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Original Article

Enhancing Vehicle Tracking through SMS: A Cost-Effective Approach Integrating GPS and GSM

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Abstract - *The rising challenge of vehicle theft impacts various stakeholders, including vehicle owners, insurers, security companies, and the community. To tackle this issue, tracking devices provide a viable and budget-friendly solution. Tracking mechanisms arise as a practical response to this problem, offering a reliable and cost-effective means to address the intricate issue of vehicle theft. This paper introduces an innovative tracking system that seamlessly integrates GSM communication, GPS technology, and web-based visualization to enable real-time monitoring of vehicles or objects. The system's operational sequence commences with a registration process, accomplished by sending an SMS code to the GSM module, ensuring secure access and authorized interaction. Successful registration prompts a confirmation message, solidifying the system's foundation of trust. The system uses GPS technology to retrieve real-time longitude and latitude coordinates, providing users with accurate location data. This data is efficiently transmitted to platforms like Google Maps through a link generated by the PHP application, enhancing user experience and facilitating informed decision-making. The system's potential is evident in its diverse applications, spanning personal asset management to fleet tracking.*

Keywords - *Tracking system, GSM modem, GPS modem, Arduino microcontroller, Vehicle tracking.*

1. Introduction

In recent years, the proliferation of vehicle usage and the increasing demand for efficient fleet management have propelled the development of sophisticated vehicle tracking systems. These systems, encompassing diverse technologies, hold immense potential in enhancing transportation safety, optimizing logistics, and streamlining operations across various sectors. Among these, the amalgamation of Arduino electronic shields and Global System for Mobile (GSM) communication technology is a promising avenue for realising an advanced vehicle tracking system [1].

The unparalleled growth in vehicular density has led to concerns regarding road safety, theft prevention, and efficient management of fleets. Traditional vehicle tracking methods have demonstrated limitations in accuracy, real-time monitoring, and integration with broader management systems. This sparked an interest in leveraging modern technologies to devise innovative solutions to overcome these challenges. Arduino, an open-source electronics platform renowned for its versatility and ease of use, has found extensive application in creating custom electronic systems. Paired with GSM technology, which provides ubiquitous cellular connectivity, the resultant vehicle tracking system has the potential to deliver real-time updates, enable remote control, and furnish data-driven insights for decision-making [2].

The fundamental concept of the proposed vehicle tracking system revolves around integrating Arduino electronic shields, which encompass a multitude of sensor modules and microcontrollers, with GSM modules that enable communication through cellular networks. This synergy empowers the system to capture vital vehicular parameters such as GPS location, speed, and direction while facilitating bi-directional communication for commands and alerts [3]. The GSM technology ensures seamless data transmission to a centralized server or a cloud-based platform, thus enabling stakeholders to monitor the vehicles in real-time from any location. This system can also be configured to generate alerts for unauthorized movement, geofencing violations, or vehicle malfunctions, enhancing its utility for fleet managers, law enforcement agencies, and individual vehicle owners [4].

Meanwhile, Somalia, characterized by diverse transportation modes and infrastructural challenges, presents a unique context for applying advanced vehicle tracking

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solutions. With a significant portion of the population lacking access to the internet but possessing GPS-enabled SIM cards, there exists a compelling opportunity to develop a tailored vehicle tracking system that addresses the specific needs of Somali citizens, particularly those who own cars and "Mooto Bajaj" - small motorcycles - which serve as indispensable assets for livelihoods and daily activities [5].

Somalia's transportation ecosystem is marked by a blend of urban and rural settings, where traditional forms of mobility coexist with evolving transportation norms. The security of vehicles for personal and commercial purposes remains a paramount concern, given the challenges posed by theft, road safety, and inefficient fleet management. However, the digital divide regarding internet access necessitates an innovative approach that leverages available technologies such as GPS-enabled SIM cards and GSM networks to overcome this barrier and provide accessible vehicle tracking solutions [6].

The convergence of GPS technology with SIM cards offers a practical and cost-effective means of tracking vehicles while circumventing the need for continuous internet connectivity. This combination enables real-time location tracking, route monitoring, and even remote immobilization of vehicles in the event of theft. By focusing on this technology, the proposed vehicle tracking system caters to the realities of Somalia's infrastructure, where internet connectivity remains limited and often unreliable in remote areas. This approach also aligns with the widespread adoption of mobile phones nationwide, ensuring that even those without internet access can benefit from the system [7].

Central to this endeavour is the application of vehicle tracking technology to both cars and "Mooto Bajaj" - a popular mode of transportation in Somalia due to its affordability and adaptability to local conditions. These small motorcycles play a pivotal role in livelihoods, offering access to markets, education, and healthcare in regions with limited transportation options. The proposed system not only safeguards these essential assets against theft but also aids in locating stolen vehicles, thereby contributing to the overall security of individuals and businesses [8].

