Advanced Anti-Theft and Safety System for Vehicles Using Biometric Authentication

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***Abstract*—This paper presents an Advanced Anti-Theft and Safety System for two-wheelers that integrates biometric fingerprint authentication, passcode verification, and smart automation features to enhance vehicle security and rider safety. The system ensures that only authorized users can start the vehicle by verifying both fingerprint and passcode credentials. A servo motor-based automatic side stand system retracts the stand after successful authentication, reducing the risk of accidents due to human negligence. To further enforce safety, an IR sensor detects helmet usage, and ignition is blocked if the helmet is not worn. An ultrasonic sensor is used to detect unauthorized lifting or movement of the vehicle, triggering a buzzer alert for immediate theft prevention. The system also includes real-time SMS alert capability through a GSM 800L module and live location tracking via a GPS module, enabling continuous remote monitoring. This smart system is designed to be energy-efficient, cost-effective, and scalable for future integration with IoT and mobile applications, making it a robust solution for modern vehicle protection.**

1. INTRODUCTION

In recent years, the rise in vehicle thefts and road safety violations has highlighted the urgent need for smarter and more secure transportation systems. Two-wheelers, in particular, are often vulnerable due to their limited built-in security mechanisms. Traditional key-based ignition systems are prone to duplication, while manual safety habits such as retracting the side stand or wearing a helmet are frequently overlooked by riders, leading to accidents and safety risks.

To address these issues, this project proposes an Advanced Anti-Theft and Safety System for Two-Wheelers that integrates biometric authentication, passcode verification, and intelligent safety automation. The system is designed to authenticate the rider using a fingerprint sensor and a numeric keypad, ensuring that only authorized users can start the vehicle. It further enhances safety by using an IR sensor for helmet detection, and a servo motor to implement automatic side stand retraction, preventing accidents caused by negligence.

To tackle theft attempts, an ultrasonic sensor monitors unauthorized lifting or movement of the vehicle and immediately triggers a buzzer alert. Additionally, a GSM 800L module is used to send real-time SMS notifications to the vehicle owner, and a GPS module allows for live location tracking of the vehicle. The system is powered by an ESP32 microcontroller, which offers low power consumption, built-in wireless communication, and scalability for future upgrades.

This proposed solution is cost-effective, energy-efficient, and highly practical, providing a complete security and safety system suitable for modern two-wheelers, especially in developing smart city infrastructures.

1.1 OBJECTIVE

The primary objective of this project is to design and implement an Advanced Anti-Theft and Safety System for vehicle using biometric authentication and smart automation technologies. The system aims to enhance vehicle security and rider safety by integrating both preventive and responsive features.

The specific objectives include:

- To prevent unauthorized access using fingerprint authentication and passcode verification.
- To ensure rider safety by enforcing helmet detection before allowing vehicle ignition.
- To implement an automatic side stand retraction system using a servo motor to prevent accidents due to rider negligence.

- To detect unauthorized vehicle movement or lifting using an ultrasonic sensor and activate a buzzer alert.
- To send real-time SMS alerts to the vehicle owner during theft attempts using a GSM 800L module.
- To provide live vehicle tracking using a GPS module for continuous monitoring.
- To develop a system that is energy-efficient, cost-effective, and scalable for future enhancements such as mobile app or IoT integration.

1.2 ADVANTAGES

Enhanced Security: Dual-level authentication using a fingerprint sensor and passcode keypad ensures that only authorized users can access the vehicle.

Rider Safety Enforcement: An IR sensor ensures helmet detection, preventing vehicle ignition unless the rider is wearing a helmet, promoting safer driving habits.

Automatic Side Stand Retraction: The system uses a servo motor to automatically retract the side stand after authentication, reducing the risk of accidents caused by rider negligence.

Real-Time Theft Detection: An ultrasonic sensor monitors for unauthorized lifting or movement, triggering an immediate buzzer alert.

SMS-Based Alerts: In case of a security breach, the GSM 800L module sends real-time SMS notifications to the vehicle owner.

Live GPS Tracking: The integrated GPS module enables real-time location tracking of the vehicle, useful during theft or emergencies.

Energy-Efficient Design: The system is powered by the ESP32 microcontroller, offering low power consumption and integrated Wi-Fi/Bluetooth capabilities.

Cost-Effective and Scalable: The system uses affordable components and is suitable for widespread deployment in low- and mid-range two-wheelers, with the potential for future IoT or app integration.

