



## Smart IoT-Based Luggage Tracking System

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### ABSTRACT :

Luggage is easily lost, moved or opened by strangers in crowded travel places. This paper presents a smart IoT-based luggage security and tracking system built around an ESP32 microcontroller. A NEO-6M GPS module gives the latitude and longitude of the bag, and a virtual geofence of about 10 m is created around the authorized location. When the bag leaves the geofence, the movement is treated as unauthorized and a SIM900D GSM module sends the current GPS location to the owner's mobile phone as an SMS. An SW-420 vibration sensor detects forced opening or rough handling; on detection, a buzzer sounds, an alert SMS is sent and an ESP32-CAM captures an image as visual evidence. GPS coordinates are also uploaded to the ThingSpeak cloud for remote monitoring. The prototype was assembled in a compact enclosure that fits inside a bag and the alerts, camera image and map location were verified on hardware. The system combines tracking, tamper detection, alerts and camera monitoring in one low-cost unit for airports, railway stations, bus terminals and hotels.

**Keywords:** *IoT, luggage tracking, GPS, GSM, geofencing, tamper detection, vibration sensor, ESP32-CAM*

### 1. Introduction

Luggage security is an important concern during travel, particularly in crowded places such as airports, railway stations, bus terminals and hotels. Conventional security methods such as locks, identification tags and manual supervision give only limited protection against theft, unauthorized movement and tampering, and they cannot monitor the luggage continuously [1], [4]. A normal lock tells the owner nothing once the bag is out of sight. Luggage problems are of two kinds. In the first kind the bag is lost or misplaced and the owner needs to know where it is. In the second kind the bag is being stolen or opened and the owner needs to know that it is happening right now. When luggage is moved from its authorized location the owner cannot quickly find its position, and a lock can neither detect tampering nor inform the owner. Most reported systems deal with the first kind of problem; a system that handles both is more useful to the traveller.

Many low-cost luggage trackers have been built using the Internet of Things (IoT). Most of them use a microcontroller with a Global Positioning System (GPS) module and a Global System for Mobile Communication (GSM) module, and send the location to the owner as a Short Message Service (SMS) text [1], [4], [9]. This work adds geofencing, a vibration sensor for tamper detection, a buzzer and an ESP32-CAM for visual evidence to such a tracker, so that location, tamper alert and picture are available from a single unit.

#### The main objectives of the proposed work are:

- To track the real-time location of the luggage using a GPS module and alert the owner via GSM/SMS when it moves beyond a defined geofence.
- To detect physical tampering or forced opening using a vibration sensor and trigger an instant security alert.
- To capture visual evidence of tampering using a camera module (ESP32-CAM) for added security.

The rest of the paper is arranged as follows. Section 2 reviews related work. Section 3 describes the proposed system, its circuit and working. Section 4 gives the hardware and software implementation. Section 5 presents the results and discussion, and Section 6 concludes the paper.

### 2. Literature Survey

Shobayo et al. built an IoT-based baggage tracking system using an Arduino microcontroller with GPS and GSM modules; the GPS coordinates are processed by the microcontroller and sent to the passenger as an SMS [1]. Navya et al. used the same GPS-GSM approach for luggage theft detection and tracking to help users locate lost, misplaced or stolen bags [9], and Jain et al. combined GPS, GSM, a microcontroller and an IoT platform for real-time location monitoring [4]. Sreenivasulu et al. reported a baggage tracking system based on Arduino Uno [6].

Other works add proximity and locking features. Paidimarry et al. proposed a smart baggage follower with theft prevention that uses GPS, GSM, Bluetooth, ultrasonic sensors and smart locking, and raises an alert when the luggage goes beyond a predefined distance from the owner [2]. Gehlot et al. discussed an IoT-enabled robotic baggage monitoring system with GPS tracking, biometric security, smart locks and geofencing [10], and Rawool et

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al. simulated a smart luggage bag with GPS-GSM tracking, theft detection, obstacle detection and password-based locking [11].

Camera and cloud based approaches have also been tried. Dange et al. developed a battery-powered smart luggage vehicle with sensors and a real-time surveillance system using GPS, GSM and ESP32 camera modules [5]. A smart lock for luggage uses NodeMCU, ESP32-CAM, vibration sensors, the Blynk IoT platform and face recognition [8]. Sairam et al. applied LSTM networks and IoT for cloud-enabled luggage protection in contactless travel [7], and Si et al. proposed a hybrid blockchain-edge system for secure airport baggage tracking [3]. For tamper detection, Afgan et al. connected an SW-420 vibration sensor and a GSM SMS module to a microcontroller so that a suitcase sends an SMS when it is slammed [12].