This research explores implementing a GPS-enabled vehicle tracking system in Somalia that aligns with the realities of limited internet connectivity. By focusing on the affordability and accessibility of GPS-enabled SIM cards, the aim is to empower all segments of society, including those with modest means, to secure their vehicles and "Mooto Bajaj" effectively. Through this approach, the research seeks to bridge the technological divide, enhance transportation security, and empower Somali citizens to harness the benefits of modern tracking solutions despite challenges related to internet access. The application of GPS-enabled vehicle tracking technology and readily available SIM cards holds immense promise for enhancing transportation security in Somalia. By catering to the country's unique context, where internet access remains limited but mobile phone usage is widespread, this technology can revolutionize vehicle tracking for both cars and "Mooto Bajaj." By addressing the needs of all segments of society, this innovative approach could foster economic growth, improve road safety, and contribute to the overall development of transportation infrastructure in Somalia.

2. Related Work

Several studies have explored the application of GPS-enabled vehicle tracking systems in various contexts, shedding light on such technology's potential benefits and challenges, particularly in regions with limited internet connectivity. This section reviews relevant academic articles that discuss the utilization of GPS-based tracking systems, focusing on their applicability to environments similar to Somalia, where internet access is constrained. For instance, Author [9] presents a low-cost vehicle tracking system that utilizes GSM and GPS technology for real-time tracking. The authors address the challenges of limited internet access by relying on SMS communication between the tracking device and the central server. The system provides location updates, speed monitoring, and remote immobilization capabilities using GSM networks, making it suitable for regions with constrained internet availability [7].

Meanwhile, the author [10] proposes a vehicle tracking system that integrates GPS and GSM technologies to track vehicle locations and monitor their movements. The authors emphasize using GSM communication for data transmission, enabling real-time tracking without consistent internet connectivity. This approach is particularly relevant to areas with limited internet access, enhancing vehicle security and management. This study presents a cost-effective vehicle tracking system that leverages GPS for location determination and GSM/GPRS for communication. The authors highlight the system's affordability and efficiency, making it suitable for deployment in regions where internet connectivity is intermittent. The system facilitates real-time tracking, vehicle immobilization, and theft prevention, thus addressing critical challenges faced by vehicle owners and fleet managers [4].

Similarly, author [11] discusses the development of a vehicle tracking system that utilizes GSM/GPRS and SMS technologies to enable remote tracking and control. The authors highlight the system's affordability and accessibility, especially in regions with limited internet penetration. By relying on SMS communication and GSM networks, the proposed system caters to the needs of users who lack consistent internet access. Also, the author [12] presents a vehicle theft detection and prevention system that combines GPS and GSM technologies. The system is designed to send alerts and control commands via SMS, ensuring effective communication even in areas with restricted internet connectivity. This approach enhances vehicle security and contributes to theft prevention, addressing challenges vehicle owners face in regions with unreliable internet access [3]. We can generally categorise Active, Passive, and Manual tracking devices.

2.1. Active Tracking Devices

An active tracking device is a specialized hardware component designed to monitor and transmit real-time information about a vehicle's location, status, and other relevant parameters. Unlike passive tracking systems that store data for later retrieval, active tracking devices continuously communicate with a central server or control centre, providing up-to-the-minute information about the vehicle's movements and activities. This real-time communication is often facilitated through Global System for Mobile (GSM) communications or satellite communication. Active tracking devices enhance security, fleet management, and logistics operations. They enable instantaneous monitoring, allowing stakeholders to promptly respond to incidents, deviations from planned routes, or unauthorized vehicle usage. Moreover, active tracking devices are adept at providing real-time alerts, geo-fencing notifications, and remote-control capabilities, making them essential tools for various applications [6].

For instance, the author [13] discussed integrating GPS and GSM technologies in vehicle tracking systems. Active tracking devices provide real-time information about vehicle locations and movements. The continuous communication facilitated by these devices ensures accurate monitoring and efficient fleet management. Author [7] emphasizes the role of active tracking devices in real-time fleet management. These devices enable fleet managers to monitor vehicle positions, optimize routes, and respond swiftly to unexpected events. The study underscores the significance of instant data transmission in enhancing operational efficiency. Meanwhile, the author [14] discusses an active tracking system incorporating GSM and GPS technologies. This system offers real-time alerts and engine immobilization features, highlighting the importance of active tracking devices in preventing vehicle theft and enhancing security. The author [15] presents a real-time vehicle tracking system based on GSM and GPS. Active tracking devices are elucidated as critical elements that enable constant communication between vehicles and a central server.

