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DESIGN AND IMPLEMENTATION OF A LOW-COST VEHICLE TRACKING SYSTEM

THESIS

B.Sc. Computer Engineering

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90052019

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CAPSTONE PROJECT

Capstone Project submitted to the Department of Engineering, Ashesi University College in partial fulfillment of the requirements for the award of Bachelor of Science degree in Computer Engineering.

Gloria Ataa Sekyere

90052019

Declaration

I hereby declare that this capstone is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: .....

Candidate's Name: .....

Date: .....

I hereby declare that the preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University College.

Supervisor's Signature: .....

Supervisor's Name: .....

Date: .....

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Abstract

Location-based services have become very popular globally and with the increasing rate in car theft in Ghana, it is necessary that such services be implemented. Vehicle tracking is an application of the Internet of Things (IoT) proposed in aiding in the recovery of stolen vehicles. This thesis presents a detailed description of the development of a low-cost real-time GPS/GSM vehicle tracking system based on an Arduino Uno board. The system uses GPS services in determining the location of the vehicle and GSM services in transmitting received data to a web server. Data is pushed to a database to be stored and then displayed in a web application using Google Maps API. The system includes a location restriction feature with email alerts.

Keywords: Internet of Things, GPS, GSM, Arduino, web server, database, web application, location restriction, email alerts

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Chapter 1: Introduction

1.1 Background

It is evident that millions of complex tasks have been made easier today by the application of technology. Internet of things (IoT) is a trending topic in the world of technology concerned with the combination of individual components to create a system of interrelated networks devices that are allowed to exchange data. Real-time vehicle tracking is one such application of IoT. This device comprises a GPS and GSM module to receive and transmit coordinates used in determining the real-time location of a vehicle.

The lack of advanced technology in Ghana's crime investigation system makes it fairly easy to get away with many crimes including car theft. Car theft was the most reported crime in 2009 according to a survey conducted by the Ghana Statistical Service (GSS). Currently, there are still many reports of car thefts in the country. This high increase in the theft of cars makes the use of vehicle tracking devices necessary in assisting the police in reclaiming stolen vehicles. [1]

There are several GPS car tracking devices being sold on the Ghanaian market most of which can be found on online sale websites such as 'Tonaton' and 'OLX Ghana'. A tracking device is a device that allows you to see the location of an object at any point in time when attached to the object. The cost of these vehicle tracking devices is averaged at approximately GHS 400.00 based on prices on OLX Ghana. Unfortunately, most people are oblivious of the existence of such devices in the country. Furthermore, they fail to see the importance of the devices until they find their cars stolen. For people living in developed areas, it is probably the last thing on their mind, to protect their vehicles against car theft.

A vehicle tracking system is a solution proposed for recovering stolen vehicles. The earlier mentioned trackers on the Ghanaian market provide vehicle owners with just the

location of the vehicle. This thesis presents a detailed description of a vehicle tracking system that includes an extra feature of location restriction. This system provides the real-time location of the vehicle and sends email alert messages to the user when the vehicle goes out of the specified perimeter.

Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth. Global System for Mobile communication (GSM) is a digital mobile network widely used on mobile phones. It is used for establishing a connection between a computer and a GSM/GPRS system. The system uses a GPS module to determine the coordinates of the vehicle. This information is transmitted to the Arduino board. The Arduino forwards the data to the GSM module which transmits the data to a web server to be stored in a database. Location data is also pushed to the web application to display the location of the vehicle using Google maps API. This is the mode of the operation of the vehicle tracking system which will be described into detail later in the thesis.

1.2 Problem Identification

In the Ghanaian crime investigation system, there is no way to track the location of stolen vehicles. This makes it very easy to get away with car theft in the country. Stolen vehicles are difficult to recover because of little information on the whereabouts of the vehicle. Individual vehicle owners and companies that control a large fleet of vehicles are forced to rely on the word of the drivers about the whereabouts of the vehicles. It is possible for these drivers to work offline to pocket cash or worse, make off with the vehicles. Parents who have another person driving their children to school with their own vehicles always need to find a driver who can be trusted, so he/she does not make off with their cars, or

worse, their children. The same problem is faced by individuals who give out their vehicles to drivers for taxi or Uber services.

