SIMULATED DESIGN OF A REAL-TIME VEHICLE TRACKING AND REMOTE ENGINE SHUTDOWN SYSTEM.

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CERTIFICATION

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in the department of Mechatronics Engineering, Faculty of Engineering, University of Benin, Benin City. Edo State, Nigeria. In partial fulfillment of the requirement for the award of Bachelor of Engineering, (B.Eng.) in Mechatronics Engineering.

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DEDICATION

This project work is dedicated to God Almighty who granted us the courage and patience to perform and carry out this project work, and without his help we would not have achieved what we have done so far.

Also, this project is dedicated to our parents for their great support, guidance, sacrifice and prayers throughout the duration of our course of study in this great institution of Learning.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS.

GPS – Global Positioning System

GSM – Global System for Mobile Communications

GPRS – General Packet Radio Service

SMS – Short Message Service

IoT – Internet of Things

ECU – Electronic Control Unit

OBD-II – On-Board Diagnostics, version II

RF – Radio Frequency

RFID – Radio Frequency Identification

SIM – Subscriber Identity Module

B.Eng. – Bachelor of Engineering

MATLAB – Matrix Laboratory

IDE – Integrated Development Environment

ESP32 – A low-cost, low-power system on a chip microcontroller

LED – Light Emitting Diode

V – Volts

mA – Milliamps

Hz – Hertz

MCU – Microcontroller Unit

PCB – Printed Circuit Board

SYMBOLS

V – Voltage (Volts)

A – Current (Amperes)

mA – Milliampere

Ω – Resistance (Ohms)

°C – Temperature (Degrees Celsius)

% – Percentage

→ – Indicates direction or signal flow

± – Plus-minus (used in tolerance or error margins)

μF – Microfarads (Capacitance)

kHz – Kilohertz (Frequency)

s – Seconds (Time)

ABSTRACT

Vehicle theft and unauthorized access to people's vehicles remain critical challenges worldwide, with developing countries such as Nigeria experiencing a rising incidence of automobile-related crimes due to inadequate security measures and poor enforcement of tracking technologies. Conventional anti-theft solutions such as alarms, mechanical locks, and immobilizers often fail against organized theft operations using signal jammers and key cloning devices. This project focuses on the simulated design of a real-time vehicle tracking and remote engine shutdown system using MATLAB Simulink and proteus as cost-effective development platforms. The proposed system integrates three primary components: a GPS module for continuous vehicle location monitoring, a GSM communication link for transmitting control signals, and a relay-based engine cutoff mechanism to remotely immobilize the vehicle when unauthorized movement is detected.

The simulation model evaluates the system's performance in terms of location accuracy, communication efficiency, and response speed, which are critical factors in environments where GSM coverage can be inconsistent, as is common in several regions of Nigeria. By leveraging Simulink's block-based modeling, the design eliminates the need for immediate physical prototyping, reducing costs while allowing early validation of functional behavior. Results indicate that the system can track vehicle position accurately and execute engine shutdown commands within seconds, offering a practical solution for private vehicle owners, logistics companies, and government agencies managing various transportation fleets.

This study demonstrates the potential of integrating real-time tracking with active control to enhance vehicle security in Nigeria and similar developing markets. It further provides a scalable platform for future extensions, including Internet of Things (IoT) connectivity, cloud data storage, and encrypted communication protocols to counter network vulnerabilities and improve reliability under real-world condition.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study: Evolution of Vehicle Tracking System.

Motor-vehicle theft is a major security problem in Nigeria. The National Bureau of Statistics' Crime Experience and Security Perception Survey (CESPS) and multiple national media reports place annual motor-vehicle thefts in the order of 1–1.6 million incidents for the May 2023–April 2024 reference period, highlighting a high incidence of vehicle-related crime nationwide. [NBS Crime Experience and Security Perception Survey (CESPS) 2024, covering May 2023–April 2024].

Vehicle tracking technologies has evolved from the simple mechanical solutions to advanced electronic and satellite-based systems. Initially, automobile security relied on physical deterrents such as steering locks, alarms, and ignition cut-off switches. These methods offered limited protection as they could be bypassed by experienced thieves. The modern era of vehicle tracking began in the late 20th century with the introduction of radio frequency (RF) transmitters. Early tracking systems used RF signals to locate stolen vehicles within a limited range. Although effective for local recovery, these systems required specialized tracking equipment and were constrained by distance and line-of-sight limitations. (www.researchgate.net/publication/328582731A_Survey_on_Vehicle_Security_Systems_Approaches_and_Technologies).

The deployment of the Global Positioning System (GPS) in the 1990s transformed vehicle tracking. Commercial GPS-based systems enabled real-time location monitoring across vast geographic areas without specialized recovery teams. By combining GPS with cellular networks such as GSM, these systems could transmit vehicle coordinates to monitoring centers or mobile devices, allowing rapid response to theft incidents. Further advancements integrated vehicle tracking with Geographic Information Systems (GIS) for route visualization, fleet management, and automated reporting. In parallel, engine immobilization technologies were developed, allowing authorized users to remotely disable a vehicle once its location was confirmed. These solutions improved recovery rates and provided new tools for logistics, law enforcement, and personal security.

In developing nations such as Nigeria, widespread use of affordable smartphones and expanding mobile network coverage have accelerated adoption of GPS/GSM-based vehicle security solutions. However, challenges such as inconsistent signal quality, limited technical infrastructure, and high implementation costs have slowed nationwide deployment. This context underscores the importance of simulated designs, such as those created in MATLAB Simulink, to validate system performance before full-scale implementation. The shift from passive theft deterrence to active, real-time monitoring and control marks a significant milestone in automotive security. This evolution lays the foundation for systems that not only track vehicles but also allow remote interventions, ensuring faster recovery and enhanced protection against theft. (World Journal of Advanced Research and Reviews, 2023, 20(02), 441–453).

With the advent of mobile networks and rapid miniaturization of electronics in the 2000s, vehicle tracking devices became affordable and widely deployed. Systems evolved beyond simple position monitoring to include telemetry data, driver behavior analysis, geofencing alerts, and even remote immobilization capabilities. Today, advanced systems integrate GPS, GSM, Internet of Things (IoT) protocols, and cloud-based platforms, enabling seamless global tracking and control.

In Nigeria and other developing countries, vehicle tracking adoption grew out of the urgent need to address high rates of vehicle theft, carjacking, and unregulated transport operations. Insurance companies, fleet managers, and security agencies now demand robust tracking solutions that combine real-time monitoring with active intervention mechanisms, such as remote engine shutdown. However, deploying these systems in Nigeria faces unique challenges, including inconsistent GSM coverage, poor infrastructure, and high equipment costs. (Car Tracker Nigeria KANDB, 2021).

1.2 Problem Statement

Vehicle theft has become a major concern globally, with significant financial losses to individuals, companies, and governments. In Nigeria, the problem is compounded by weak surveillance infrastructure, delayed law enforcement response, and limited adoption of modern security technologies. Conventional anti-theft measures such as mechanical locks, alarms, and manual engine immobilizers are easily bypassed by organized criminals using advanced tools.

Even when tracking devices are installed, most only provide location information without the ability to actively control the vehicle. Recovery is delayed when authorities must physically reach the vehicle, allowing thieves to disable or destroy the tracking unit. Furthermore, building and testing real-world vehicle control systems is expensive and time-consuming. Without prior simulation, there is a high risk of design flaws, integration errors, and hardware damage during early development. These challenges create a pressing need for a low-cost, accurate, and remotely controllable system that can be validated virtually before physical deployment.

1.3 Aim and Objectives

Aim:

To design and simulate a reliable, real-time vehicle tracking and remote engine shutdown system using MATLAB-Simulink and proteus to validate performance before hardware implementation.

Objectives:

1. To develop a GPS-based vehicle tracking model capable of continuously reporting accurate location data.
2. To integrate GSM or GPRS modules within the simulation for sending and receiving remote shutdown commands.

3. To model an electronic relay-based engine cutoff mechanism within Simulink to demonstrate immobilization logic.
4. To analyze and evaluate system performance, including response time, accuracy, and stability under various simulated operating conditions.
5. To establish a simulation framework that minimizes cost and risk in subsequent physical prototyping.

1.4 Advantages of the Study

1. **Improved security:** Provides the ability to track and immobilize vehicles in real time, reducing theft and increasing recovery rates.
2. **Cost-effective development:** Using Simulink eliminates the need for expensive early-stage prototypes, lowering development costs.
3. **High flexibility:** The simulated system can be adapted to different vehicle types, network conditions, and user requirements before actual deployment.
4. **Scalability:** The design can be extended to include additional features such as geofencing, cloud-based control, or integration with Internet of Things (IoT) platforms.
5. **Educational value:** Demonstrates how simulation tools can accelerate engineering design cycles while providing insight into the behavior of cyber-physical systems.