The study emphasizes the benefits of this approach in improving vehicle security and management. Active tracking devices are pivotal in vehicle tracking systems by enabling continuous communication, real-time monitoring, and instant alerts. By employing technologies like GPS and GSM, these devices facilitate efficient fleet management, enhance vehicle security, and contribute to optimized logistics operations. Their significance lies in their ability to provide stakeholders with accurate and timely information, even in areas with limited internet connectivity [12].

2.1.1. AVLS Tracker

An Automatic Vehicle Location System (AVLS) tracker, often simply an AVLS tracker, is a sophisticated device used in vehicle tracking systems to accurately determine and transmit vehicles' real-time location and other relevant information. AVLS trackers enhance fleet management, logistics, and transportation security by providing continuous data about vehicle movements, status, and operational parameters. The AVLS tracker is equipped with various technologies to perform its functions effectively:

Global Positioning System (GPS): AVLS trackers are integrated with GPS receivers to obtain precise geospatial coordinates of the vehicle's current location. GPS technology enables accurate positioning regardless of the vehicle's movement and location.

Communication module (GSM, GPRS, or Satellite): To transmit the collected data, AVLS trackers are equipped with communication modules such as Global System for Mobile (GSM) communications or General Packet Radio Service (GPRS) for cellular networks or satellite communication for remote or areas with poor cellular coverage. These modules enable the tracker to send location updates and information to a central server or control center. Sensors and Inputs: Depending on the specific application, AVLS trackers can be fitted with various sensors and inputs to collect additional data. These may include sensors for monitoring vehicle speed, engine status, fuel level, temperature, door openings, and more. These inputs provide a comprehensive view of the vehicle's operational state.

Microcontroller: The microcontroller is the brain of the AVLS tracker, responsible for processing data from various sources, managing communication, and executing predefined tasks, such as generating alerts based on certain conditions.

Power management: AVLS trackers often have power management features to optimize energy consumption and ensure continuous operation. This is especially important to maintain tracking capabilities without excessively draining the vehicle's battery [16]. The collected data from the AVLS tracker is transmitted to a central server or a control centre, where it is processed and displayed on a user interface. This allows fleet managers, logistics operators, and other stakeholders to monitor vehicle movements in real-time, analyze routes, optimize operations, and respond swiftly to emergencies or deviations from planned routes [11].

2.1.2. AGPS

Assisted GPS (AGPS) trackers, also known as A-GPS trackers, are a specialized subset of GPS-based tracking devices that utilize additional data sources to improve the speed and accuracy of location determination. AGPS technology enhances the performance of traditional GPS tracking systems by leveraging assistance from cellular networks or other external references, thereby overcoming some limitations of standard GPS in challenging environments like urban canyons or areas with obstructed line of sight to satellites. The main principle behind AGPS is to supplement the information obtained from GPS satellites with assistance data that provides predictions about satellite positions and other relevant parameters. This assistance data is usually obtained from cellular networks or preloaded onto the AGPS device, allowing it to quickly and accurately calculate its position [15].

For instance, author [17] discussed the advantages of AGPS technology in improving GPS accuracy and time-to-fix. The authors emphasize the importance of assistance data obtained from cellular networks and how it aids in rapid position calculation, making AGPS particularly useful in situations with weak GPS signals. Moreover, the author [8] presented a system that utilizes AGPS for vehicle localization in urban environments. The study highlights the effectiveness of AGPS in urban canyons where direct satellite visibility is limited. The authors emphasize the system's ability to provide accurate and rapid position updates, contributing to enhanced navigation and tracking.

Meanwhile, the author [18] investigated the benefits of AGPS in mobile phones. The study discusses how AGPS technology aids in faster position fixes and improved accuracy by combining GPS satellite data with assistance data from cellular networks. The authors highlight the impact of AGPS on location-based services and navigation applications. This study assesses the performance of AGPS in urban and suburban settings. The authors examine how AGPS can mitigate challenges associated with signal multipaths and weak satellite signals.

The study underscores AGPS's potential to enhance GPS accuracy and reliability, particularly in areas with obstacles. AGPS trackers enhance traditional GPS tracking systems by incorporating assistance data from cellular networks or other sources to expedite and refine location determination. By leveraging external information, AGPS technology overcomes the limitations of GPS signals in challenging environments, leading to quicker position fixes and improved accuracy. Academic research underscores the value of AGPS in scenarios where timely and accurate location updates are critical, such as urban canyons or areas with obstructed satellite visibility [2].