The motivation behind this project is to ease vehicle owners the burden of having to rely on the word of their drivers on the location of their vehicles, improve safety and aid in the recovery stolen vehicles and.

1.3 Objective of the Project Work

The main objective of this project is to create a low-cost real-time GPS/GSM Vehicle tracking system that alerts the vehicle owner via email when the vehicle goes beyond the specified perimeter. The objective is further broken down below:

- build a low-cost vehicle tracking circuit
- create a database to store data
- create a web server to push coordinates to a web application and database
- create a web application to retrieve coordinates and display location in using google maps API.

1.4 Expected Outcomes of the Project

A low-cost circuit that:

- tracks real-time location,
- sends email alerts when the vehicle goes beyond restricted borders

If successful, this device can be adopted in these areas:

Parental monitoring: Parents will be able to monitor their personal vehicles that drive their children around.

Fleet management: Owners of construction companies, delivery companies and other organization that rely on transportation in their business and move a significant

number of vehicles face the risk of the vehicles being made off with by the drivers or being stolen. By having a tracking device that provides the location, managers can minimize the risks involved in managing their fleet.

Recovery of stolen vehicles: Car snatchers and thieves who are oblivious of the existence of the tracker in the vehicle can be apprehended with ease.

Car rental services: To avoid customers from running off with vehicles, car rental companies can employ the services of the tracking device to keep track of their vehicles and tracking to ensure the rented vehicles remain within bounds.

1.5 Justification of the Project Topic

Most of the current vehicle tracking devices sold on the Ghanaian market only provide the location of the vehicle. This additional location restriction feature with email alerts, to the vehicle tracking system, makes it more efficient in its operation. If the vehicle goes beyond the specified perimeter, an email alert is sent to the owner. With the help of this location restriction system, the owner can quickly notify the driver or the police in the case of suspicion.

1.6 Project Methodology

1.6.1. System Architecture

A general overview of how the system interacts with its various components is shown in the diagram below. A more detailed description of the architecture is provided in Chapter 3.

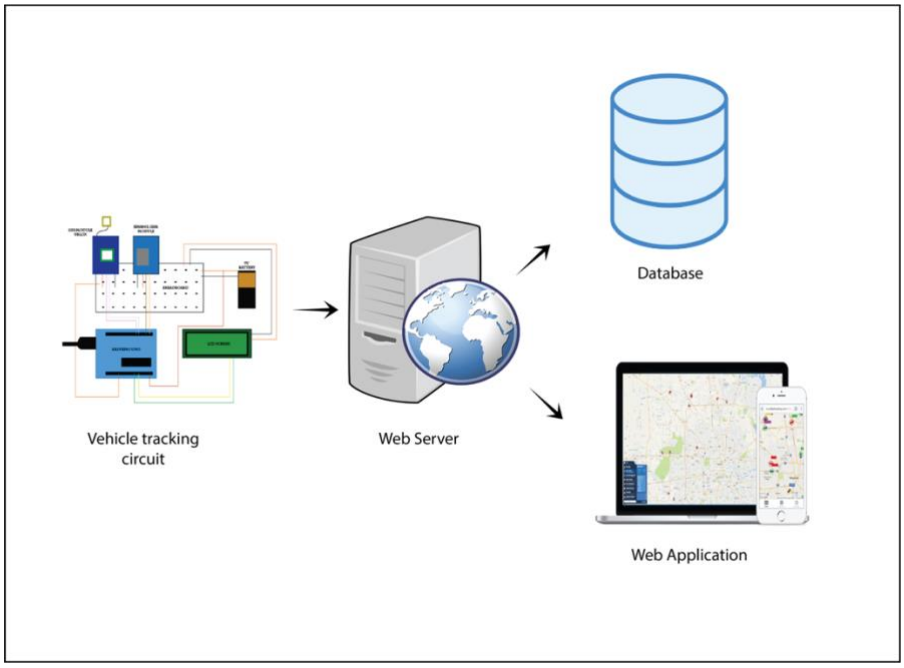

Figure 1-1: High-level system architecture showing the main components of the system

The Circuit houses the GPS/GSM modules for receiving and transmitting coordinates. The information is transmitted to a web server which pushes the data to a web application. The server also sends the data to a database to be stored. The web application displays the location of the vehicle in real-time.