1.5 Limitations

1. **Simulation vs reality gap:** Simulated models cannot fully replicate environmental noise, hardware imperfections, or unexpected real-world conditions.
2. **Network dependence:** The system's reliability is limited by GSM or GPRS signal availability, which is inconsistent in rural or remote areas of Nigeria.
3. **No hardware verification:** Since the study focuses solely on software simulation, practical challenges such as power consumption, heat dissipation, and vibration resistance are not addressed.

4. **Potential cyber vulnerabilities:** While not implemented in this project, remote control systems in real deployments must address security risks such as signal interception or unauthorized access.

1.6 Scope of the Study

This study is limited to the **design and simulation phase** of a vehicle tracking and remote engine shutdown system. MATLAB Simulink and Proteus 8 are used exclusively as the modeling platform, allowing a detailed functional validation of GPS location tracking, GSM command transmission, and relay-based engine control logic. No physical hardware implementation is performed at this stage. The focus is on demonstrating how these components interact in real time and assessing performance metrics such as shutdown delay and location accuracy. Cost analysis, large-scale deployment, and ruggedization of hardware are beyond the scope of this work but form potential areas for future research.

CHAPTER TWO:

LITERATURE REVIEW

Technological advancements are accelerating (developing), and businesses are striving for new market share. Nevertheless, all those developments are aiming for the same purpose in which to make the user's life easier, to assure their safety, and to safeguard the environment. These ideas are also applied to automobiles and motorcycles. A car's security system is fitted to deter theft and ensure that the vehicle is always safe and secure. There has been a slew of recent attempts concerning car networking, whether between vehicles or within a vehicle.

This project mainly will be discussing regarding the alternatives offered for extra safety and precaution and further facilitates car and motorcycle use. This smart control is a system used to control the vehicle system by using a mobile phone. Among the system that can be controlled is to turn off and turn on the vehicle engine automatically. These smart controls are intended to facilitate the users to access their own vehicles remotely via the internet. Sometimes, vehicles owner tends to misplace their car key or motorcycle key which caused further problems in their life. Thus, this project aimed to solve and ease the problem. This system incorporates the usage of micro-controllers and electronic devices such as relays. An android smartphone application that connects with the integrated development environment (IoT) platform to communicate with the ESP32 is developed to control the vehicle system securely via the internet. Existing vehicle systems are now increasingly sophisticated in the market. But there are some systems that are not available in commercial vehicles but in expensive vehicles.

Vehicle theft cases recorded in Nigeria exceeded 1.5 million in a single year, with the North-West and rural areas being the most affected regions. According to statistics, Nigeria falls among list of countries in the world of car theft. The objective of this project is to study IoT (Internet of Things) safety systems in automotive applications. The second is to design an engine start-stop system and tracking for vehicles and lastly to analyze battery voltage, GPS location data, and engine start-stop system from the vehicles with safety futures.

2.1 Existing Remote Vehicle Tracking Technologies.

1. **GPS-Based Vehicle Tracking Systems**

   GPS technology determines vehicle location using satellite triangulation and transmits data to a monitoring center. Globally, limitations include signal blockages in tunnels, multipath errors in urban canyons, and dependence on internet or GSM coverage. In Nigeria, challenges such as inconsistent mobile network availability, high subscription costs, and vulnerability to jamming reduce effectiveness. Maduka, N. C., & Ibrahim, M. H. (2023). *Microcontroller-based vehicle tracking system using GPS and GSM module: A mini review*. International Journal of Science for Global Sustainability, 9(2), 154–163.

2. **GSM/GPRS/SMS Tracking Systems**

   These systems transmit vehicle location data via SMS or GPRS. They are low-cost but suffer from latency and limited bandwidth globally. In Nigeria, unstable cellular connectivity, frequent power outages at telecommunication towers, and high operation costs restrict reliability. Afolayan, I., & Idachaba, F. (2023). *Developing a GSM-GPS based tracking system: Vulnerable Nigerian school children as a case study*. In *Information and Communication Technology and Applications* (pp. 553–562). Springer.

3. **RFID-Based Tracking Systems**

   RFID is used in controlled zones such as toll gates or parking lots. It cannot provide continuous tracking since it depends on fixed readers. Globally, it is limited by short range and infrastructure requirements. In Nigeria, cost of deployment and low adoption hinder large-scale use. Kamel, M. B. M., Alwan, S. A., & Al-Sherbaz, A. (2015). *Real-time GPS/GPRS based vehicle tracking system*. International Journal of Engineering and Computer Science, 4(4), 1125–1131.

4. **Satellite Communication-Based Tracking**

Satellite systems like Inmarsat and Iridium provide wide-area coverage beyond GSM networks. Globally, their adoption is limited by high hardware cost and subscription fees. In Nigeria, affordability and lack of local expertise remain barriers. Akanda, N. I., Rahman, M. S., & Hasan, M. K. (2023). *Cost-effective and user-friendly vehicle tracking system using GPS and GSM technology based on IoT*. International Journal of Electrical and Computer Engineering, 13(2), 1979–1989.

5. **IoT-Based Vehicle Tracking Systems**

IoT integrates GPS, GSM, and cloud computing to enable real-time monitoring and analytics. Globally, it faces issues such as cybersecurity vulnerabilities, data privacy, and dependence on internet quality. In Nigeria, high cost of IoT hardware, limited 4G penetration, and low awareness among users are major constraints. Ikpe, A. E., Ekanem, I. I., & Ohwoekevwo, J. U. (2023). *Integration of Internet of Things in conventional vehicle technology and its synergy with vehicle telematics systems and fleet management sequence*. Sustainable Internet of Things, 1(1), 27–40.

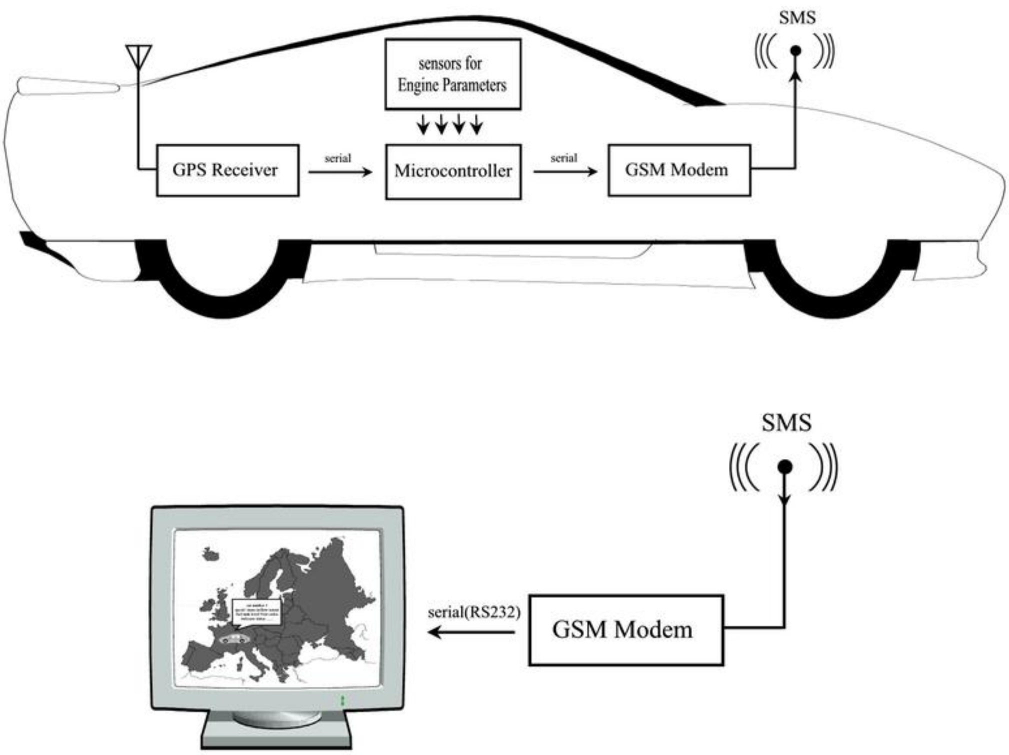

Fig 2.1 System Architecture: GPS tracking and GSM modules.

2.1 System Integration Into Vehicles:

We designed a remote ignition and tracking prototype that combines GPS, GSM, a micro-controller, and relay outputs to monitor vehicle location and permit authorized remote control functions. We checked a vehicle to see how this system can be integrated. The Toyota Corolla 2004 model was the exact vehicle type we used. The system reads vehicle state, sends position and telemetry over GSM to a secure backend which is connected to our mobile device for easy monitoring, and enforces safety rules and multi-factor authorization before any remote action. The design prioritizes non-invasive integration, fusing, and tamper detection so it is safe for demonstration.