Table 1 compares some of the reviewed systems with the proposed one. The works above mainly concentrate on finding the location of the luggage or on one extra feature. A single compact unit that combines a geofence alert, vibration based tamper detection, a local buzzer and a camera image is not the main design of these systems, and the proposed system tries to cover them together.

**Table 1 - Comparison of existing luggage systems and the proposed system**

| Ref.     | Main technology                                               | Alert / output                                              |
|----------|---------------------------------------------------------------|-------------------------------------------------------------|
| [1]      | Arduino, GPS, GSM                                             | Location sent to the passenger by SMS                       |
| [2]      | GPS, GSM, Bluetooth, ultrasonic sensor, smart lock            | Alert and location when the bag moves beyond a set distance |
| [5]      | GPS, GSM, ESP32 camera, sensors (luggage vehicle)             | Real-time surveillance                                      |
| [8]      | NodeMCU, ESP32-CAM, vibration sensor, Blynk, face recognition | Smart lock with camera and app                              |
| [10]     | GPS, biometric lock, geofencing                               | Real-time monitoring of baggage                             |
| [12]     | Microcontroller, SW-420, GSM                                  | SMS when the suitcase is slammed                            |
| Proposed | ESP32, NEO-6M GPS, SIM900D GSM, SW-420, ESP32-CAM, buzzer     | Geofence SMS, tamper SMS, buzzer, image and cloud log       |

### 3. Proposed System

#### 3.1. Existing system and its limitations

Existing luggage security systems mainly use conventional locks, GPS trackers, GSM, Bluetooth or proximity-based monitoring. Locks give basic protection but cannot detect tampering or track the bag. GPS-GSM systems provide location information and proximity-based systems detect when the luggage moves away from the owner, but many of them mainly focus on tracking. Their limitations are:

- limited protection against theft and tampering;
- no continuous monitoring in conventional methods; and
- geofencing, tamper detection, immediate alerts and camera monitoring are not combined in a single system.

#### 3.2. Proposed system

The proposed system integrates GPS, GSM, geofencing, a vibration sensor and an ESP32-CAM with an ESP32 microcontroller. GPS tracks the luggage location and the geofence detects movement beyond the predefined safe area. The vibration sensor identifies abnormal movement or tampering, and the GSM module sends an alert with the luggage location to the owner. The ESP32-CAM provides visual information during the security event. Thus tracking, tamper detection, alerts and visual monitoring are combined on one platform.

#### 3.3. Block diagram

The block diagram is shown in Fig. 1. The ESP32 is the central control unit. It receives the GPS data, monitors the vibration sensor, checks the geofence condition and controls the GSM module, the buzzer and the ESP32-CAM during a security event. The whole circuit is powered by a rechargeable battery through a regulated power supply.

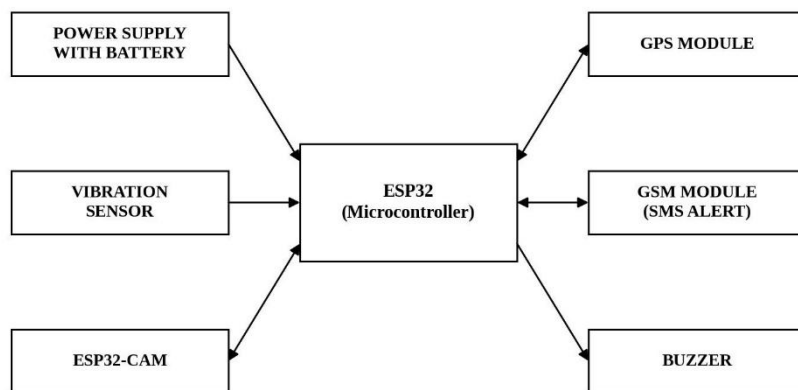


**Fig. 1 - Block diagram of the proposed luggage security and tracking system.**

### 3.4. Circuit diagram

The complete circuit diagram is given in Fig. 2. A rechargeable 7.4 V battery pack (two 18650 Li-ion cells in series) is connected through an ON/OFF switch to a DC-DC buck converter, which gives a regulated 5 V supply to the ESP32, the GPS and GSM modules, the vibration sensor and the ESP32-CAM. Capacitors C1 to C5 are provided across the supply rails to keep the voltage stable, especially during the current surge when the GSM module transmits. The GPS module is connected to the second hardware serial port (UART2, GPIO16/GPIO17) of the ESP32, the GSM module and the ESP32-CAM are interfaced through their TXD and RXD pins, and the OUT pin of the vibration sensor is read as a digital input.