2.1.3. RFID Tracker

An RFID (Radio Frequency Identification) tracker is a technology-based system that uses radio frequency signals to identify and track objects or individuals. RFID trackers consist of RFID tags, small devices containing a microchip and an antenna, and RFID readers emitting radio signals to communicate with the tags. RFID technology is widely applied in various fields, including supply chain management, inventory tracking, access control, and livestock tracking. RFID trackers send radio frequency signals from the RFID reader to the RFID tag. The tag affixed to the tracked object responds with its stored information, such as a unique identifier or data about the object. This information is then captured by the RFID reader, facilitating real-time identification and tracking without the need for a direct line of sight [8].

For instance, author [19] proposed a study that provides an overview of RFID technology's applications in supply chain management. The authors discuss the benefits of using RFID trackers for real-time inventory tracking, reduced labour costs, and improved visibility across the supply chain. The article also addresses challenges and implementation considerations. Similarly, author focused on implementing RFID trackers in the healthcare sector for asset-tracking purposes. The article highlights how RFID technology improves medical equipment tracking, enhances asset utilization, and reduces manual data entry errors. The study emphasizes the potential of RFID to improve healthcare operations [5].

Meanwhile, the author [20] delved into RFID technology's applications and discussed its implications for consumer privacy. While not exclusively focused on tracking, the article highlights the versatile nature of RFID technology in various contexts and underscores the importance of considering privacy concerns. Similarly, author [21] provides a practical introduction to RFID technology's applications in logistics. The article explains how RFID trackers track goods, improve supply chain efficiency, and reduce inventory inaccuracies. It also addresses the role of RFID in enhancing security and reducing theft. RFID trackers utilize radio frequency signals to identify and track objects by interacting with RFID tags and readers. The technology's versatility has led to its adoption in diverse fields, ranging from supply chain management to healthcare. Academic research highlights the benefits of RFID trackers, including improved inventory tracking, asset management, and supply chain visibility. However, discussions also address privacy considerations and implementation complexities [16].

2.2. Passive Tracking Devices

A passive tracking device is a tracking technology that collects and stores location and other relevant data over time without transmitting that information in real-time. Unlike active tracking devices that continuously communicate with a central server or control centre, passive tracking devices record data locally on the device itself, typically on an internal memory or storage component. The stored data can later be retrieved for analysis and review.

Passive tracking devices are commonly used when real-time tracking and communication are not essential or when there are constraints on continuous communication, such as in areas with limited cellular coverage. These devices are beneficial for scenarios where the main goal is to collect historical data about a vehicle's or object's movements rather than monitoring them in real-time [22].

The author [22] explored passive RFID tracking technology for indoor environments. Although not exclusively focused on vehicles, the research demonstrates the feasibility of passive tracking devices in capturing movement data. The authors discuss how passive RFID technology can track objects in confined spaces. Moreover, the author [9] presented a passive GPS tracking system for monitoring mobile assets. The article explains the development of a device that collects GPS data from moving assets and stores it locally. The authors discuss the potential advantages of passive tracking, including reduced communication costs.

Meanwhile, the author [13] investigated the application of passive RFID technology in vehicle tracking and remote monitoring. The authors discuss how passive RFID tags attached to vehicles can be used to record data about vehicle movements and then retrieved for analysis. The article emphasizes the feasibility of using passive tracking devices for vehicle monitoring. The passive tracking device is a tracking technology that records location and other relevant data over some time without transmitting it in real time. The stored data can be later retrieved and analyzed. Passive tracking devices are beneficial when real-time tracking is not necessary, and they find applications in various contexts, including vehicle tracking, asset monitoring, and indoor tracking scenarios [10].

2.2.1. GPS-Based Solar Tracker

A GPS-based solar tracker is a technology that utilizes GPS (Global Positioning System) signals to orient solar panels or photovoltaic systems toward the sun's optimal position for maximum energy capture. These trackers enhance the efficiency of solar energy generation by continuously adjusting the orientation of solar panels to ensure they are perpendicular to the sun's rays. The tracker precisely determines the sun's position using GPS signals, enabling accurate alignment of the solar panels throughout the day [7].

For instance, authors [23, 24] presented a study on a dual-axis solar tracking system that employs GPS-based technology for accurate orientation. The article discusses the integration of GPS signals to adjust the solar panel angles based on real-time sun positioning. The authors emphasize the improved energy efficiency achieved through precise tracking. Also, the author [25] described a solar tracking system that utilizes GPS technology alongside light sensors to optimize solar panel alignment. The study highlights how GPS signals are employed to calculate the sun's azimuth and elevation angles, aiding in accurate tracking for enhanced energy harvesting.