Fig 2.2 Checking the car ignition mechanism

The Image above shows how we carried a test on the vehicle to see how the system can be integrated into a real car and how a car ignition system works._When the car is started, the battery supplies 12 V power to the starter circuit. Turning the key sends a signal through the ignition switch, and the starter solenoid closes the high-current path to the starter motor. The starter motor turns the engine's crankshaft so the pistons begin moving. As the crankshaft turns, sensors tell the engine control unit the exact piston position. The ECU then controls fuel injection and triggers the ignition coils to create high voltage for the spark plugs. Each spark plug fires at the right moment, igniting the air-fuel mixture inside the cylinders. Once combustion begins, the engine starts running on its own power. At that point, the alternator takes over supplying electrical power and recharges the battery. When you switch the engine off, the ECU stops sending fuel and stops triggering the coils, so combustion ends and the engine comes to a stop.

We aim to integrate a relay between the car's 12V battery and the starter motor so we can remotely cut off power to the starter motor so when there is an unauthorized access, the car would not be turned on. We also tested the car battery voltage because we aim to tap current from there to power our GPS-GSM system using a buck converter to reduce it from 12v to 5v that would be required for our embedded system.

Fig 2.3 Checking Car Battery voltage.

For the remote tracking, we checked the car to find the best enclosure suitable for the electronic mount. The GPS requires an out - door usage to get signals so we extended the antenna outwards close to the windshield area to get maximum signal strength while every other part of the system was enclosed inside.

Fig 2.4 Finding the right location to mount the GPS

2.2 COMPARISONS OF MAJOR TRACKING TECHNOLOGIES.

To better understand the strengths and weaknesses of different tracking methods, a comparative analysis of major vehicle tracking technologies is presented. The comparison highlights their operating principles, global limitations, and context-specific challenges in Nigeria. This provides a clear basis for justifying the simulated design of a more reliable and cost-effective real-time vehicle tracking and remote engine shutdown system.

Technology	Operation Principle	Global Limitations	Nigerian Limitations	Reference
GPS	Uses satellites to determine vehicle position and transmits data via GSM/Internet	Signal blockage in tunnels, multipath errors in cities, dependence on internet/GSM	Inconsistent mobile network, high data cost, GPS jamming/spoofing	Maduka & Ibrahim (2023)
GSM/GPRS/SMS	Sends vehicle coordinates over mobile network via SMS or GPRS	Latency during poor network, limited bandwidth	Unstable GSM coverage, frequent power outages at base stations, high subscription cost	Afolayan & Idachaba (2023)
RFID	Vehicle carries RFID tag read at checkpoints	Short range, infrastructure dependent, unsuitable for continuous tracking	High infrastructure cost, low adoption beyond tolls/parking	Kamel et al. (2015)
Satellite Comm.	Communicates directly with satellites (e.g., Inmarsat, Iridium)	Expensive hardware and subscription, complex deployment	Too costly for general users, lack of local expertise	Akanda et al. (2023
IoT-Based	Integrates GPS, GSM, and cloud computing for real-time analytics	Cybersecurity risks, data privacy concerns, dependence on internet	Limited 4G coverage in rural areas, high IoT device cost, low awareness	Ikpe et al. (2023)

Table 2.1 comparison of major tracking technologies

2.3 Factors Affecting Remote Monitoring

Remote monitoring systems are influenced by several technical and environmental factors. Network availability and reliability play a major role, since poor GSM or internet coverage leads to data delays or loss. Power supply stability is critical, as both devices and communication infrastructure must remain active. Hardware quality and calibration affect the accuracy of sensors and GPS modules. Environmental conditions such as tall buildings, tunnels, or dense foliage can obstruct signals. Finally, cost and scalability influence adoption, especially in developing regions where high subscription fees and limited infrastructure reduce system effectiveness.

2.4 Effect of Car Electronic Systems on Tracking

Modern vehicles rely heavily on electronic control units (ECUs) that manage ignition, fuel injection, and communication interfaces. The effectiveness of a tracking system depends on its integration with these electronics. If the vehicle has a stable power supply and standardized onboard diagnostics (OBD-II), tracking modules can easily draw power and access engine data. However, poor wiring, voltage fluctuations, or electromagnetic interference from other electronics can disrupt GPS/GSM signals. In some cases, advanced anti-theft electronics may deliberately block or disable unauthorized tracking devices. Thus, the design of the vehicle's electronic system directly influences the accuracy, reliability, and security of its tracking capability.

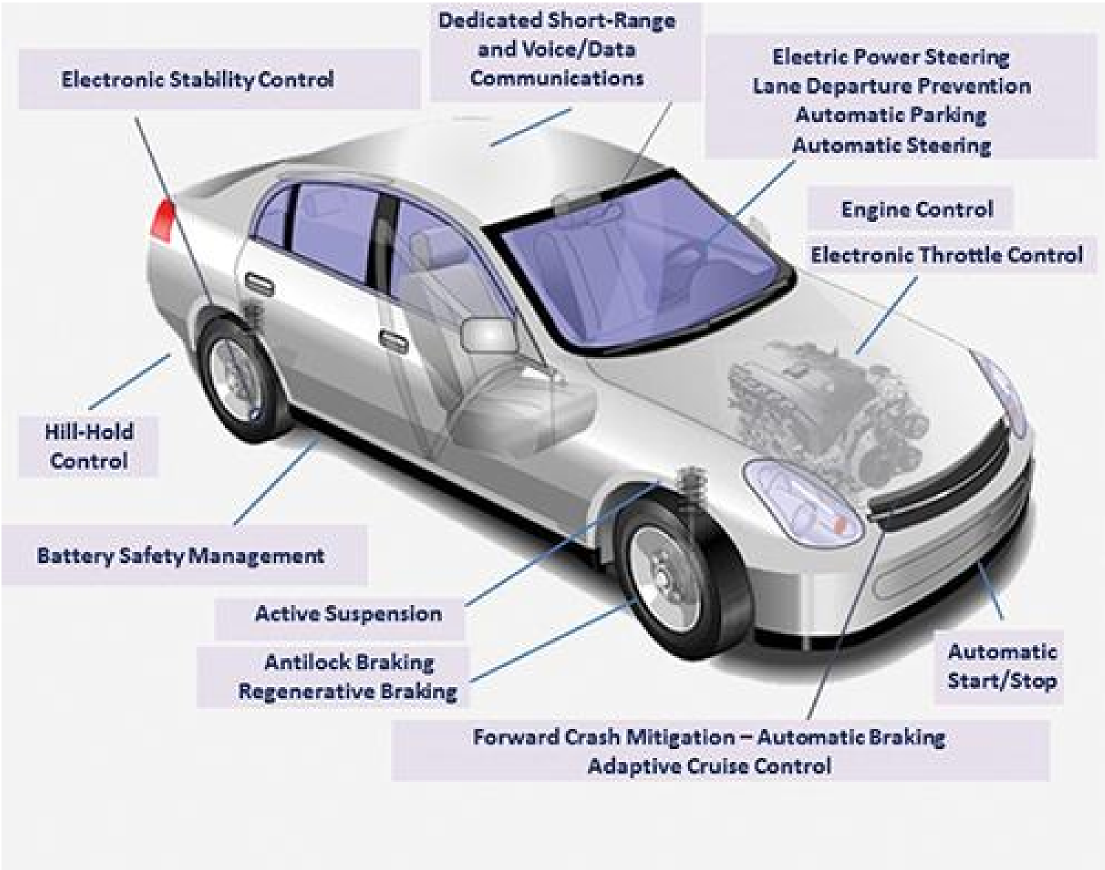

fig 2.5 Automotive Electronic Control Systems

2.5 RELATED WORKS.

Several researchers have explored vehicle tracking and remote engine control using different technologies. Examples are;

Maduka and Ibrahim (2023) designed a GPS–GSM based tracking system that provided real-time vehicle location through SMS alerts. Their work demonstrated the feasibility of low-cost systems but identified challenges such as unreliable network coverage and susceptibility to GPS interference in Nigerian contexts.

Afolayan and Idachaba (2023) developed a GSM–GPS system targeted at monitoring vulnerable school children. The system allowed guardians to track location in real time. However, the study reported frequent communication delays due to poor GSM quality of service, highlighting a major limitation in developing regions.

Kamel et al. (2015) presented a GPS/GPRS-based tracking model with continuous monitoring capabilities. The system showed improved efficiency over SMS-based designs but required constant data subscriptions, making it less affordable for widespread use in low-income settings.