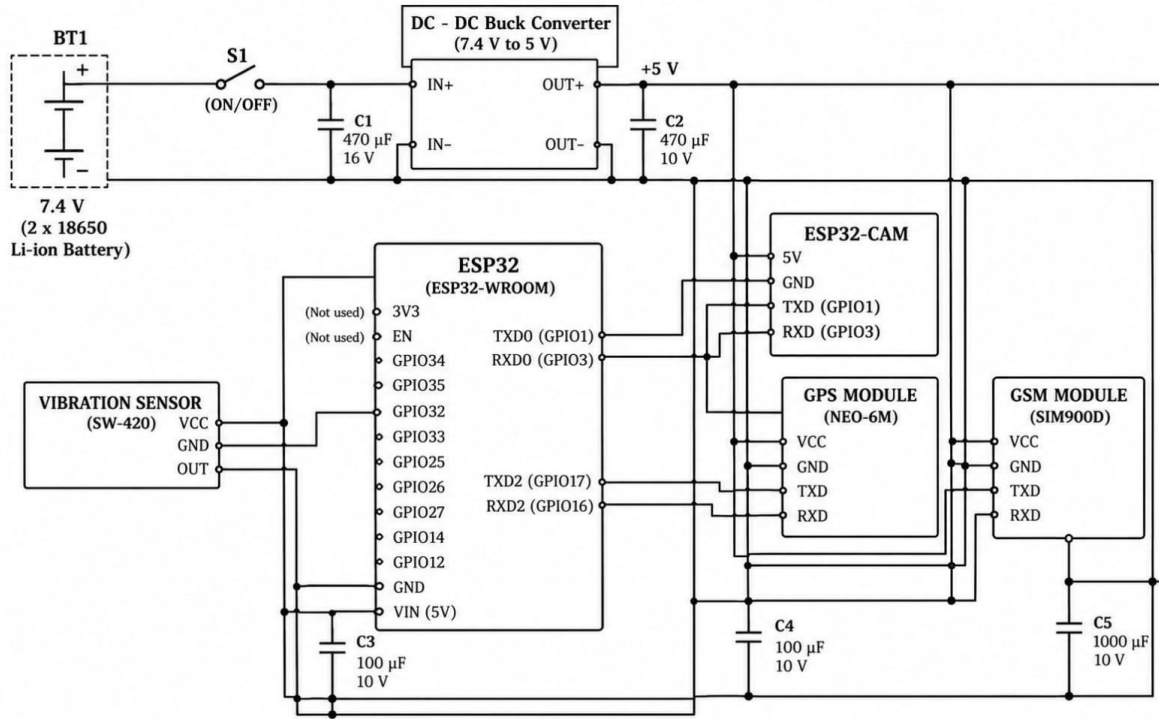


Fig. 2 - Circuit diagram of the entire system.

### 3.5. Working principle

When the system is switched on, the ESP32 reads the latitude and longitude of the luggage from the GPS module. A geofence of about 10 m is set around the authorized location or the position of the owner, and every new position is compared with it. If the luggage moves outside the geofence, the ESP32 identifies it as unauthorized movement and the GSM module sends an SMS with the current GPS location to the owner's registered mobile number.

The vibration sensor keeps watching the luggage for tampering. When abnormal vibration, a hard shock or forced opening crosses the set threshold, the ESP32 sounds the buzzer for a local warning, sends an SMS alert and triggers the ESP32-CAM to capture an image of the surroundings or the person handling the bag. The GPS coordinates are also uploaded to ThingSpeak so that the owner can review the history remotely.

### 3.6. Geofence distance calculation

To decide whether the luggage is inside the geofence, the distance between the present GPS position and the reference point is calculated. The great-circle distance between two points on the Earth is found with the haversine formula [13], given in (1) and (2).

$$a = \sin^2(\Delta\phi / 2) + \cos \phi_1 \cdot \cos \phi_2 \cdot \sin^2(\Delta\lambda / 2) \quad (1)$$

$$d = 2R \cdot \arcsin(\sqrt{a}) \quad (2)$$

where  $\phi_1$ ,  $\phi_2$  are the latitudes and  $\lambda_1$ ,  $\lambda_2$  are the longitudes of the two points in radians,  $\Delta\phi = \phi_2 - \phi_1$ ,  $\Delta\lambda = \lambda_2 - \lambda_1$ ,  $R$  is the mean radius of the Earth (about 6371 km) and  $d$  is the distance between the two points. If  $d$  is greater than 10 m, the ESP32 marks the luggage as outside the geofence.