1.6.2. System Specifications

- GPS module for transmitting GPS data to the server
- GSM module for establishing a connection between hardware circuit and web server
- Web server for pushing data to web application and database
- Database for storing data
- Web application using Google Maps API for tracking vehicle position

1.7 Facilities/Materials to be Used for Project

1.7.1. Software Applications

- Arduino for programming hardware
- Visual Studio code for developing a web server, database, and web application.
- SendGrid for sending email alerts
- Postman for testing

1.7.2. Hardware Materials

- GPS module Ublox
- SIM 800L GSM module
- Breadboard
- Arduino Uno Board

1.8 Scope of Work

This project is made up of two main parts. These are:

- The hardware system
- The software system

1.8.1 The Hardware System

This part of the project consists of the Arduino Uno board that houses the GPS, GSM components of the vehicle tracking device.

1.8.2 The Software System

This part of the project is concerned with the development of the server, database and web application that displays the location of the vehicle using Google Maps API.

1.9 Proposed Chapter Outline

This thesis is divided into the following chapters: Chapter 1 presents the project proposal. It gives the background of the project, introducing the main hardware components. This chapter also covered the objective and expected outcomes of the project. The problem identification and scope of the project are also listed in this chapter. Chapter 2 presents the review of related work and the borrowed and additional features that make this project unique. Chapter 3 presents the design of the system. This chapter details out the design decisions made, the system requirements and high-level implementation of the design. Chapter 4 describes in detail the methodology used in developing and implementing the system. Chapter 5 discusses the results obtained from the implementation and testing of the system. Chapter 6 presents the conclusion and future works.

Chapter 2: Literature Review

Location-based services are in increasing demand globally. With the evolution of technology has come many different implementations of tracking devices. The basic functionality of tracking devices is to show the location of objects to which they are attached, in real time. There have been many additional improvements made to tracking devices which gives edges over competing companies.

The Electrical Engineering Department team from Walchand College of Engineering published a paper on “Real Time Vehicle Monitoring and Tracking System based on Embedded Linux Board and Android Application".This paper describes an advanced real-time GPS/GSM vehicle monitoring and tracking system based on an embedded Linux board for monitoring a school vehicle from location A to B. the GPS module gives the current location of the vehicle, the General Packet Radio Service (GPRS) pushes the information to the server and the Global System for Mobile Communication (GSM) modem sends alert messages to the vehicle owner's mobile phone. Information is stored in the database and accessed on the mobile phone through an android application. The driver follows a specified path. An alert will be sent once the vehicle goes off the specifies paths or goes beyond the specified speed limit. The Raspberry Pi has embedded in it the specified path, speed sensor, temperature sensor and LPG leakage sensor for the travelers' safety.

This paper is from a credible source published on IEEE. The major strength of the project is the clearly defined scope of developing the system mainly for student busses. The vehicle tracking system is augmented by the addition of speed, temperature, and gas leakage sensors which gives the system an upper hand in the product market. Also, the development of the Android application which shows drivers the specified paths makes the system

advanced and likely to be a top choice as compared to the other reviewed articles. It provides more safe and secure traveling using the alert system. Seeing how the project was made easy to understand by clearly defining the scope, I will incorporate in my project the knowledge from this paper to clearly define the scope of my project.