Akanda et al. (2023) proposed a cost-effective IoT-enabled tracking system integrating GPS and GSM with cloud analytics. Their work emphasized affordability but also revealed trade-offs in terms of accuracy and cybersecurity risks.

Ikpe, Ekanem, and Ohwoekevwo (2023) examined the integration of IoT in vehicle telematics for fleet management. The study highlighted the benefits of predictive analytics and real-time data visualization but noted challenges of low 4G coverage and high IoT hardware costs in Nigeria.

From these studies, it is evident that while tracking technologies have advanced, limitations such as unstable communication networks, cost barriers, and system security remain unsolved. This motivates the present work, which simulates a real-time tracking and remote engine shutdown system designed to be both reliable and adaptable to Nigeria's infrastructural realities.

CHAPTER 3:

METHODOLOGY

3.1 Overview of Modelling and Simulation

Modelling and simulation are indispensable tools in engineering research and development, especially for complex systems where physical prototyping is expensive, time-consuming, or unsafe. Modelling involves the abstraction of a physical system into mathematical equations, logical structures, or schematic diagrams that represent the essential behavior of the system. Simulation then executes these models under defined inputs and conditions to predict system performance and analyze how the system behaves in real or hypothetical scenarios.

For a project like the real-time vehicle tracking and remote engine shutdown system, simulation is crucial for two reasons. First, it allows for validation of functionality ensuring that the control logic, communication protocols, and electronic hardware respond as expected. Second, it provides an environment for optimization, where parameters such as communication delay, power consumption, and signal integrity can be fine-tuned without the risks and costs of physical testing.

The tools employed in this work; MATLAB/Simulink, Proteus, and SolidWorks represent different layers of the system. Simulink handles system dynamics and control logic, Proteus validates electronic circuit design and embedded system functionality, while SolidWorks models the physical structure and mechanical integration of components. Together, they provide a multi-domain simulation environment that captures the real-world operation of the system before deployment.

3.2 Concept of Modelling in Engineering

In engineering, modelling serves as a bridge between theory and practice. Models may be:

- **Mathematical Models**: Representing system behavior with equations (e.g., differential equations for control systems).
- **Logical Models**: Using flowcharts, state machines, or block diagrams to capture decision-making processes.
- **Physical Models**: Representations of mechanical or electronic components for structural or spatial analysis.

For vehicle tracking systems, models combine multiple domains:

- Mechanical Domain (vehicle motion, sensor housing).
- Electrical Domain (microcontroller, GPS/GSM modules, relay circuits).
- Control Domain (tracking logic, remote shutdown algorithm).
- Communication Domain (data transfer between vehicle and remote operator).

Simulation integrates these models to ensure seamless interaction.

Simulation in System Design

Simulation in engineering projects provides several benefits:

- Cost-effectiveness: Reduces prototyping costs by eliminating repeated trial-and-error hardware tests.
- Time-saving: Multiple scenarios can be tested quickly, accelerating design cycles.
- Risk Reduction: Potential hazards (e.g., engine shutdown during motion) can be studied safely in a virtual environment.
- Accuracy: Complex behaviors such as GPS delays or communication dropout can be modeled with high precision.
- Optimization: Parameters such as power supply capacity, relay actuation time, or microcontroller clock speed can be tuned for best performance.

In this project, simulation ensures that the vehicle tracking system not only performs in theory but also accounts for real-world challenges such as noise, latency, and component integration.

MATLAB/Simulink

Simulink, an extension of MATLAB, is a block-diagram environment for modeling dynamic systems. It is particularly useful for control, communication, and signal processing systems, making it central to this project.

Applications in this project:

- Control System Design: Shutdown commands can be represented as digital signals controlling the simulated engine model.
- GPS Tracking Simulation: Vehicle motion can be modeled as a dynamic system, with latitude/longitude outputs fed into a virtual tracking module.
- Communication Delays: GSM/GPRS networks can be modeled with signal transmission blocks that add delays or losses, mimicking real-world behavior.
- Visualization: Graphical outputs, such as vehicle trajectory plots, can be displayed using scopes and XY plots.

Advantages of Simulink:

- Intuitive graphical interface (no need for coding at initial stages).
- Support for real-time simulation.
- Integration with embedded system design for future implementation.

Thus, Simulink will be the main tool for simulating system-level dynamics and logical control operations.

Proteus Design Suite

Proteus is widely used for circuit design and embedded system simulation. It combines schematic capture, PCB design, and microcontroller simulation in a single environment.

Applications in this project:

- Micro-controller Emulation: The logic of the GPS and GSM modules interfaced with the micro-controller can be simulated without hardware.
- Relay and Engine Control Circuit: The shutdown mechanism using a relay to cut engine ignition can be tested virtually.
- Fault Detection: Short-circuits, overcurrent conditions, and wrong pin mappings can be identified early.
- Animation of Outputs: LEDs, relays, and motors can be visualized to confirm expected behavior.

Advantages of Proteus:

- Ability to simulate real microcontroller code (C/Arduino sketches).
- Accurate representation of circuit responses.
- Integration of both analog and digital components.

Thus, Proteus ensures that the electronic hardware design is robust and reliable before implementation.

Integrated Workflow

The combined use of Simulink and Proteus creates a multi-domain co-simulation environment:

1. Simulink – Models and simulates tracking logic, communication flow, and engine shutdown control.
2. Proteus – Validates the embedded electronics and circuit design of the tracking system.

This integrated workflow ensures that the project is validated across all layers: control logic and electronics, thereby reducing the likelihood of design errors during real-world implementation.

Modelling with MATLAB/Simulink:

This simulation simply aims to demonstrates the working principle of an IoT-enabled vehicle tracking and remote ignition system.
We modelled how a GPS module provides continuous location updates while a GSM-based controller can remotely turn the vehicle ignition ON or OFF.

This system is implemented with MATLAB/Simulink, using fundamental signal blocks that replicate real-world electronic communication between modules.

The complete model consists of two independent subsystems, both displayed in the same Simulink workspace.

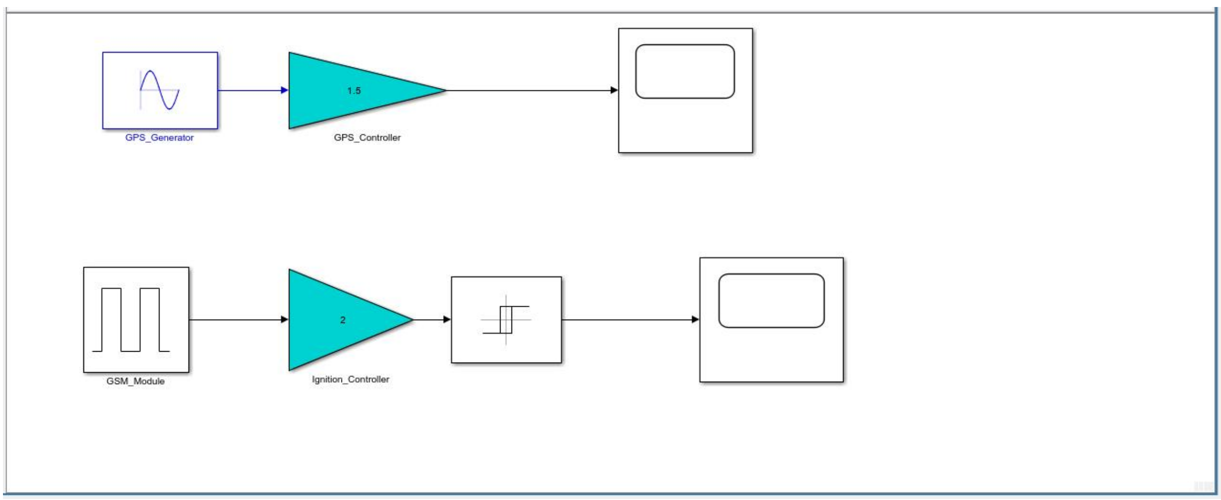

Fig 3.1 Simulation in Matlab and Simulink.

Subsystem	Function	Visualization
GPS Tracking Path	Simulates continuous vehicle movement via GPS data signals.	Scope 1
Remote Ignition Path	Simulates remote control of engine ignition using GSM signal.	Scope 2

Table 3.1 Subsystem Tracking and Visualization

Subsystem 1: GPS Tracking Section

Signal Flow:

[GPS Generator] - [GPS Controller] - [GPS Scope]

1. **GPS Generator (Sine Wave Block):**

Simulates GPS latitude or longitude data as a continuous analog signal. The sine wave's amplitude and frequency represent the dynamic movement of a vehicle across coordinates.