### 3.7. Flowchart

The program flow is shown in Fig. 3. After initialization, the ESP32 continuously reads the GPS position, finds the distance  $d$  and compares it with 10 m. The vibration sensor is checked in every loop. When either event occurs the matching alert is sent and the loop repeats, so that the luggage is monitored continuously.

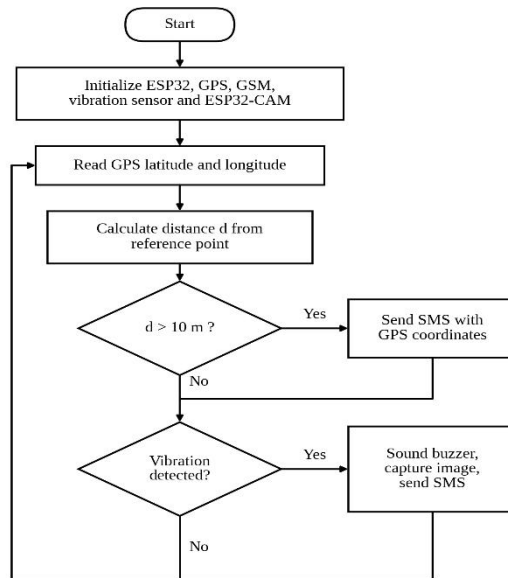


Fig. 3 - Flowchart of the proposed system.

## 4. Hardware and Software Implementation

### 4.1. Hardware components

The components used in the system and their main specifications are listed in Table 2. The ESP32-WROOM-32 has a dual-core processor running up to 240 MHz with built-in Wi-Fi and Bluetooth [14], which is enough to handle all the modules and the ThingSpeak upload.

Table 2 - Components used in the system

| Component        | Specification                                                | Function                               |
|------------------|--------------------------------------------------------------|----------------------------------------|
| ESP32 controller | ESP32-WROOM-32, dual-core 32-bit LX6, 240 MHz, Wi-Fi and BLE | Main controller of the system          |
| GPS module       | NEO-6M, UART, 9600 bps, up to 5 Hz update                    | Latitude and longitude of the luggage  |
| GSM module       | SIM900D, UART (TTL), SIM card                                | Sends location and alerts as SMS       |
| Vibration sensor | SW-420 with LM393, 3.3–5 V, adjustable threshold             | Detects vibration or tampering         |
| ESP32-CAM        | ESP32-S, OV2640 camera, 4 MB PSRAM, TF card slot, 5 V        | Captures image during a security event |
| Buzzer           | 5 V DC, 9 mA max, 3 kHz, 85 dB min                           | Audible warning                        |
| Power supply     | 2 × 18650 Li-ion (7.4 V), buck converter to 5 V              | Regulated 5 V supply                   |

### 4.2. Hardware prototype

The prototype was assembled inside a compact black enclosure so that it can be placed inside the luggage, as shown in Fig. 4. The ESP32-CAM is mounted on the top cover, the vibration sensor and the GPS module are fixed on the side of the enclosure, and the ESP32, GSM module, buzzer, buck converter and battery holder are arranged on a perforated board inside the enclosure. The GSM antenna is kept outside the enclosure.



(a) Prototype



(b) Internal view



(c) Top view

Fig. 4 - Hardware prototype of the luggage tracking system.

### 4.3. Software implementation

The firmware is written in Embedded C using the Arduino IDE and uploaded to the ESP32. The program has two main functions: `setup()`, which runs once and initializes the serial ports, the GPS and GSM modules, the vibration sensor pin and the ESP32-CAM, and `loop()`, which repeatedly reads the GPS position, checks the geofence, monitors the vibration sensor and sends alerts. The software is organized into the following blocks.