The Electrical and Technical team from College of Engineering, India, published a paper on “RTOS Based Vehicle Tracking System". This project aims at tracking vehicles with Real Time Operating Systems (RTOS) programming. The author identifies the need for vehicle tracking in the security of personal vehicles, public transportation systems. The system uses the Global Positioning System (GPS) to indicate the location of the vehicle. All sensory data from the alcohol sensor, temperature and speed sensors collectively with the GPS coordinates are sent to the user via SMS. The Global System for Mobile Communication (GSM) modem, using General Packet Radio Service (GPRS) makes the communication between the hardware device and mobile phone possible. The system is based on ARM7, GPS and GSM technology. The monitoring system uses a Graphical User Interface (GUI) to display information using Google Maps API.

This source is a credible one published on IEEE. A strength of the paper is the use of several diagrams in illustrating the processes involved in the development of the system. This makes the paper easy to follow and understand what the author is doing at every stage in the developmental process. The use of sensors augments the vehicle tracking system by acting as additional features which makes the system a more desirable product. The downside to this paper is found in the testing phase. Since the project was only tested in the lab, results cannot be fully relied upon since sensory data gathered in different areas might produce different results. The use of sensors in augmenting the vehicle tracking system can be incorporated into my project.

The Electrical Engineering Department team from University of Ghana published a paper on the "Design and development of GPS/GSM based vehicle tracking and alert system for commercial inter-city buses." This article proposes the design, development, and deployment of GPS and GSM based tracking and alert system which allows inter-city transport companies to track their vehicles in real-time. An alert system also exists for reporting armed robbery and accidents. The GPS is used to determine the vehicle location and the information is either stored or transmitted either by SMS which will be through the use of the GSM module or by a TCP/IP connection over the internet to a database, which will require the use of a GPRS modem or a satellite modem. The GPS module receives the position and speed information and transmits it to the microcontroller. The microcontroller then sends the information to the GSM module which transmits it via SMS. A software is developed for viewing the location of the vehicle using the Google Maps API. Hardware used include the mentioned GSM/GPS modules, ATMega32 processor, LCD screen and a switch for the alert system.

This paper is from credible sources published on IEEE. The paper clearly defines the scope of the project purposely for use by commercial inter-city buses. This project distinguishes itself from the similar projects in the area by the incorporation of the alert system which processes information based on a trigger from the airbag circuitry, in the case of an accident, or a panic button pressed by the driver in the case of an armed robbery attack. The use of SMS makes the project applicable on all mobile platforms. The article is addressed to the computer engineering audience in Ghana.

M. A. Elahi, Y. A. Malkani, and M. Fraz. "Design and implementation of real-time vehicle tracking system". This article presents an accurate, low-cost, adaptive and reliable

real-time tracking system using GPS (Global Positioning System) and GSM (Global System for Mobile Communications) services. It makes use of Google Maps APIs in displaying the location on Google maps. The tracking device is attached to the person or object. The GPS receiver receives the location coordinates from satellites, the information is processed by the microcontroller and is sent to the mobile device through the GSM module or TCP/IP connection. The main hardware used in this project is GPS, GSM, PIC18F248 interface board.

This article is limited to tracking using a GPS module and viewed on a mobile device via a GSM module. I believe a clearly defined scope would make the paper easier to follow. The project can be augmented by the addition of sensors as seen in the earlier discussed papers.

A team from the school of computer sciences in Universiti Sains Malaysia published a paper on "Vehicle Tracking Device Fatin". This paper discusses the process involved in developing a vehicle tracking device. The author believes that this project could be used as a theft prevention and retrieval device due to the continuously increasing rate of car theft in Malaysia. The Global Positioning System (GPS) and Global System for Mobile Communication (GSM) are used to track the vehicle using google maps application or Waze. The system is based on Arduino Uno, GPS, and GSM as the main hardware. This project is a combination of hardware and software. The GPS modem receives the longitudes and latitudes from the GPS satellite and gives the information to the microcontroller. The GSM modem then pushes the information to the user through SMS.

The author is a credible writer published on IEEE. I like the problem definition arising from the increase in the rate of car theft. A strength of this project is the effective use of simple technology and a detailed description of the development process. The project

can be augmented by adding some additional features such as rote learning, location restrictions, etc., to the tracking system. The use of Arduino Uno board, GPS and GSM technology can be incorporated in my project. This paper will be an excellent source for my paper because it includes the same components with similar steps in the developmental process.

