking and the buzzer is activated to indicate unauthorized movement

**Simulation Result:**

Circuit Condition

| S/W Position | Green LED | Blue LED | Distance | Motor Status |
|---|---|---|---|---|
| Open | OFF | OFF | Distance < 60cm | Stationary |
| Close | ON | OFF | Distance < 60cm | Stationary |
| Close | ON | ON | 60cm < distance < 100cm | Running |

Motor Running Status

| Object Distance | Blue LED Status | Motor Running Status |
|---|---|---|
| 54 cm | OFF | Stationary |
| 56 cm | OFF | Stationary |
| 64 cm | ON | Running |
| 65 cm | ON | Running |
| 87 cm | ON | Running |
| 102 cm | OFF | Stationary |

**Password Lock Simulation Working:**

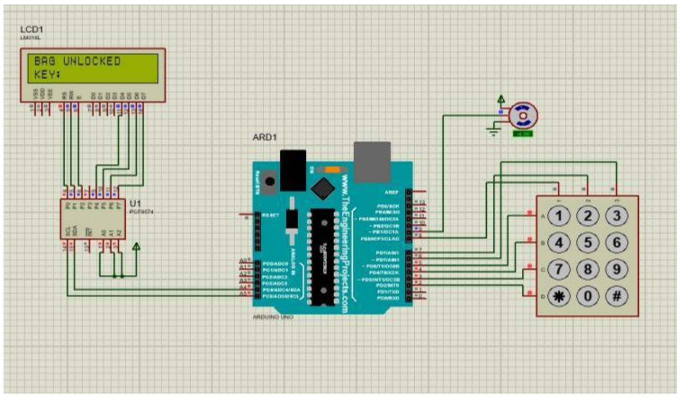


**Figure 4: Simulation for Password Lock**

The bag can be accessed only when the correct password is entered using the keypad. When the entered password is correct, the servo motor connected to the locking mechanism changes its position to unlock the bag. If the password is incorrect, the servo motor remains in its locked position. After entering the password, the user must press either the '[*]' key (used to change the password) or the '[#]' key (used as the enter key).

 

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**Simulation Result:**

Circuit Condition

| Password | Access | Servo Motor Position | Lock Status |
|---|---|---|---|
| Correct | Granted | Change | Open |
| Wrong | Not Granted | Not Changed | Close |
| Correct | Granted | Change | Open |

**LCD Display & Lock Status (Simulation):**

Consider Password is 1234

| Entered Password | Key Password | LCD Display | Lock Status |
|---|---|---|---|
| 1234 | # | Access Granted (Back Unlocked) | Open |
| 2345 | # | Wrong password | Open |
| 1234 | # | Access Granted | Close |
| 2345 | * | Enter Old Password | Close |
| 4545 | # | Wrong Old Password | Close |
| 1234 | # | Old Password is okay Enter New Password | Close |
| 0505 | # | Password Changed | Close |
| 0505 | # | Access Granted | Open |

**Human following Feature Simulation Working:**

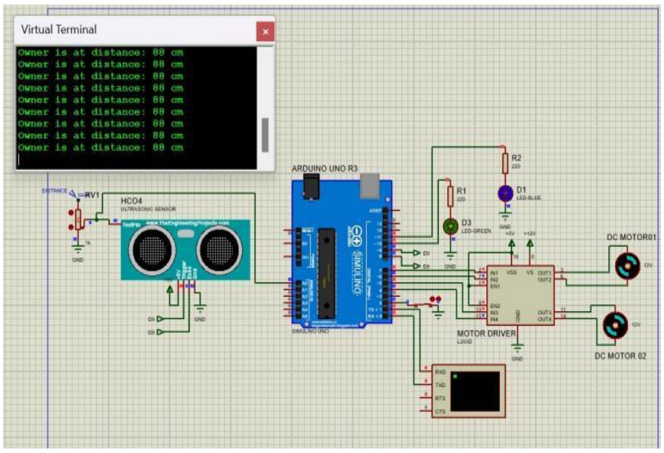


**Figure 5: Simulation for Human Following Feature**

Bag will only follow the human at specific distance (Here it is used analog input for distance measurement). Movement is done by DC Motors which are connected to the bag wheels. Green LED shows Circuit OPEN/CLOSE status & Blue LED shows Motor Running Status.