- **GPS data acquisition:** the NMEA sentences from the GPS module are read over UART and decoded with the TinyGPS++ library to get latitude and longitude.
- **Geofence check:** the haversine distance to the reference point is calculated and compared with the 10 m limit.
- **GSM alert messaging:** the GSM module is controlled with AT commands (AT+CMGS) sent over UART. The SMS contains the alert text and a Google Maps link made from the GPS coordinates.
- **Vibration monitoring:** the digital output of the SW-420 is read in every loop. On vibration the buzzer is switched on for two seconds, an SMS is sent and the camera trigger is activated.
- **Image capture:** the ESP32-CAM takes a photograph on the trigger and stores it on its micro-SD card, giving visual evidence along with the SMS.
- **Cloud monitoring:** the ESP32 connects to ThingSpeak [15] over Wi-Fi and uploads the latitude and longitude at an interval of 15 s, so that the history can be viewed remotely in addition to the SMS alerts.

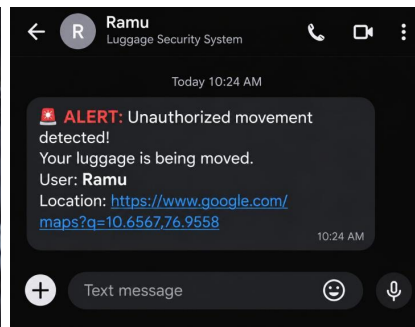
## 5. Results and Discussion

### 5.1. Hardware output

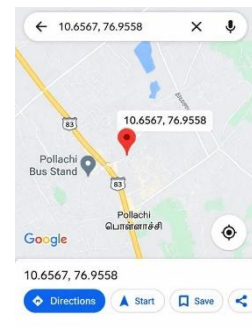
The prototype was tested by moving and opening the luggage. When tampering was detected, the ESP32-CAM captured the image shown in Fig. 5(a), which shows the person handling the bag. At the same time the owner received the SMS alert in Fig. 5(b), which gives the alert text, the user name and a Google Maps link with the GPS coordinates. Opening the link shows the position of the luggage on Google Maps, as in Fig. 5(c); the coordinates 10.6567, 76.9558 lie in Pollachi.



(a) Image captured by ESP32-CAM



(b) SMS alert on owner's mobile



(c) Location on Google Maps

Fig. 5 - Hardware output of the system.

### 5.2. System response

The response of the system for each event is summarized in Table 3.

Table 3 - Response of the system

| Event                                 | Response                                                       |
|---------------------------------------|----------------------------------------------------------------|
| Luggage inside geofence, no vibration | No alert; GPS position keeps updating                          |
| Luggage moves beyond 10 m             | SMS with current GPS coordinates is sent to the owner          |
| Abnormal vibration or forced opening  | Buzzer sounds, SMS is sent and the ESP32-CAM captures an image |
| Both events together                  | Alerts for both events are sent                                |

### 5.3. Advantages

- **Real-time location tracking:** GPS gives the current geographical location of the luggage.
- **Geofencing security:** an alert is generated when the luggage moves outside the predefined safe area.
- **Tamper detection:** the vibration sensor detects abnormal movement or possible tampering.
- **Immediate SMS alerts:** alerts reach the registered mobile number directly, without internet or a special application.
- **Camera monitoring:** the ESP32-CAM gives additional visual information during security events.
- **Remote monitoring:** the owner can monitor the luggage without continuous physical supervision.

### 5.4. Limitations

GPS position error of a few metres is not small compared with a 10 m geofence, and the GPS signal is weak inside buildings, so the geofence size and alert conditions should be chosen with this in mind. The SMS alerts need GSM network coverage and a SIM card with SMS balance, and the ThingSpeak upload needs a Wi-Fi connection.

### 5.5. Applications

The proposed system can be used for luggage security and tracking at airports, railway stations, bus terminals, hotels and other travel environments. The same unit can also be fitted to other valuables such as a laptop bag or a cash box.

## 6. Conclusion and Future Scope

A smart IoT-based luggage security and tracking system using GPS, GSM, geofencing, a vibration sensor and an ESP32-CAM has been designed and tested as a hardware prototype. The system informs the owner by SMS when the luggage leaves a zone of about 10 m, warns of forced opening with a buzzer and an alert message, and captures an image as visual evidence. It reduces the need for continuous manual supervision and gives several levels of protection in a single compact unit.

In future, the system can be improved with the following features: (i) a mobile application to show the luggage location, security status, alerts and tracking history; (ii) cloud storage of GPS coordinates and security events for remote monitoring, with live camera streaming; (iii) AI-based image processing to identify suspicious activity around the luggage; and (iv) a smart lock with biometric or electronic locking and low-power techniques to extend the battery life.