Based on the reviewed literature, a GPS/GSM Vehicle tracking device with additional features that are not found in the reviewed literature is proposed. In our Ghanaian society, the most common trackers are just that, vehicle tracking devices. The proposed device brings to the Ghanaian context an opportunity to track vehicle location as well as receive alerts when the vehicle goes beyond the restricted borders specified by the user. The proposed project allows vehicle owners to constantly know the whereabouts of their vehicles. The hardware device is an Arduino Uno board housing the GSM module, GPS module, ATMega32P Processor.

Chapter 3: Design

3.1 Design Objective

To design a low-cost circuit that houses the GPS and GSM components, and a system that enables the user to track the vehicle as well as perform all other supporting functions.

3.2 Design Decisions

This section presents the critical decisions behind the design of the vehicle tracking system. A Pugh matrix was used in selecting which components were ideal for the system. The Pugh matrix is a tool used to facilitate a disciplined, team-based process for concept generation and selection. Several concepts are evaluated according to their strengths and weaknesses against a reference concept called the datum (base concept).

3.2.1 Pugh Matrix for Processor

		Option A	Option B	Option C	Option D
Criteria	Weight	ATMega328P	ELM327	Raspberry Pi	ARM Cortex
Cost	4	0	+1	-1	-1
Availability	5	0	-1	-1	-1
Power Consumption	2	0	+1	-1	+1
Versatility	1	0	-1	+1	-1

The ATMega328P processor was selected for this project mainly because of its availability. The Arduino Uno board operates on this processor. It was the most convenient for the project.

3.2.2 Pugh Matrix for GPS Module

		Option A	Option B	Option C	Option D
Criteria	Weight	GPS module Ublox	GPS Module - Venus 638FLPx-L	GPS module Copernicus II	GPS module Copernicus II DIP
Cost	4	0	-1	-1	-1
Availability	5	0	-1	-1	-1
Power Consumption	2	0	0	0	0
Versatility	1	0	0	0	0

The GPS module Ublox component was selected for this project because of its affordable cost and availability.

3.2.3 Pugh Matrix for GSM Module

		Option A	Option B	Option C	Option D
Criteria	Weight	SIM 800L GSM module	SIM 800 GSM module	SIM 900 GSM module	SIM 900A GSM module
Cost	4	0	+1	-1	-1
Availability	5	0	-1	-1	-1
Power Consumption	2	0	0	0	0
Versatility	1	0	0	0	0

The SIM 800L GSM module component was selected for this project because of its affordable cost and availability

3.2.4 Cost Breakdown

The purpose of the cost breakdown is to buttress the point that this is a low-cost vehicle tracking system. As stated earlier in section 1.1, vehicle tracking devices on the Ghanaian market are averaged at GHS 400.00. the cost breakdown in the table below shows that the total cost incurred was GHS 190.00. Monetizing time used in creating software will increase

the total cost to about GHS 300.00. This is GHS 100.00 lower than the average cost and provides additional functions.

Component	Cost (GHS)
Arduino Uno Board	60
GPS Module	40
GSM Module	80
SIM Card	2
Wires pack	8
Total	190

3.3 System Requirements

3.3.1. Functional Requirements

- The user should be able to track the location of the vehicle on the web application via google maps API.
- The user should receive an email alert should the specified perimeter be breached.
- The system should update vehicle location every 10 seconds
- The server should first push GPS data directly to the webpage and then to the database to be stored for future access.

3.3.2 Non-Functional Requirements

Non-functional requirements describe what the system will do. It can be described as the quality attributes of the system. The following are the non-functional requirements of the vehicle tracking system:

- **Reliability:** Since the tracking is expected to be real-time**,** the system will be at work at all times. The Arduino will send location updates every 10 seconds, so the user can be assured of accurate location of the vehicle at all times.

- **Usability:** The system will be simple and easy to understand and use. Once the system is deployed, the user will be able to view the location of the vehicle simply by opening the web application.
- **Performance** The system will execute the expected functions listed in the section in 1.4.