2. LITERATURE REVIEW

1.The paper titled *"Advanced Fingerprint and Passcode Based Anti-Theft Vehicle System,"* published in the *Proceedings of the 3rd IEEE International Conference on Artificial Intelligence for Internet of Things (AIIoT 2024)* by P. M. Vijayan, Puligundla Vandana, Maka Yogeswar, Siva Sravan Kumar, Ayyappa Vijayalakshmi, and Rallapalli Vishnu, presents a dual-authentication vehicle security system that utilizes both fingerprint recognition and passcode verification for ignition control. Implemented on an Arduino MEGA, the system includes a camera module to capture images during unauthorized access attempts, thereby enhancing vehicle access monitoring. While this approach provides basic theft protection, it lacks real-world safety features such as helmet detection, automatic side stand retraction, and real-time GPS tracking with GSM alerts. Despite these limitations, the paper lays a strong foundation for integrated, user-authenticated vehicle access systems and directly supports the motivation for the multi-layered, automated safety enhancements implemented in the present work.

2.The paper titled *"Vehicle Anti-Theft System Using Fingerprint & Passcode with Speed Control and Obstacle Detection,"* published in *IJRASET*, Volume 12, Issue V, May 2024, by Shivesh Mehta, Swadha Srivastava, Tapesh Pratap Singh, and Geetanjali Raj, proposes a vehicle protection system integrating fingerprint authentication, passcode entry, speed regulation, and ultrasonic obstacle detection. Built on Arduino Uno, the system also includes IR sensors and a buzzer for safety alerts, with a server interface for speed notifications. Although the project successfully combines access control with driving safety features, it does not enforce helmet usage, implement automatic side stand retraction, or support real-time GSM/GPS-based tracking. The current project improves on this by offering a more holistic and automation-based approach to both rider safety and theft prevention.

3.The paper titled *"Biometric Authentication for Vehicle Security System Using Raspberry Pi,"* published in *IJARCCE*, Volume 13, Issue 5, May 2024, by Sudarshan T. B. Ramana, Rohini H. N., Priyanka N., Ankitha V., and Rashmi M. Hullamani, describes a high-security vehicle system that integrates face recognition, fingerprint scanning, and keypad-based password authentication using Raspberry Pi. The system uses a servo motor to unlock the vehicle and an ultrasonic sensor to detect lifting during theft attempts, with alerts sent via GPS and email. Although it delivers strong access control, it lacks essential safety integrations like helmet detection, side stand automation, and uses power-intensive hardware, which limits practicality in two-wheelers. In contrast,

the proposed system focuses on low-power ESP32 control, integrated GSM alerts, and safety features designed for real-world use.

4.The paper titled *"Vehicle Theft Control System Using Fingerprint Sensor and IoT Devices,"* published in *IJARSET*, Volume 9, Issue 11, November 2022, by Diksha Malhotra, Manjot Kaur Bhatia, Aprajita Shahi, and Jai Narula, presents an IoT-based solution that combines fingerprint authentication with RFID access, and uses Intel Galileo Gen2, GPS, GSM, camera monitoring, and vibration sensors to detect and respond to theft attempts. Real-time alerts are sent to the owner via cloud-based platforms. While the system offers rich IoT integration and alerting, it omits critical safety enforcement such as helmet detection, side stand retraction, and is dependent on high-cost components. The current project enhances its practicality by using affordable, energy-efficient modules like ESP32, while integrating safety-focused automation.

3. EXISTING SYSTEM

In current two-wheeler security systems, most vehicles rely on traditional key-based ignition mechanisms and manual safety practices. The security is limited to mechanical locks or remote key systems, which are vulnerable to key duplication, physical tampering, and theft. Such systems do not provide real-time monitoring or notification features, making them ineffective in responding promptly to unauthorized access. Moreover, rider safety is not enforced. Riders can start and ride the vehicle without wearing a helmet, increasing the risk of head injuries during accidents. Similarly, the side stand retraction is manual, and riders often forget to lift the stand before riding, which can lead to serious accidents, especially at turns. Some high-end vehicles offer additional features such as mobile app locking or GPS tracking, but these solutions are generally expensive and not accessible to common users. Additionally, existing systems do not include theft detection through motion sensing or biometric verification, which limits their effectiveness in real-world scenarios.

Thus, there is a strong need for a cost-effective, automated, and intelligent vehicle security system that not only prevents theft but also ensures rider safety — which is addressed in the proposed system.

4. PROPOSED SYSTEM

The proposed system is designed to enhance both vehicle security and rider safety through a combination of biometric authentication, passcode verification, and smart automation technologies. It eliminates the limitations of traditional ignition systems by integrating multiple layers of protection using low-cost, energy-efficient hardware.