Meanwhile, the author [14] focused on developing a real-time sun-tracking system using GPS signals. The authors discuss how GPS data are processed to determine the solar panel's optimal orientation. The article emphasizes the benefits of using GPS-based technology to ensure accurate and responsive solar tracking.

Meanwhile, the authors [26, 27] provided an overview of solar tracking technologies, including GPS-based systems. The authors discuss how GPS signals aid in tracking the sun's position and ensuring the maximum utilization of solar energy. The article highlights the increased energy output achieved through precise solar panel alignment. GPS-based solar tracker employs GPS signals to determine the sun's position and adjust the orientation of solar panels for optimal energy capture. Academic research underscores the benefits of such trackers in enhancing solar energy efficiency by precisely aligning panels with the sun's rays. GPS-based solar trackers contribute to increased energy generation and improved performance of photovoltaic systems.

2.2.2. Environmental Surveillance

A GPS-based environmental surveillance tracker is a technology designed to monitor and collect data related to various environmental parameters while utilizing GPS signals to determine the geographical location of the measurements precisely. These trackers are crucial in monitoring environmental conditions and gathering data for analysis, research, and decision-making related to environmental protection and management. For instance, author [19] presented an IoT-based environmental monitoring system incorporating GPS technology for location tracking. The article discusses how GPS-enabled sensors collect data on environmental parameters such as air quality, temperature, and humidity, while the GPS component provides accurate location information for each measurement. The authors emphasize the benefits of using GPS-based tracking in environmental monitoring networks.

Also, author describes developing an environmental monitoring system for agriculture that integrates GPS technology. The system utilizes GPS to track the geographic locations of sensors placed in the agricultural field, enabling researchers to associate environmental data with specific locations. The article highlights how GPS-based tracking enhances the accuracy and utility of collected environmental data [20].

Meanwhile, the author [28] discussed the sensor scope project, which involves deploying wireless sensor networks for environmental monitoring. The authors highlight the integration of GPS technology in tracking sensor nodes' positions and collecting data from diverse environmental conditions. The study underscores the importance of GPS-based tracking for accurate and context-rich environmental surveillance. Similarly, the authors [29, 30] presented a real-time environmental monitoring system incorporating wireless sensor networks and mobile applications. The article discusses how GPS-enabled sensors collect data from various locations, enhancing the accuracy of collected environmental information.

The authors emphasize the role of GPS-based tracking in ensuring spatial relevance for collected data. GPS-based environmental surveillance tracker employs GPS signals to determine the geographic location of environmental measurements precisely. These trackers contribute to accurate and context-rich data collection, supporting research and decision-making in various environmental monitoring applications. Academic research highlights the benefits of integrating GPS technology into environmental surveillance systems to ensure accurate spatial associations for collected data [20].

2.3. Manual Tracking Devices

A manual tracking device, also known as a handheld tracking device, is a portable technology used to manually track and record the movement and location of objects or individuals. Unlike automated tracking systems that rely on continuous communication or sensor data, manual tracking devices require human intervention to collect and input data. These devices are often used in scenarios where real-time tracking is not necessary, or the precision of automated systems is not required. Manual tracking devices typically consist of a handheld unit with a display screen and user interface, allowing individuals to input location data, timestamps, and other relevant information. The collected data can then be analyzed and interpreted as needed [31]. While manual tracking devices do not rely on complex technologies like GPS or RFID for real-time monitoring, they can still serve valuable purposes in specific applications.

The author [16] presented a manual tracking device to monitor outdoor physical activities. The authors describe the device's features, including the ability for users to input their activities and locations manually. The article emphasizes the potential of such devices for promoting physical fitness and wellness. The author [12] also reviewed the applications and methods of manual tracking in animal behavior research. The article discusses the benefits of manual tracking devices in tracking animal movements and behaviours, providing insights into ecological and behavioural studies.

Meanwhile, the author [29] discussed using handheld devices for post-disaster resource tracking and management. The article explores how manual tracking devices can aid disaster responders in recording resource allocation and distribution, even in areas with limited connectivity. The manual tracking device is a portable technology that relies on human input to manually track and record the movement and location of objects or individuals. These devices find application in various contexts, including outdoor activity monitoring, animal behaviour research, disaster response, and resource management. While not as technologically complex as automated tracking systems, manual tracking devices can still play a valuable role in collecting and managing data in scenarios where real-time tracking is not essential [32].

3. Methodology

This section explains the model and the fundamental ideas behind the proposed system. The designed Vehicle Tracking System (VTS) comprises three main components: a GPS receiver, a GSM modem, and a microcontroller (specifically, an ARDUINO UNO 68). This entire system is interconnected with the vehicle or Mooto Bajaj that needs to be monitored. On the counterpart at the control centre, a GSM mobile phone is linked to a PHP application computer. The structure of the proposed system is visually depicted in Figure 1 as a block diagram. The operational sequence of the proposed system is illustrated through a flowchart in Figure 2. The central control hub of this system is the ARDUINO UNO 68 microcontroller.