3.4 High-Level Implementation

3.4.1 Block Diagram

A block diagram is a visual representation of a system that uses simple, labeled blocks that represent single or multiple items, entities or concepts, connected by lines to show relationships between them. An entity relationship diagram (ERD), one example of a block diagram, represents an information system by showing the relationships between people, objects, places, concepts or events within that system. [1]

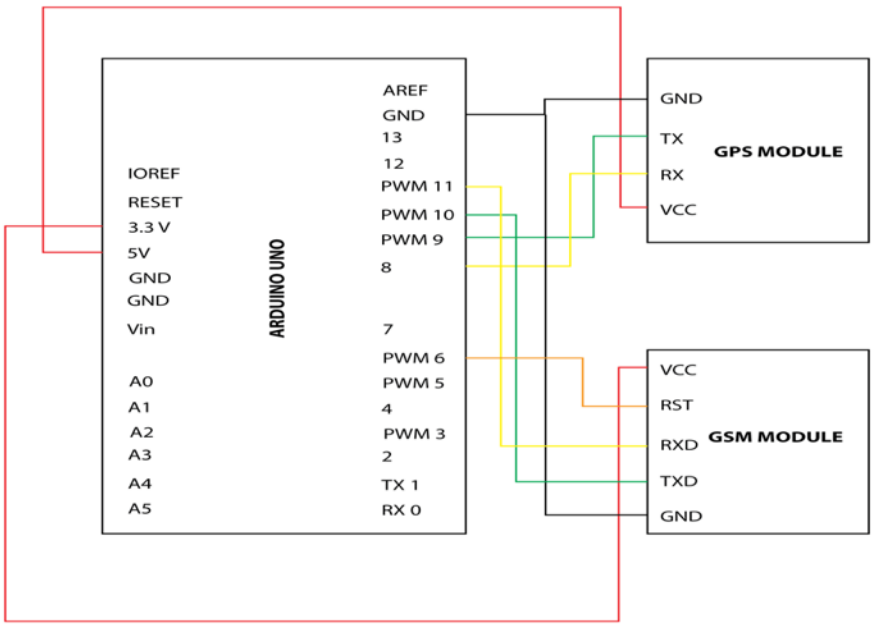

Figure 3-1: Block diagram of the vehicle tracking circuit showing the connection between the various components

3.4.2 Use Case Diagram

The purpose of a use case diagram in UML is to demonstrate the different ways that a user might interact with a system. Create a professional diagram for nearly any use case using our UML diagram tool. [2]