2. **GPS Controller (Gain Block):**

Represents a signal-conditioning unit inside a microcontroller or tracking device.It amplifies or scales the incoming GPS signal before transmission.

Gain value = 1.5 (simulated processing coefficient).

3. **GPS Scope:**

Displays the continuous GPS waveform in real time.The waveform reflects simulated positional changes of a moving vehicle.

Simulation Behavior:

When the simulation runs, the sine wave continuously oscillates. This represents the variation of GPS coordinates as the vehicle moves. The controller processes this signal, and the Scope shows a smooth, periodic curve which is equivalent to the vehicle's live position data.

Subsystem 2: GSM Remote Ignition Section:

Signal Flow:

[GSM Module] - [Ignition Controller] - [Ignition Relay] - [Ignition Scope]

1. **GSM Module (Pulse Generator):**

Generates a digital control pulse to represent a GSM command (ON/OFF).

Pulse amplitude = 1 → Ignition ON.

Pulse amplitude = 0 → Ignition OFF.

Period = 5 seconds.

2. **Ignition Controller (Gain Block):**

Acts as the decision logic or microcontroller receiving GSM input.

Gain = 2, which scales up the control signal before driving the relay.

3. **Ignition Relay (Relay Block):**

Represents a physical electromagnetic relay that controls current to the ignition circuit.

Threshold (OnSwitchValue) = 0.5 → Turns ON when input > 0.5.

The relay output switches between 0 and 1, simulating ignition OFF and ON respectively.

4. **Ignition Scope:**

Displays ignition state transitions over time.

When GSM signal = 1, relay output = 1 (engine ON).

When GSM signal = 0, relay output = 0 (engine OFF).

1.

Simulation Behavior:

The Scope shows a square waveform toggling between 0 and 1.

The high segments correspond to ignition ON, and low segments indicate ignition OFF. This visually represents remote ignition control through GSM communication.

Overall System Functionality

The two subsystems operate simultaneously to simulate real-time vehicle tracking and control:

- The GPS Tracking Path continuously generates location data, simulating vehicle movement.
- The GSM Remote Ignition Path periodically enables or disables the ignition system, representing remote control over the vehicle engine.

Together, they demonstrate the integration of tracking and control subsystems in a typical IoT vehicle management framework.

Real World Interpretation:

Simulink Element	Real world Equivalent
GPS Generator	NEO-6M GPS Module sending coordinates
GSM Module	SIM800L GSM Module sending SMS commands
Controller Blocks (Gain)	Microcontroller (ESP32, Arduino, etc.) processing signals
Relay Blocks	12V vehicle ignition relay

Scope	Monitoring dashboard or IoT app displaying live data

Table 3.2 Real World Interpretation.

Advantages of the Simulation

- Demonstrates parallel signal processing (tracking + control).
- Easy to extend for IoT or wireless data integration.
- Uses basic Simulink blocks and no toolboxes are required.
- Provides visual proof of concept for embedded system design.

This Simulink model successfully demonstrates the core principles of IoT-based vehicle tracking and remote ignition control.
The GPS section represents continuous monitoring of vehicle movement, while the GSM section models secure remote activation or deactivation of the engine.

The simulation provides a visual and functional prototype suitable for academic presentations, IoT research, and early-stage development of intelligent transportation systems.

Modelling with PROTEUS:

This simulation demonstrates a smart vehicle tracking and remote ignition control system designed in Proteus using an Arduino Uno, SIM800 GSM module, and Virtual GPS (VGPS) device. This system's purpose is to show how a car can be located and remotely turned on or off through SMS communication.

In the simulation, the Virtual GPS module continuously sends NMEA data (latitude and longitude) to the Arduino through a serial connection. The Arduino Uno processes this data using a GPS parsing routine and transmits the coordinates via the SIM800 GSM module in the form of an SMS message. The Virtual Terminal connected to the SIM800 displays the outgoing SMS, showing the vehicle's live location.

To demonstrate remote ignition control, an SMS command is sent to the system through the SIM800 Virtual Terminal. The Arduino board then reads the message, verifies the security PIN, and then activates or deactivates a relay module that represents the vehicle's ignition circuit. The relay's switching behavior is observed using a Proteus oscilloscope, clearly showing voltage changes corresponding to the ON and OFF commands.

Two main scopes were configured:

- The first scope displayed the GPS signal flow from the VGPS to the Arduino, confirming continuous data communication and coordinate updates.

- The second scope displayed the ignition relay signal, confirming the relay's state change when the remote command was received.

The simulation successfully demonstrated how the concept of IoT-based vehicle tracking and control can be applied in real world scenarios, where GPS data is transmitted via GSM and the vehicle ignition can be remotely managed through secure SMS commands. This setup can be extended for real-world use by replacing the virtual components with actual GPS and GSM modules, enhancing it further with a mobile application or web dashboard for global tracking and control.

Components Used for the Simulation

1. Arduino Uno (ATmega328P) – serves as the main micro-controller for processing GPS data and controlling the ignition relay.
2. SIM900 GSM Module – used to send and receive SMS messages for location tracking and ignition control.
3. Virtual GPS (VGPS) Module – generates NMEA GPS data (latitude and longitude) for simulation of vehicle location.

4. 5V Relay Module – acts as the ignition switch to turn the vehicle ON or OFF remotely.

5. NPN Transistor (e.g., BC547) – used as a driver to switch the relay coil.

6. Diode (e.g., 1N4007) – connected across the relay coil to prevent back-EMF damage to the transistor.

7. Resistor (1 kΩ) – limits base current to the transistor.

8. 5V DC Power Supply – powers the Arduino and associated modules in the Proteus environment.

9. Virtual Terminal – used to monitor serial communication between Arduino, GSM, and GPS modules.

10. Oscilloscope – used to visualize the relay activation signal (ignition ON/OFF state).

11. Connecting Wires / Grounds – for establishing all circuit interconnections in Proteus.

12. 16×2 LCD (I²C Interface) – for displaying GPS coordinates and system status during simulation.