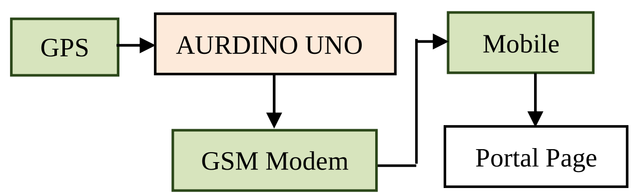

Fig. 1 Proposed methodology

At the control center, there is another essential setup in place. A GSM-enabled mobile phone is connected to a computer that is running in PHP. This PHP application serves as the interface through which interactions and commands can be sent to the proposed system.

Figure 1 offers a visual representation of how the different components, such as the GPS receiver, GSM modem, and microcontroller, are interconnected and operate together to create a cohesive tracking system. To provide a clearer understanding of how the proposed system functions in a step-by-step manner, Figure 2 presents a flowchart. This flowchart outlines the sequential steps that the system follows to achieve its intended purpose, revealing the order in which various actions take place and decisions are made.

As mentioned before, the pivotal core of this entire system is the ARDUINO UNO 68 microcontroller. This microcontroller serves as the central processing unit that coordinates and controls the functioning of all the connected components.

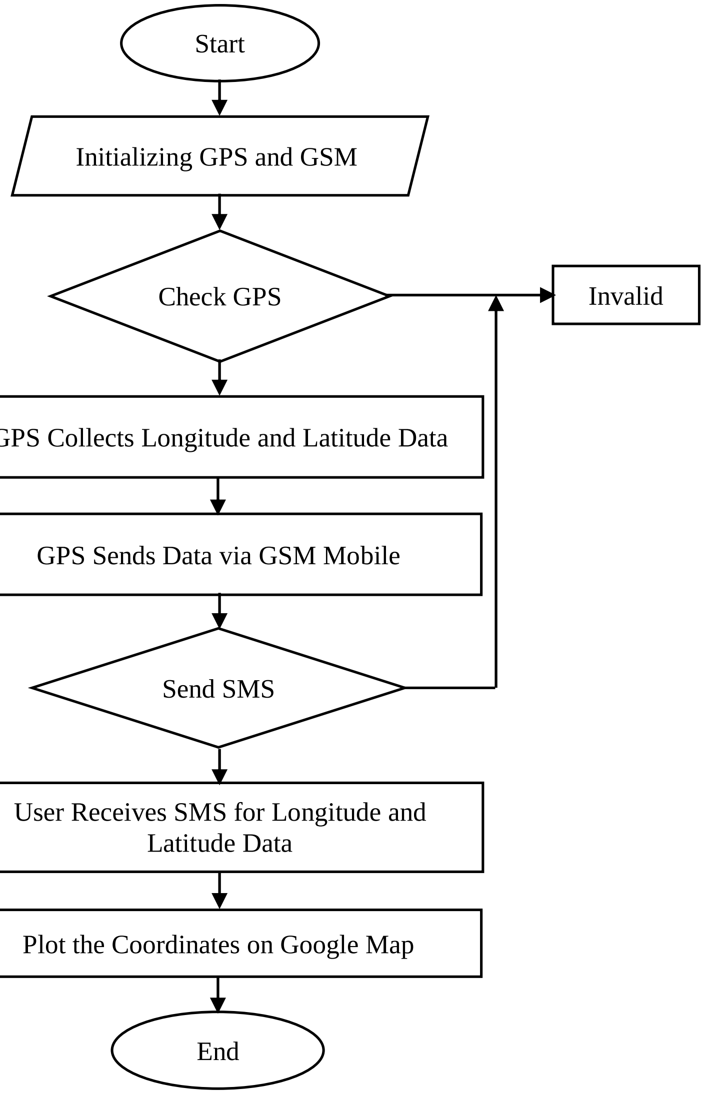

Fig. 2 Flowchart of the proposed methodology

When the entire system is initiated or turned on, a Liquid Crystal Display (LCD) connected to the microcontroller becomes active. This display shows a specific message: "Policing is about the passion for serving people." This message indicates that the system is operational and ready to perform its tasks. The control centre involves the integration of a GSM mobile phone with a computer running a PHP application, serving as a means to interact with the proposed tracking system.