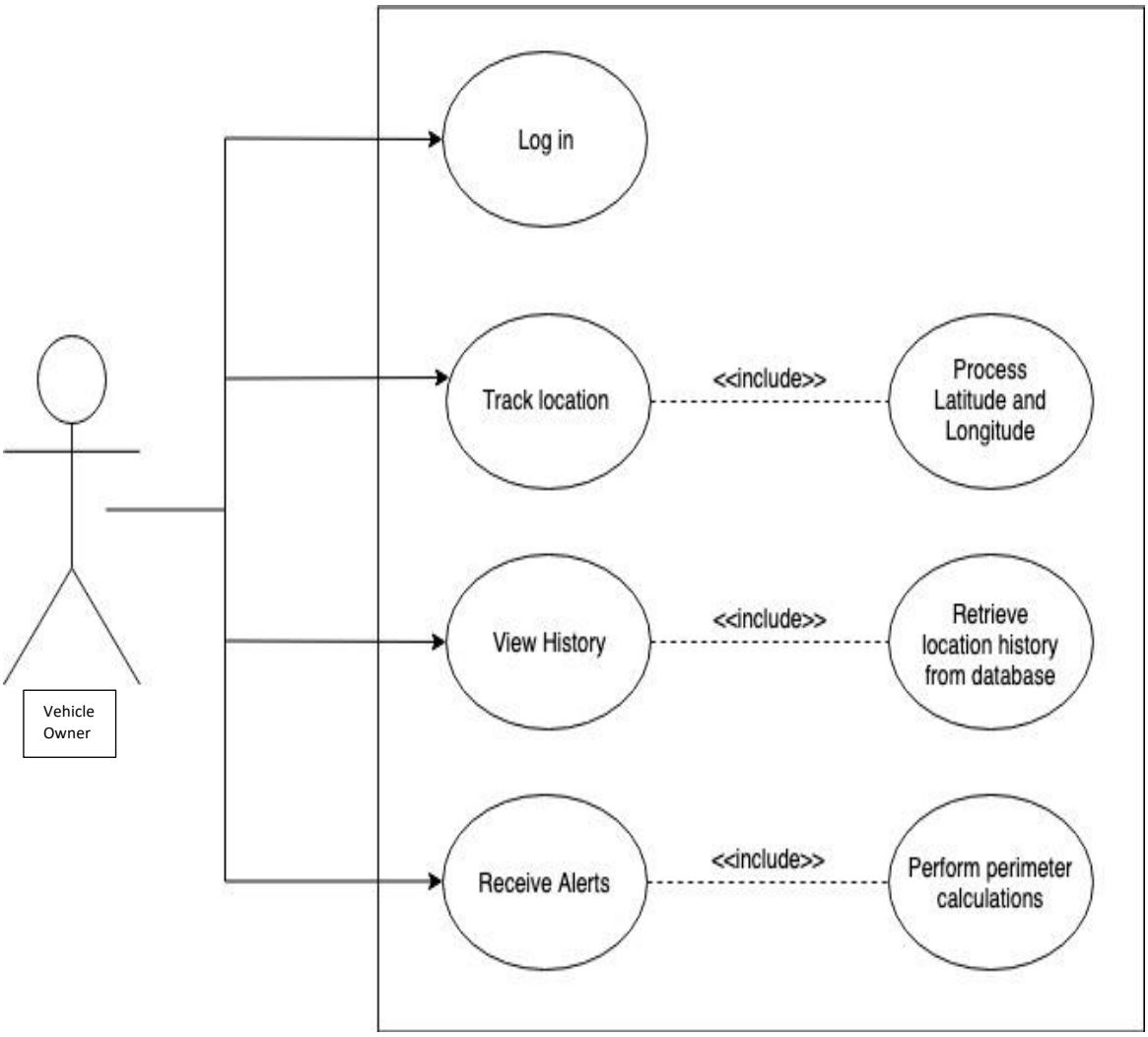

Figure 3-2: Use case diagram showing how the user interacts with the system

3.4.3 Flow Chart

A flowchart is a formalized graphic representation of a logic sequence, work or manufacturing process, organization chart, or similar formalized structure. The purpose of a flow chart is to provide people with a common language or reference point when dealing with a project or process. [3]