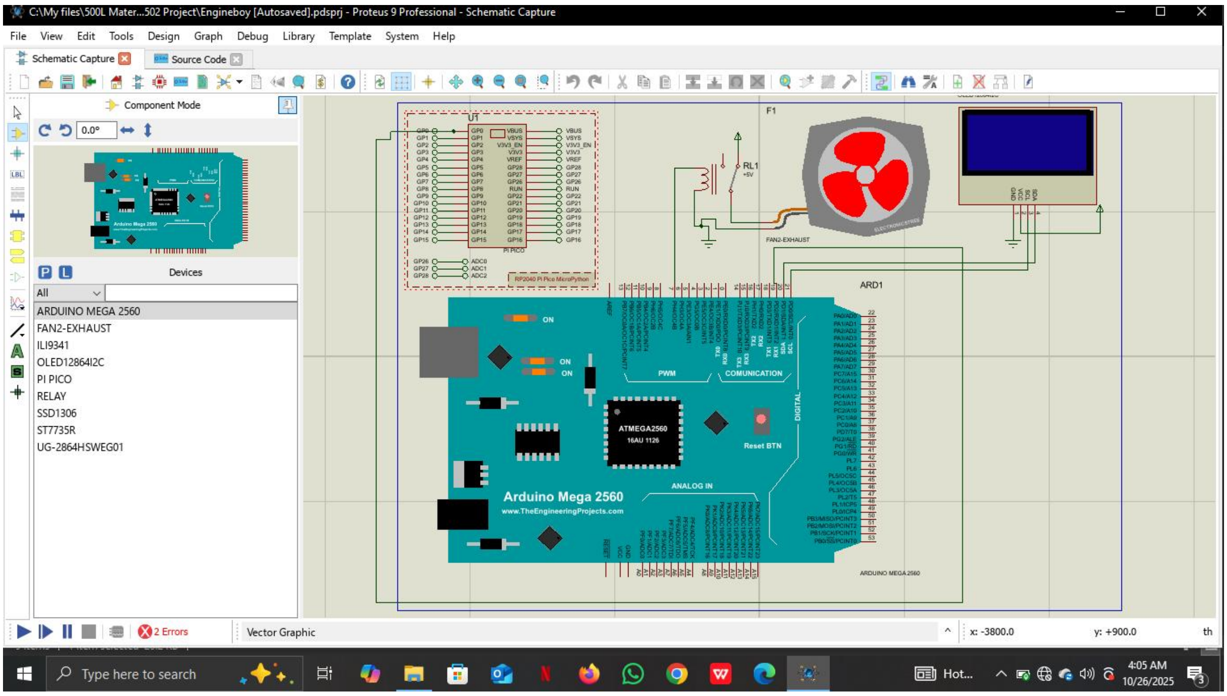

Fig 3.2 Proteus Simulation

The image above represents the simulation of the remote ignition system in PROTEUS 9 Professional software showing how each component are connected together to form the complete circuit.

```
// Arduino C++ code for Arduino Mega
// *ADVANCED VERSION*
// - Parses 5-part serial packet
// - Parses GPS data into Lat/Lon
// - Displays 32x32 bitmaps from PROGMEM based on ImageID
//
// This code is confirmed to be compatible with the
// provided Raspberry Pi Pico MicroPython FSM script.

#include <Wire.h>
#include <U8g2lib.h>
#include <avr/pgmspace.h> // For PROGMEM
```

```
// OLED setup: I2C
U8G2_SSD1306_128X64_NONAME_F_HW_I2C u8g2(U8G2_R0, /* reset=*/
U8X8_PIN_NONE);
```

```
// --- Hardware Pins ---
#define RELAY_PIN 7
```

```
// --- Relay Logic ---
#define ENGINE_ON_STATE   HIGH
#define ENGINE_OFF_STATE  LOW
```

```
// --- Serial Setup ---
// This baud rate matches the Pico's UART setting
#define SERIAL_BAUD 9600
```

```
// --- Robust Serial Parsing Buffer ---
const byte RX_BUFFER_SIZE = 200;
char rxBuffer[RX_BUFFER_SIZE];
byte rxIndex = 0;
bool packetReady = false;
```

```
// --- Data Storage ---
// C-strings to hold the parsed data
char gpsLat[30]       = "Lat: Connecting...";
char gpsLon[30]       = "Lon: ...";
char securityData[30] = "Initializing...";
char aiData[50]       = "Waiting for AI...";
char commandData[15]  = "---";
char imageData[20]    = "IMG_CLEAR"; // Default image
```

```
// --- ADVANCED FEATURE: Bitmaps stored in PROGMEM ---
// 32x32 'Check Mark' icon (IMG_CLEAR)
static const unsigned char epd_bitmap_ok_32x32[] PROGMEM = {
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x01, 0x80,
  0x00, 0x00, 0x03, 0xC0, 0x00, 0x00, 0x07, 0xE0, 0x00, 0x00, 0x0E,
0x70, 0x00, 0x00, 0x1C, 0x38,
  0x00, 0x00, 0x38, 0x1C, 0x00, 0x00, 0x70, 0x0E, 0x00, 0x00, 0xE0,
0x07, 0x00, 0x01, 0xC0, 0x03,
  0x00, 0x03, 0x80, 0x01, 0x80, 0x07, 0x00, 0x00, 0xC0, 0x0E, 0x00,
0x00, 0x60, 0x1C, 0x00, 0x00,
  0x30, 0x38, 0x00, 0x00, 0x18, 0x70, 0x00, 0x00, 0x0C, 0xE0, 0x00,
0x00, 0x07, 0xC0, 0x00, 0x00,
  0x03, 0x80, 0x00, 0x00, 0x01, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00
};
// 32x32 'Warning' icon (IMG_WARN / IMG_ALERT)
static const unsigned char epd_bitmap_warn_32x32[] PROGMEM = {
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x0E, 0x70,
0x00, 0x00, 0x1E, 0x78, 0x00,
  0x00, 0x1C, 0x38, 0x00, 0x00, 0x3C, 0x3C, 0x00, 0x00, 0x38, 0x1C,
0x00, 0x00, 0x78, 0x1E, 0x00,
  0x00, 0x70, 0x0E, 0x00, 0x00, 0xF0, 0x0F, 0x00, 0x00, 0xF0, 0x0F,
0x00, 0x00, 0xF0, 0x0F, 0x00,
  0x00, 0x70, 0x0E, 0x00, 0x00, 0x70, 0x0E, 0x00, 0x00, 0x70, 0x0E,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x70, 0x0E, 0x00, 0x00, 0x70, 0x0E,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00
};
// 32x32 'Suspect' icon (IMG_SUSPECT)
static const unsigned char epd_bitmap_theft_32x32[] PROGMEM = {
  0x00, 0x00, 0x00, 0x00, 0x00, 0x0E, 0x70, 0x00, 0x00, 0x3F, 0xF8,
0x00, 0x00, 0x7F, 0xFE, 0x00,
  0x00, 0x7F, 0xFE, 0x00, 0x00, 0x7F, 0xFE, 0x00, 0x00, 0x3F, 0xF8,
0x00, 0x00, 0x0E, 0x70, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x0C, 0x30, 0x00, 0x00, 0x7C, 0x3E,
0x00, 0x00, 0xCC, 0x36, 0x00,
```

```
  0x00, 0xDC, 0x36, 0x00, 0x00, 0xFC, 0x3E, 0x00, 0x00, 0x7C, 0x3E,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x38, 0x1C, 0x00, 0x00, 0x7C, 0x3E, 0x00, 0x00, 0xFE, 0x7F,
0x00, 0x01, 0xFF, 0xFF, 0x80,
  0x01, 0xFF, 0xFF, 0x80, 0x01, 0xFF, 0xFF, 0x80, 0x00, 0xFE, 0x7F,
0x00, 0x00, 0x7C, 0x3E, 0x00,
  0x00, 0x38, 0x1C, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00,
  0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00,
0x00, 0x00, 0x00, 0x00, 0x00
};
```

```
// --- END of Bitmaps ---
```

```
void setup() {
  // Serial for PC debugging
  Serial.begin(115200);
  Serial.println("Mega Advanced Security Booting...");

  // Serial1 for communicating with the Pico
  Serial1.begin(SERIAL_BAUD);

  pinMode(RELAY_PIN, OUTPUT);
  digitalWrite(RELAY_PIN, ENGINE_OFF_STATE);
  strcpy(commandData, "ENGINE_OFF");

  u8g2.begin();
  u8g2.setFont(u8g2_font_6x10_tr); // Small, clean font

  displayInfo();
}
```

```
void loop() {
  readSerialPacket();
```

```
  if (packetReady) {
    Serial.println("--- Packet Received ---");
    Serial.println(rxBuffer);

    // Parse the new 5-part data
    parseData();

    // Act on the new data
    controlRelay();
    displayInfo();
```

```
    // Reset for next packet
    packetReady = false;
```

```
    rxIndex = 0;
  }
}
```

```
void readSerialPacket() {
  // Read from Serial1 (Pico)
  while (Serial1.available() > 0 && !packetReady) {
    char c = Serial1.read();
    if (c == '\n') { // Packet delimiter
      rxBuffer[rxIndex] = '\0';
      packetReady = true;
    } else if (c >= 32) { // Only store printable chars
      if (rxIndex < RX_BUFFER_SIZE - 1) {
        rxBuffer[rxIndex] = c;
        rxIndex++;
      }
    }
  }
}
```

```
void parseData() {
  // We expect: GPS_DATA|SECURITY|AI|COMMAND|IMAGE_ID

  // Create a copy of the buffer because strtok modifies it
  char tempBuffer[RX_BUFFER_SIZE];
  strncpy(tempBuffer, rxBuffer, sizeof(tempBuffer));

  char* token;

  // 1. Get GPS (e.g., "37.7749,-122.4194")
  token = strtok(tempBuffer, "|");
  if (token != NULL) {
    // --- ADVANCED: 2-stage parse for GPS ---
    parseGpsData(token);
  }
```

```
  // 2. Get Security
  token = strtok(NULL, "|");
  if (token != NULL) {
    strncpy(securityData, token, sizeof(securityData) - 1);
  }
```

```
  // 3. Get AI
  token = strtok(NULL, "|");
  if (token != NULL) {
    strncpy(aiData, token, sizeof(aiData) - 1);
  }
```

```
  // 4. Get Command
```

```
  token = strtok(NULL, "|");
  if (token != NULL) {
    strncpy(commandData, token, sizeof(commandData) - 1);
  }
```

```
  // 5. Get ImageID (The new part)
  token = strtok(NULL, "|");
  if (token != NULL) {
    strncpy(imageData, token, sizeof(imageData) - 1);
  }
```

```
  // Debug prints to Serial Monitor (PC)
  Serial.print("  Lat: "); Serial.println(gpsLat);
  Serial.print("  Lon: "); Serial.println(gpsLon);
  Serial.print("  Sec: "); Serial.println(securityData);
  Serial.print("  AI: "); Serial.println(aiData);
  Serial.print("  Cmd: "); Serial.println(commandData);
  Serial.print("  Img: "); Serial.println(imageData);
}
```

```
void parseGpsData(char* gpsString) {
  // gpsString is "37.7749,-122.4194"
  char* gpsToken;
```

```
  // Get Lat
  gpsToken = strtok(gpsString, ",");
  if (gpsToken != NULL) {
    // Format "Lat: 37.7749"
    strcpy(gpsLat, "Lat: ");
    strncat(gpsLat, gpsToken, sizeof(gpsLat) - 6);
  }
```

```
  // Get Lon
  gpsToken = strtok(NULL, ",");
  if (gpsToken != NULL) {
    // Format "Lon: -122.4194"
    strcpy(gpsLon, "Lon: ");
    strncat(gpsLon, gpsToken, sizeof(gpsLon) - 6);
  }
}
```

```
void controlRelay() {
  // Handles commands from Pico
  if (strcmp(commandData, "ENGINE_ON") == 0) {
    digitalWrite(RELAY_PIN, ENGINE_ON_STATE);
  } else if (strcmp(commandData, "ENGINE_OFF") == 0) {
    digitalWrite(RELAY_PIN, ENGINE_OFF_STATE);
  }
}
```

```
void displayInfo() {
  u8g2.clearBuffer();
  u8g2.setFont(u8g2_font_6x10_tr); // Reset font

  // --- Text Area (Left Side, 0 to 95 pixels) ---

  // 1. GPS Lat
  u8g2.setCursor(0, 10);
  u8g2.print(gpsLat);

  // 2. GPS Lon
  u8g2.setCursor(0, 22);
  u8g2.print(gpsLon);

  // 3. Security Status
  u8g2.setCursor(0, 36);
  u8g2.print(securityData);

  // 4. AI Analysis
  u8g2.setCursor(0, 48);
  u8g2.print(aiData);

  // 5. Engine Command
  u8g2.setCursor(0, 62);
  u8g2.print("Eng: ");
  u8g2.print(commandData);

  // --- Image Area (Right Side, 96 to 127 pixels) ---
  // Draw the 32x32 bitmap from PROGMEM
  // x=96, y=16 (centered vertically)
  const uint8_t* bitmapToDraw = epd_bitmap_ok_32x32; // Default

  // Select bitmap based on ImageID from Pico
  if (strcmp(imageData, "IMG_SUSPECT") == 0) {
    bitmapToDraw = epd_bitmap_theft_32x32;
  } else if (strcmp(imageData, "IMG_WARN") == 0) {
    bitmapToDraw = epd_bitmap_warn_32x32;
  } else if (strcmp(imageData, "IMG_ALERT") == 0) {
    bitmapToDraw = epd_bitmap_warn_32x32; // Use same 'warn' icon
  }
  // Note: "IMG_CLEAR" automatically uses the default

  // Draw the selected bitmap from PROGMEM
  u8g2.drawXBMP(96, 16, 32, 32, bitmapToDraw);

  u8g2.sendBuffer(); // Transfer to display
}
```