The GPS coordinates are initialized, and the GPS module subsequently transmits the vehicle's current longitude and latitude coordinates to the GSM modem. To illustrate, consider a scenario where a tracked vehicle begins its journey at 5 a.m. If authorized personnel (such as an officer) aim to locate the vehicle accurately, they interact with the computer. Within the PHP program, they select the vehicle's unique identification number. This action triggers the dispatch of a text message to the vehicle's designated phone number.

Following setup, the GPS module becomes active, consistently acquiring the vehicle's real-time longitude and latitude coordinates. These coordinates pinpoint the vehicle's exact location on Earth's surface. When an authorized individual interacts with a connected computer, the PHP program allows them to select the vehicle's identification number. This choice initiates a series of actions, leading to the sending of a text message containing location-related instructions.

The GSM-enabled mobile phone within the vehicle receives this message, and the GSM modem forwards it to the microcontroller, the system's brain. The microcontroller evaluates the message's content and authenticity. If aligned with predefined criteria, it executes the specified instructions.

The system's GPS module captures real-time coordinates sent to the GSM modem. For instance, if a vehicle starts at 5 a.m., the system updates its location. To pinpoint the exact position, authorized personnel use a computer and PHP program to send a text message. This message reaches the vehicle's GSM-enabled mobile phone and is processed by the microcontroller. The SMS, routed via the GSM provider, is crucial for this communication. The microcontroller processes the SMS and executes commands as needed. Notably, each set of coordinates corresponds to a specific location name. This data is sent from the GSM receiver to the computer via a serial port connection. The PHP program cross-references this data with its database, providing comprehensive vehicle details on the computer screen.

4. Results and Discussions

The implemented tracking system successfully integrates GSM communication, GPS technology, and web-based visualization for efficient vehicle or object monitoring. The initial registration process, facilitated by sending the code "000" to the GSM module, ensures secure and authorized access to the system. The subsequent confirmation message establishes a robust foundation of trust and authentication. The system uses GPS technology to acquire real-time longitude and latitude coordinates, providing users with accurate location data. The seamless transmission of this data via a link from the PHP application to platforms like Google Maps enhances user experience and decision-making capabilities. While the system showcases commendable capabilities, potential challenges such as connectivity issues in remote areas and the need for heightened security measures warrant consideration. The upcoming points will be discussed clearly.

4.1. ARDUINO UNO 68

The "Microcontroller (ARDUINO UNO 68)" refers to the ARDUINO UNO microcontroller board, specifically version 68, a versatile and programmable integrated circuit designed to control electronic components and systems. Microcontrollers are compact devices incorporating a single chip's processor, memory, and input/output interfaces. The ARDUINO UNO 68 is a member of the ARDUINO microcontroller family, renowned for its user-friendly platform that enables both novices and experts to develop interactive and responsive projects.

The ARDUINO UNO 68 microcontroller has various digital and analogue input/output pins that allow it to interact with sensors, actuators, and other electronic components. It runs on a specific code written in the ARDUINO programming language, a simplified version of C/C++. Users can upload their code to the microcontroller using a USB connection, enabling it to execute tasks based on the programmed instructions. The ARDUINO UNO 68, like its predecessors, has gained popularity in various fields, and that is why we use it, from hobbyist projects to industrial automation, due to its open-source nature, extensive community support, and ease of use.

4.2. GPS NEO-6

The "GPS NEO-6" refers to the NEO-6 series of Global Positioning System (GPS) modules produced by u-blox, a Swiss technology company specializing in positioning and wireless communication solutions. The NEO-6 modules are compact and competent devices designed to receive signals from GPS satellites and provide accurate global positioning information. These modules are frequently used in various applications, including navigation systems, mapping, geolocation, and tracking devices.

The GPS NEO-6 modules feature advanced satellite tracking capabilities, supporting multiple satellite constellations such as GPS, GLONASS, and Galileo. They offer impressive accuracy in determining latitude, longitude, altitude, speed, and time information. These modules have a high-sensitivity receiver, enabling them to lock onto satellite signals even in challenging environments like urban areas or dense foliage. The NEO-6 series modules are known for their easy integration, as they often communicate with host systems through standard serial communication protocols. They have become popular among hobbyists, professionals, and developers seeking reliable and accurate GPS solutions for their projects and applications.

4.3. Results

The proposed tracking system presents an innovative vehicle or object monitoring approach by leveraging a combination of GSM communication, GPS technology, and web-based integration. The system begins with registering the designated phone number with the GSM module. This initial registration process is a pivotal security measure, ensuring only authorized devices can interact with the tracking system. By sending the code "000" to the GSM module, users effectively establish a link between the system and their device. The subsequent receipt of a confirmation message indicating successful registration establishes a foundation of trust and authentication, allowing for seamless interaction between the system and the authorized device, as Figure 3 shows.