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## REFERENCES

- [1] O. Shobayo, A. Olajube, O. Okoyeigbo, and J. Ogbonna, "Design and implementation of an IoT based baggage tracking system," in *Information and Communication Technology and Applications (ICTA 2020)*, Commun. Comput. Inf. Sci., vol. 1350. Cham, Switzerland: Springer, 2021, pp. 618–631.
- [2] S. N. Paidimarry, C. K. K. Reddy, and L. G. Lolla, "Internet of Things enabled smart baggage follower with theft prevention," *J. Phys.: Conf. Ser.*, vol. 1950, no. 1, Art. no. 012002, 2021, doi: 10.1088/1742-6596/1950/1/012002.
- [3] P. Si, F. Wang, E. Sun, and Y. Su, "BEI-TAB: Enabling secure and distributed airport baggage tracking with hybrid blockchain-edge system," *Wireless Commun. Mobile Comput.*, vol. 2021, Art. no. 2741435, 2021, doi: 10.1155/2021/2741435.
- [4] S. Jain, S. Aithal, V. Allamsetty, S. K. S., N. Gobi, and R. Rathi, "Smart luggage tracking using IoT and GPS technology," *Int. J. Adv. Res. Comput. Commun. Eng. (IJARCCE)*, vol. 12, no. 4, Apr. 2023, doi: 10.17148/IJARCCE.2023.12403.
- [5] V. Dange, P. Shinde, N. Shinde, and P. Shelke, "Battery-powered and sensors based smart luggage vehicle with real time surveillance system using GPS, GSM and ESP32 camera modules," in *Proc. 3rd Int. Conf. Innov. Mech. Ind. Appl. (ICIMIA)*, 2023, doi: 10.1109/ICIMIA60377.2023.10425863.
- [6] M. Sreenivasulu, J. Tejitha, B. Dharani, and G. Sai Kiran, "Design and implementation of baggage tracking system using Arduino Uno," *Int. J. Multidiscip. Res. (IJFMR)*, vol. 6, no. 2, Mar.–Apr. 2024, doi: 10.36948/IJFMR.2024.v06i02.14256.
- [7] A. S. Sairam et al., "Cloud-enabled security for luggage protection through LSTM networks and IoT in contactless travel," in *Proc. IEEE Int. Conf. Smart Mach. Artif. Intell. (I-SMAC)*, 2024, pp. 163–168, doi: 10.1109/I-SMAC61858.2024.10714792.
- [8] "Smart lock for enhancing luggage security using Internet of Things," in *Proc. IEEE Int. Conf. Commun., Comput. Signal Process. (IICCCS)*, Sep. 2024, doi: 10.1109/IICCCS61609.2024.10763867.
- [9] J. Navya, G. N. Swamy, S. S. Sri, B. Pujitha, and S. Varun, "Smart luggage theft detection and GPS tracking system," in *Proc. 1st Int. Conf. Res. Develop. Inf., Commun., Comput. Technol. (ICRDICCT)*, 2025, pp. 101–107, doi: 10.5220/0013908800004919.
- [10] A. Gehlot, R. Singh, R. Mahala, V. K. Singh, and M. R. Gupta, "Internet of Things-enabled smart robotic baggage monitoring and tracking system for enhanced traveler convenience and security," *IAES Int. J. Robot. Autom.*, vol. 14, no. 2, pp. 290–300, 2025, doi: 10.11591/ijra.v14i2.pp290-300.
- [11] V. Rawool, A. Gorde, D. Raut, S. Sapkale, and S. Murari, "Design and simulation of a smart luggage bag with integrated tracking and security features," *Int. Res. J. Innov. Eng. Technol. (IRJIET)*, vol. 10, no. 2, pp. 50–55, Feb. 2026, doi: 10.47001/IRJIET/2026.102007.
- [12] R. A. Afgan, M. T. Salsabila, and W. Djatmiko, "Sistem pendeteksi getaran pada koper dengan sensor getaran SW420 dan modul SMS SIMA6 GSM berbasis mikrokontroler," *Autocracy: J. Otomasi, Kendali, Apl. Ind.*, vol. 7, no. 1, pp. 19–26, 2020, doi: 10.21009/autocracy.071.4.
- [13] R. W. Sinnott, "Virtues of the haversine," *Sky Telesc.*, vol. 68, no. 2, p. 159, 1984.
- [14] Espressif Systems, "ESP32-WROOM-32 datasheet," ver. 3.4, 2023. [Online]. Available: [https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-wroom-32_datasheet_en.pdf)
- [15] MathWorks, "ThingSpeak." [Online]. Available: <https://thingspeak.com>