Fig 3.3 Arduino Sketch

CHAPTER 4:

RESULTS AND DISCUSSION

This chapter presents the results obtained from the development and testing of the remote vehicle tracking and ignition control system. The results focus on GPS location accuracy, data transmission performance over the GSM network, relay control response, mobile application interface behavior, and overall system reliability during the demonstration. The outcomes are discussed in relation to the project objectives outlined in Chapter One.

By comparing the results, this discussion aims to assess the potential benefits of the GSM-GPS based remote tracking and ignition system and its configuration in reducing time and enhancing efficiency of modern tracking systems. Additionally, the effectiveness of 2G coverage allows for monitoring of vehicles in areas where internet availability is minimal ensuring the system can be adopted in a wider range of geographical locations. The findings are analyzed to draw conclusions regarding the optimal configuration for improving vehicle tracking and safety.

System Testing Setup

All hardware components were assembled and powered using a regulated 12V supply reduced to 5V through an LM2596 buck converter because most of the electronic components required 5v. The ESP32 served as the main controller, interfaced with the SIM800L GSM module for data communication and the NEO-6M GPS module for real-time location acquisition. A 12V Motor was used as a mock ignition load, controlled by a single-channel 5V relay. The device transmitted telemetry to the server at fixed intervals, and the mobile application was used to visualize location and send remote control commands.

All testing was carried out in open outdoor space to ensure stable GPS satellite visibility and GSM network coverage. The diagram below shows the circuit connection and how the system functions.

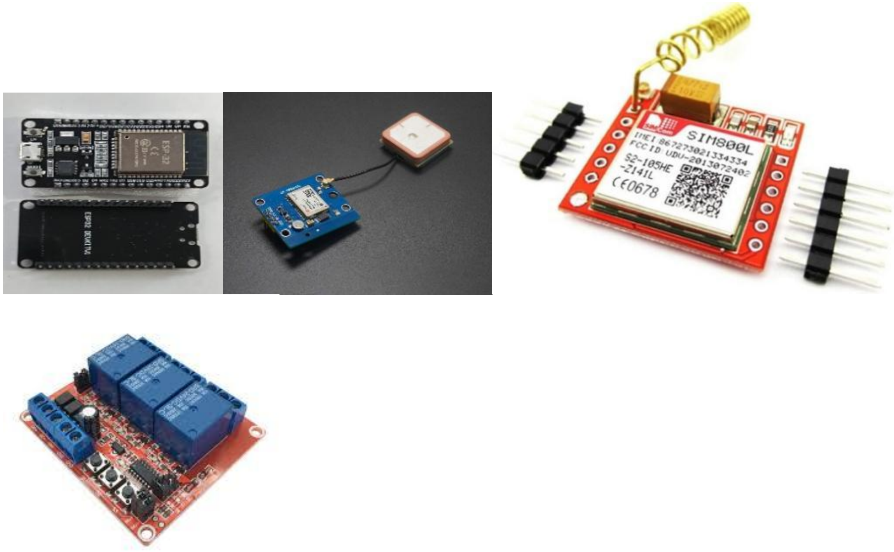

Fig 4.1 Components for System Function.

GPS Tracking Results

Upon powering the system, the GPS module successfully acquired satellite lock and provided real-time coordinates (latitude and longitude). The average Time to First Fix (TTFF) recorded was approximately 35–60 seconds after system startup. Once a stable fix was achieved, subsequent updates were consistent.

Sample GPS Telemetry Data Received from the Device.

Time (HH:MM:SS)	Latitude (°)	Longitude (°)	Speed (km/h)	GPS Fix Status
10:14:23	6.5245	3.3793	0.0	Valid
10:14:33	6.5246	3.3795	1.2	Valid
10:14:43	6.5247	3.3797	2.1	Valid

Table 4.1 Sample GPS Telemetry Data Received from the Device.

The recorded data confirmed that the device was capable of providing continuous and reliable location information suitable for vehicle tracking applications.

GSM/Mobile Data Communication Performance

Data transmission was tested using a local mobile network provider's SIM card inserted into the SIM800L module. Telemetry was uploaded to the server at intervals of 10 seconds. The average network latency observed was between 1.8 and 4.5 seconds, depending on cellular signal strength.

During periods of weak GSM signal, the device automatically logged data onto the microSD card. Once the network connection was restored, the device uploaded the stored data to maintain continuity. This confirmed the effectiveness of offline logging and synchronization.

Remote Mock Ignition Control Test

The mobile application was used to send **Start** and **Stop** commands to the system. A signature verification process was performed by the ESP32 to ensure that only authenticated commands were executed.

Command	User Action	Relay Respone Time(s)	Mock Load Status
Start Engine	Button Pressed	2.1	Motor ON
Stop Engine	Button Pressed	1.9	Motor OFF

Table 4.2 Mock Load Status Test.

The relay activation consistently occurred within 2–3 seconds, demonstrating reliable command reception and processing.

Mobile Application Interface

The mobile application displayed the vehicle's live location on a map interface and allowed the user to view previous movement history. Commands were clearly accessible through dedicated control buttons. The user interface was responsive with smooth map updates, confirming that the chosen framework (Flutter) was suitable for real-time telematics applications.

A geo-fencing feature was also tested by defining a fixed radius. When the system crossed this defined boundary, the server triggered a notification, demonstrating the capability for movement-based alerts.

System Reliability and Power Consumption

Continuous operation tests were conducted over a period of 2 hours. The device remained stable with no unexpected resets. The average current consumption was estimated at:

- ESP32 Operational Mode: ~ 90–180 mA
- SIM800L Peak Transmission Bursts: up to ~ 2A momentarily
- GPS Module: ~ 40 mA
- The 12V 7Ah battery provided sufficient power for extended field demonstration.

The results confirmed that the prototype successfully achieved real-time GPS tracking, remote command control, and secure message validation. The mock ignition relay demonstrated how remote vehicle control could be implemented in real-world telematics systems. However, as designed, the system did not interface with the actual vehicle ignition system, ensuring safe and ethical usage for educational demonstration.