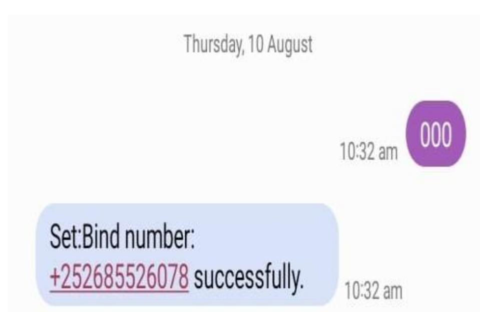

Fig. 3 Binding number

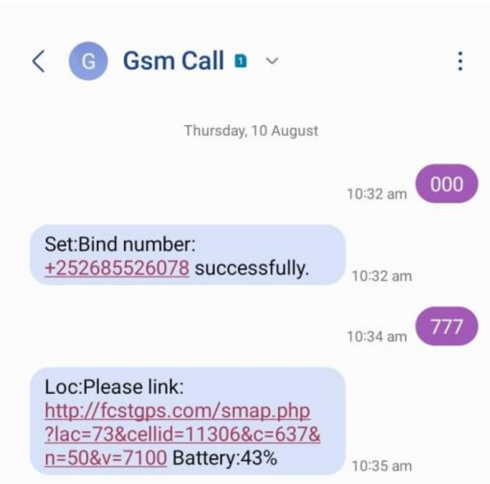

Fig. 4 Data retrieval

Subsequently, another message is sent to retrieve real-time geographic data. This message prompts the system to gather and transmit longitude and latitude coordinates, which indicate the precise location. Upon acquiring this data, the system conveys the information to the user via a link facilitated by the PHP application. This link enables users to access the provided coordinates and conveniently input them into platforms such as Google Maps, as Figure 4 demonstrates. Through this process, users can visualize the exact position of the tracked vehicle or object on the map, enhancing their situational awareness.

This means that a significant strength of this system lies in its real-time data acquisition capabilities. By sending a follow-up message to trigger the retrieval of longitude and latitude coordinates, users can promptly access the precise location of the tracked vehicle or object. The integration of GPS technology plays a vital role here, enabling the system to determine the geographical coordinates of the target accurately. This real-time data retrieval enhances situational awareness and fosters efficient decision-making. The subsequent transmission of this data to users via a link from the PHP application further augments the system's usability. Users can conveniently access and visualize the coordinates on familiar platforms like Google Maps, fostering a seamless and intuitive experience, as Figure 5 shows.

However, it is essential to consider potential challenges and limitations. The system's reliance on GSM networks might lead to connectivity issues in remote areas with weak signal coverage. Additionally, while the system's registration step adds a layer of security, it could be further enhanced by including more robust authentication mechanisms to prevent unauthorized access. Moreover, the location data's accuracy hinges on the GPS module's performance and environmental factors could impact its precision.

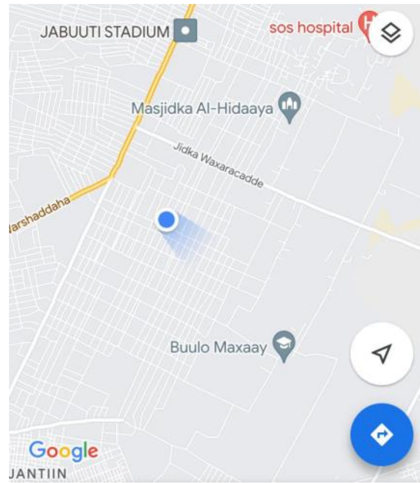

Fig. 5 Map data

5. Conclusion

The developed tracking system effectively combines GSM communication, GPS technology, and web-based integration to offer a comprehensive real-time vehicle or object monitoring solution. The system's registration process ensures secure access, while GPS technology provides accurate location data. The integration of the PHP application facilitates user-friendly data visualization on platforms like Google Maps, enhancing usability. While challenges such as connectivity and security considerations exist, the system's potential for diverse applications, from fleet management to personal tracking, is evident.

For future work, several avenues present themselves for further enhancement. Firstly, the system's security measures could be fortified by implementing multi-factor authentication protocols, ensuring authorized access. Additionally, the system could be extended to incorporate predictive analytics, enabling users to anticipate and optimize routes or patterns based on historical data. Exploring alternative communication methods like satellite communication would mitigate connectivity issues in remote areas. Moreover, integration with Internet of Things (IoT) devices could expand the system's capabilities, allowing for more comprehensive data collection beyond location alone. Lastly, incorporating machine learning algorithms could contribute to real-time anomaly detection and predictive maintenance, elevating the system's utility in various domains.

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