A fingerprint sensor and a 4x4 keypad are used to implement dual authentication, ensuring that only authorized users can start the vehicle. To promote rider safety, the system uses an infrared (IR) sensor to detect helmet usage, and ignition is permitted only if the rider is wearing a helmet.

One of the key features of the system is the automatic side stand retraction, implemented using a servo motor. This feature prevents riders from operating the vehicle while the side stand is down, thereby reducing the risk of accidents.

To prevent theft, an ultrasonic sensor is used to detect unauthorized lifting or movement of the vehicle. When triggered, the system activates a buzzer alarm to alert nearby individuals and sends an SMS alert to the owner using the GSM 800L module. The GPS module provides real-time location tracking of the vehicle, enhancing post-theft recovery.

All modules are controlled by the ESP32 microcontroller, which supports low power consumption and offers built-in Wi-Fi and Bluetooth for future scalability. The overall system is cost-effective, energy-efficient, and practical for use in two-wheelers, especially in urban and smart transportation environments.

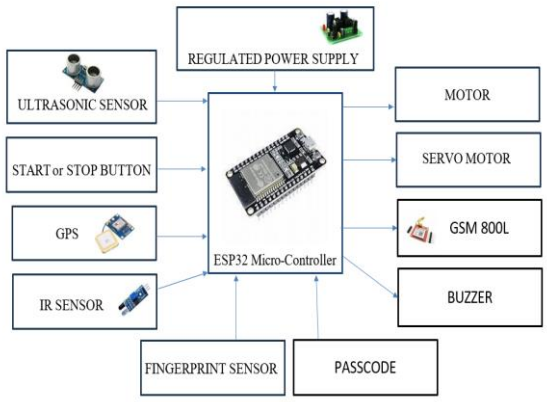


FIG 1. *PROPOSED BLOCK DIAGRAM*

5.SYSTEM REQUIREMENTS

5.1 Hardware Requirements

ESP32 Microcontroller – Main control unit (Wi-Fi and Bluetooth enabled, energy-efficient)
Fingerprint Sensor – For biometric authentication
4x4 Keypad – For passcode input
IR Sensor – For helmet detection before ignition
Servo Motor – For automatic side stand retraction
Ultrasonic Sensor (HC-SR04) – For movement/lifting detection (theft attempt detection)
GSM Module (SIM800L) – For sending real-time SMS alerts
GPS Module (NEO-6M) – For live vehicle location tracking
Buzzer – For sounding alarm during unauthorized movement
Motor (for simulation) – Representing ignition system
Motor Driver Circuit – To control motor safely
Start/Stop Button – For manual ignition control after authentication
Regulated Power Supply – To provide stable 3.3V/5V DC to the components
Connecting Wires, Breadboard or PCB Board – For hardware assembly

5.2 Software Requirements

Arduino IDE – For writing and uploading code to ESP32
Embedded C Programming Language – For programming logic and hardware control
ESP32 Board Package for Arduino IDE – To support ESP32 coding
GSM and GPS Libraries – For managing communication with SIM800L and NEO-6M modules
Serial Monitor (in Arduino IDE) – For testing and real-time debugging
Windows 7/8/10/11 PC or Laptop – For software development and uploading

5.3 Hardware Description

1.ESP32 Micro-controller

Function: Acts as the central processing unit of the system, interfacing with all modules.
Specifications:

- Dual-core Tensilica LX6 processor
- Wi-Fi and Bluetooth built-in
- 32 GPIO pins
- Operating Voltage: 3.3V
- Flash Memory: Up to 16MB
- Excellent for IoT and wireless communication

2.Fingerprint sensor

Function: Provides biometric authentication to prevent unauthorized vehicle access.
Specifications:

- Optical type sensor
- Image Resolution: 500 dpi
- Operating Voltage: 3.6–6V
- Stores multiple fingerprint templates

3.Passcode

Function: Passcode-based second-layer authentication.
Specifications:

- 4x4 Matrix Keypad
- Membrane type
- Durable and lightweight

4.IR sensor

Function: Helmet detection before ignition.
Specifications:

- Range: 2–30 cm
- Digital output
- Operating Voltage: 3.3–5V

5.Servo motor

Function: Controls automatic side stand retraction.
Specifications:

- Rotation: 180°
- Operating Voltage: 4.8–6V
- Torque: ~3.5 kg/cm

6.Ultrasonic sensor

Function: Detects vehicle movement or lifting to trigger theft alerts.
Specifications:

- Range: 2 cm to 400 cm
- Accuracy: ±3 mm
- Operating Voltage: 5V

7.Buzzer

Function: Alarm during unauthorized movement or access.
Specifications:

- Type: Piezoelectric
- Voltage: 3V–12V
- Sound level: ~85 dB

8.GSM SIM800L

Function: Sends real-time alerts to the vehicle owner.
Specifications:

- Frequency: 850/900/1800/1900 MHz
- Voltage: 3.4–4.4V
- Supports SMS and GPRS

9.GPS

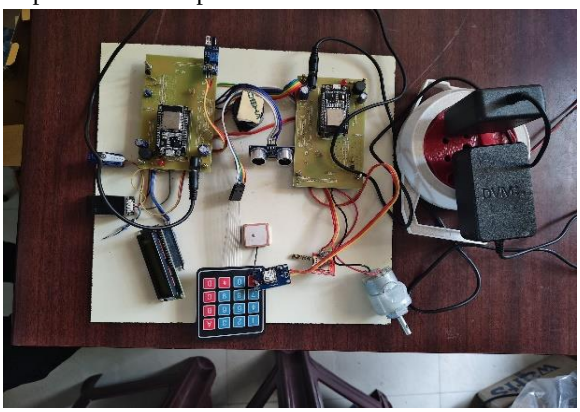
Function: Provides real-time location tracking of the vehicle.
Specifications:

- Accuracy: 2.5 meters
- Baud Rate: 9600
- Voltage: 3.3–5V

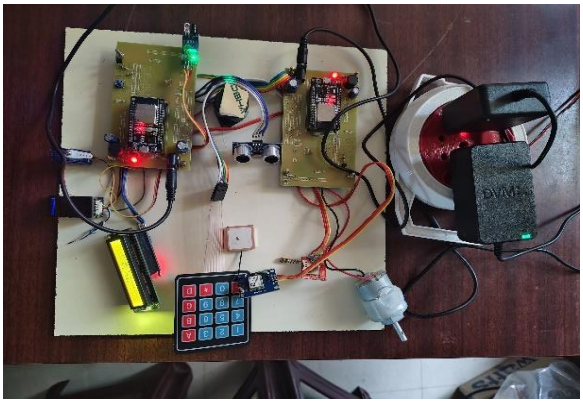
6. RESULT ANALYSIS

The development of an advanced anti-theft and safety system for vehicle required in-depth research into existing vehicle security mechanisms, biometric technologies, and embedded system platforms. A comprehensive analysis of current solutions revealed significant limitations in affordability, automation, and rider safety enforcement.

Experimental setup



Experimental output



7. CONCLUSION

This project successfully implements an Advanced Anti-Theft and Safety System for two-wheelers by combining biometric fingerprint authentication, passcode verification, automatic side stand retraction, and helmet detection.By introducing ultrasonic-based theft detection, real-time GSM alerts, and GPS tracking, the system offers complete protection against unauthorized access and ensures rider safety.

The use of smart automation reduces human errors like forgetting to retract the side stand or riding without a helmet. The system is designed to be cost-effective, energy-efficient, user-friendly, and scalable for future enhancements such as mobile app control and IoT connectivity.

Overall, this project provides a reliable, intelligent, and practical solution for modern vehicle security and rider safety, making it highly suitable for personal, commercial, and smart city applications.

8. FUTURE ENHANCEMENT

Mobile Application Integration: A custom mobile app can be developed to allow users to remotely lock/unlock the vehicle, view GPS location, receive alerts, and monitor system status in real time via Bluetooth or cloud communication.

Cloud-Based Data Logging: Vehicle usage data, theft alerts, and location history can be stored in a secure cloud server, enabling centralized monitoring and data analytics for maintenance or law enforcement purposes.

Voice Command Activation: Integration of voice recognition modules can enable voice-controlled ignition and system functions, adding convenience and accessibility, especially for differently-abled users.

Face Recognition Authentication: Adding a camera module for facial authentication can provide an additional layer of security and reduce the reliance on physical input methods.

Accident Detection and Auto-Alert System: Accelerometers or gyroscopes can be used to detect vehicle crashes, triggering automatic alerts to emergency contacts along with live GPS coordinates.

Geo-Fencing Feature: Implementation of a geo-fence boundary would allow the system to trigger alerts when the vehicle moves beyond a user-defined safe zone.

Solar-Powered Operation: Integration of a compact solar charging unit can provide energy autonomy and extend battery life, making the system more sustainable and eco-friendlier.

Mobile OTP-Based Remote Unlocking: Temporary access can be granted to trusted users via one-time passcodes (OTP) sent to mobile phones for shared or rental vehicles.

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