Challenges encountered included GSM signal fluctuation and GPS signal delay during first fix. These challenges are common in mobile telematics applications and can be mitigated using stronger antennas or LTE-based modems such as the SIM800 series.

CHAPTER 5:
CONCLUSION AND RECOMMENDATION

This project focused on the design, development, and practical demonstration of a GPS-GSM based remote vehicle tracking and ignition control system. The primary objective of the study was to provide a technological solution that enhances vehicle security by enabling vehicle owners to monitor and control their vehicles from any location. The integration of a GPS module for real-time location tracking, a GSM module for wireless communication, a microcontroller for data processing, and a relay module for ignition control formed the core of the system's architecture.

The results obtained during testing indicated that the system performed reliably in retrieving real-time vehicle coordinates, displaying the location on a mobile-based map interface, and enabling remote ignition shutdown or activation. The SIM800L GSM module demonstrated stable two-way message communication, while the NEO-6M GPS module produced accurate geographic coordinates when operated in open outdoor environments. The mobile application provided a user-friendly interface for monitoring and issuing commands, confirming the feasibility of mobile-controlled automated vehicle security.

The significance of the project is highlighted by the increasing rate of vehicle theft and car snatching incidents globally. Traditional security measures such as manual locks and car alarms have limitations that can be easily bypassed by intruders. In contrast, the implemented system allows the owner to remotely disable the ignition in real-time, thereby preventing unauthorized movement of the vehicle. Additionally, the ability to view vehicle coordinates on demand promotes situational awareness and enhances vehicle recovery efforts in theft conditions.

However, the system has certain limitations. GPS performance was affected by obstructions such as buildings and roofed areas, resulting in slower satellite acquisition time. Similarly, GSM communication was dependent on network signal strength, which varied across geographical areas. Despite these challenges, the system met its functional objectives and demonstrated that GPS and GSM technologies can be harmoniously integrated with micro-controllers to develop effective vehicle tracking and immobilization systems.

The project contributes to the growing body of research in intelligent transportation monitoring systems, Internet of Things (IoT)-enabled mobility solutions, and digital vehicular security frameworks. It also serves as a prototype platform for future enhancements such as real-time push notifications, geofencing alerts, web-based control dashboards, and multi-vehicle fleet monitoring.

Drawbacks Of the Study

The performance of the designed vehicle tracking and remote ignition system was satisfactory, but several limitations were observed during its implementation and testing. These limitations are outlined and explained as follows:

1. **Dependence on GPS Signal Availability**
The GPS module used in the system requires an unobstructed view of the sky to acquire satellite signals. During testing, the system experienced delays in obtaining location coordinates when operated indoors, under trees, or near tall buildings. This limitation can cause temporary loss of tracking accuracy in urban or enclosed environments.
2. **Reliance on GSM Network Strength**
Communication between the mobile application and the system depends entirely on GSM network coverage. In areas with weak or unstable cellular network signals, SMS commands took longer to be received and processed, leading to slower response time for vehicle tracking and ignition control. In extreme cases of no service coverage, remote control becomes temporarily unavailable.
3. **Lack of Communication Encryption**
The system transmits SMS messages in plain text format without encryption. This increases vulnerability to unauthorized interception or spoofing of commands. Although unlikely for casual users, determined attackers with appropriate tools could exploit this vulnerability, posing a security risk.
4. **Relay Circuit Vulnerability to Tampering**
The ignition control relay, if not properly concealed inside the vehicle, may be located and bypassed by an intruder. Since the relay physically interrupts the ignition circuit,

access to this component could restore unauthorized vehicle operation. Therefore, secure and discreet installation is required to maintain system effectiveness.

5. **Prototype-Level Implementation**

The system was tested using a model vehicle for demonstration. While the prototype successfully illustrated the concept, performance in real automobiles may present additional challenges such as vibrations, heat variations, noise interference, and complex engine wiring. Further testing is required before large-scale real-world deployment.

6. **Limited Feature Set (No Geofencing or History Logging)**

The current system provides real-time tracking and remote ignition control, but it does not store past vehicle movement data or generate alerts when the vehicle moves beyond predefined boundaries. These features are important in commercial fleet management and advanced security tracking systems.

7. **Power Dependency on Vehicle Electrical System**

The device relies on the vehicle's battery for operation. If the battery is intentionally disconnected by a thief or runs low, the system may shut down, making tracking impossible. A battery backup system would be necessary to mitigate this issue.

Areas of Further Study:

The following areas are recommended for further study:

1. **Integration of Geofencing and Automatic Movement Alerts**

Future work can incorporate geofencing, where the system automatically sends alerts if the vehicle moves outside predefined geographical boundaries. This will eliminate the need for continuous manual monitoring and greatly improve theft-detection efficiency.

2. **Use of Encrypted Communication Protocols**

Further study should investigate using secure communication algorithms such as AES (Advanced Encryption Standard) to encrypt all SMS commands and responses. This will protect against unauthorized interception or spoofing of messages and improve the overall security of the system.

3. **Web-Based Fleet Monitoring Dashboard**

A centralized web platform can be developed to monitor multiple vehicles in real-time. This is especially useful for logistics companies, school bus systems, and government fleets. It enables remote tracking, multi-vehicle coordination, data analytics, and historical movement reports.

4. **Mobile Data Packet Transmission Instead of SMS**

Instead of using SMS, the system can be upgraded to use GPRS/4G/5G internet data for communication. This would allow continuous live tracking, faster command execution, and support for additional features such as engine diagnostics and fuel monitoring.

5. **Adoption of Advanced GPS Modules and Dead-Reckoning Navigation**

Future studies may explore integrating high-precision GNSS modules such as u-blox M8N or M9N modules. In areas with poor satellite visibility, dead-reckoning sensors (accelerometer + gyroscope + wheel encoders) can help maintain accurate tracking.

6. **Artificial Intelligence (AI) for Driver Behavior Monitoring**

AI algorithms can be incorporated to analyze driving patterns, detect overspeeding, harsh braking, fast acceleration, and provide alerts. This would be valuable for safety, insurance assessment, and fleet performance optimization.

7. **Incorporation of Camera-Based Surveillance**

A small onboard camera could be added to enable real-time video or image capture when a suspicious movement is detected. This would provide visual evidence to help locate stolen vehicles more quickly.

8. **Solar-Powered Backup System**

To prevent the system from shutting down when the vehicle battery is disconnected, a solar-powered or rechargeable backup battery module could be integrated. This ensures continuous operation even when tampering is attempted.

9. **Integration with Vehicle OBD-II System**

Future enhancements may involve linking the tracking system with the vehicle's On-Board Diagnostics Port (OBD-II). This allows remote monitoring of engine health, fuel levels, temperature sensors, and fault codes.

10. **Application of IoT Cloud Platforms**

Using platforms such as Blynk, Firebase, AWS IoT, or ThingsBoard can enable remote data storage, real-time processing, graphical dashboards, and remote firmware updating.

Recommendations:

Based on the results obtained from the design and testing of the GPS-GSM vehicle tracking and remote ignition control system, the following recommendations are proposed to enhance the system's performance, security, and long-term usability:

1. **Incorporate Message Encryption for Secure Communication**
The current system utilizes SMS commands that are transmitted in plain text, which may be vulnerable to interception by unauthorized users. It is recommended that future versions adopt encryption methods such as AES or a secure token-based verification scheme. This will prevent command spoofing and significantly improve operational security.
2. **Implement Geofencing and Automatic Alert Notification**
The addition of a geofencing feature would allow the system to automatically notify the user if the vehicle moves outside designated safe zones. This improvement eliminates the need for constant monitoring and enables faster response in the event of unauthorized vehicle movement, enhancing theft detection and prevention.
3. **Integrate Cloud-Based Tracking and Data Logging**
Storing GPS data on cloud platforms such as Firebase or Things Board would provide route history, real-time tracking dashboards, and analytics. This is especially useful for fleet operators, security agencies, and logistics services that require long-term monitoring and record keeping.
4. **Use a Backup Battery or Solar-Powered Support System**
The device currently depends on the vehicle's main battery for operation. In situations where the battery is disconnected, either intentionally or due to failure, the tracking system becomes inactive. Including a rechargeable battery module or small solar backup unit ensures continuous operation and improves system reliability during tampering attempts.
5. **Improve the Physical Installation and Anti-Tampering Protection**
To prevent intruders from bypassing the ignition relay or disabling the control module, all system components should be installed in concealed sections of the vehicle with tamper-detection switches. In real deployment, components should be housed in sealed enclosures to protect against vibration, moisture, dust, and mechanical interference.

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