**Simulation Result:**

Circuit Condition

| Accelerometer Movement Angle | Blue LED | Buzzer | Unnecessary Movement Detected |
|---|---|---|---|
| <50° | OFF | Not Triggered | NO |
| >50° | Blinking | Triggered | YES |

Simulation

| Accelerometer Movement Angle | Blue LED | Buzzer | Unnecessary Movement |
|---|---|---|---|
| 45° | OFF | Not Triggered | NO |
| 47° | OFF | Not Triggered | NO |
| 54° | Blinking | Triggered | YES |
| 65° | Blinking | Triggered | YES |

**GSM & GPS Tracking Simulation:**

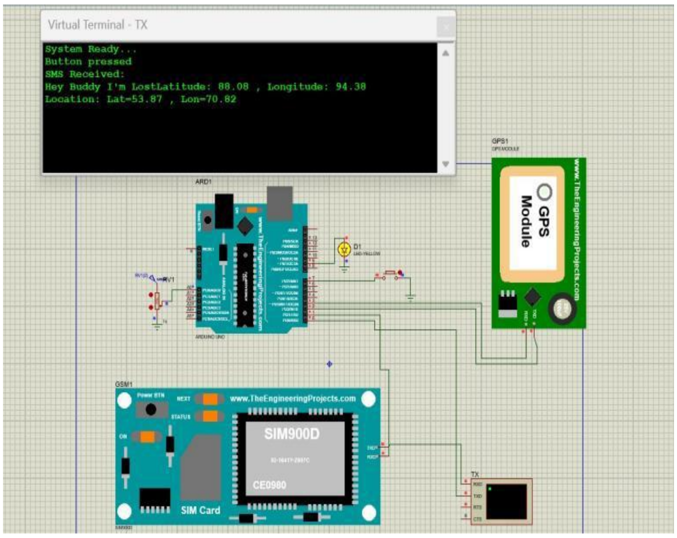


**Figure 6: Simulation for GPS & GSM Tracking**

The GSM and GPS modules are connected to the Arduino to enable communication. Voice commands are simulated virtually by adjusting potentiometer (POT) values, with different POT values corresponding to different features. A push button is also used to trigger the SOS or lost device function. The simulation for communication, calling, and voice commands is displayed sing the Virtual Terminal.

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**Simulation Result:**

| Condition | Simulation |
|---|---|
| Push Button Pressed | Virtual Terminal Displays "Hey Buddy I'm here with Longitude & Latitude |
| 20% POT Value i.e. Voice Command (Where is my bag value) | Yellow LED Blink |
| 50% POT Value i.e. voice command (Location) | Virtual Terminal Display: Longitude & Latitude |
| 70% POT Value i.e. voice command (call to my companion) | Virtual Terminal Display: Calling my companion |

## VI. RESULT & DISCUSSION

The Smart Luggage System was successfully simulated and tested, with Arduino Uno R3, ESP32, ultrasonic sensor, L298N driver, GPS, GSM, MPU6050, and keypad lock functioning reliably under stable power. In Travel Mode, the ultrasonic sensor enabled accurate distance measurement and smooth motor-driven following, while in Alert Mode, the MPU6050 detected unwanted movement, triggering the buzzer. GPS and GSM modules provided precise location tracking and two-way communication, the keypad lock ensured security, and the mobile charging port worked effectively. Voice commands were correctly received via ESP32 and executed by Arduino, confirming seamless integration. Overall, the system met all objectives, demonstrating a practical and reliable solution for safe and convenient travel.

## VII. CONCLUSION

The Smart Luggage System was successfully designed, simulated, and tested, achieving all its objectives. The system demonstrated reliable autonomous movement, accurate human-following, theft detection, GPS-based tracking, secure locking, voice control, and effective communication. Overall, the project provides a safe, convenient, and innovative solution for modern travel needs.

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