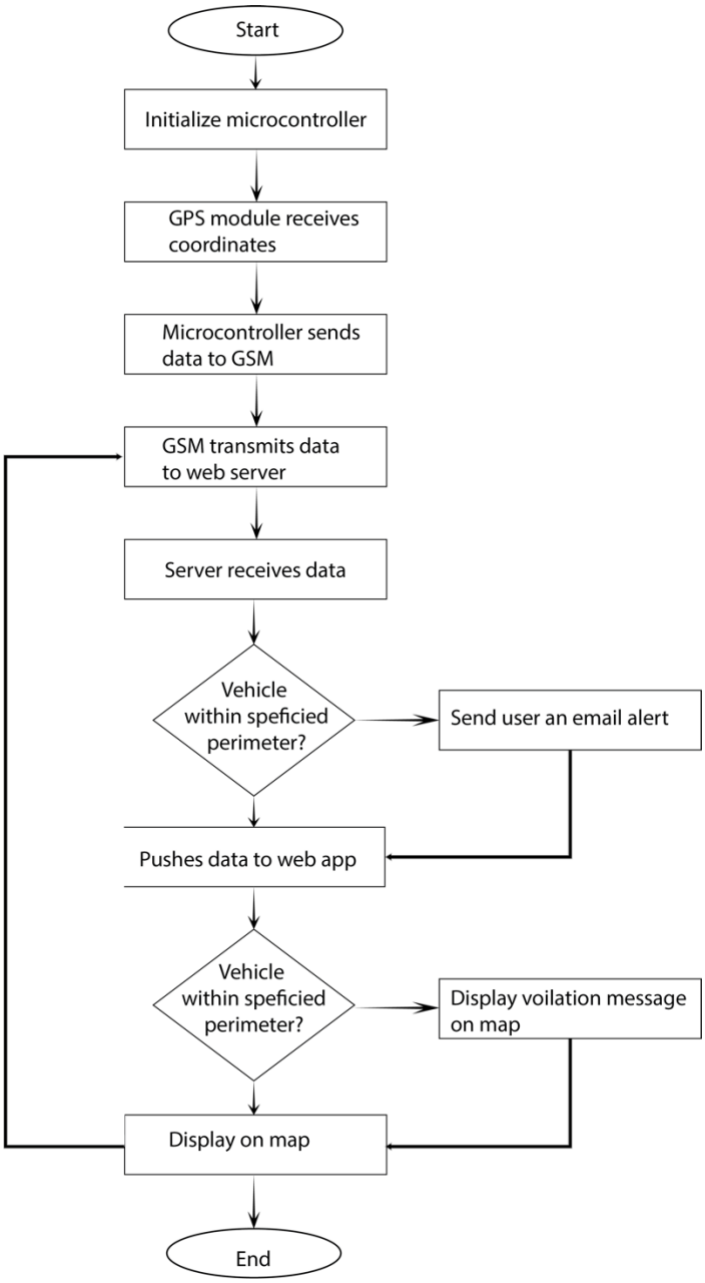

Figure 3-3: Flow chart showing the series of activities involved in the usage of the system

3.4.4 Web Application Layout

This is an expectation of how the web application interface will look like. The Haversine formula will be used to implement the location restriction feature. [4] This will be indicated by a red circle as seen in the figure below. The current coordinates are displayed at the top of the map. The current status is also displayed below the coordinates, indicating whether the vehicle is within the range or not.

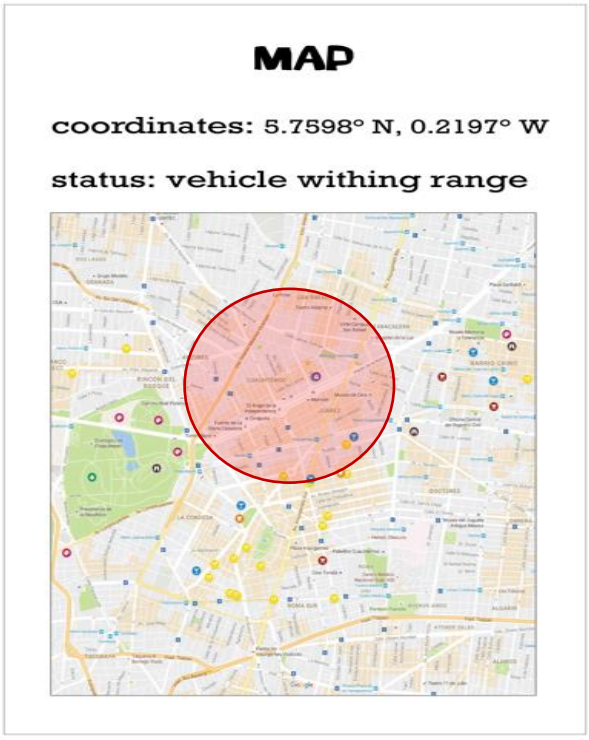

Figure 3-4: Expected layout of web application

3.4.5 Functions of Hardware and Software Tools

Hardware	Function
Arduino Uno	This is a microcontroller based on the ATMega328P processor. It houses the GPS and GSM components and provides an interface with the Arduino software tool.
GPS Module	Receives GPS coordinates and determines the location of the vehicle. Data received is sent to the micro-controller
GSM Module	Responsible for transmitting received GPS coordinates from the micro-controller to the web server.
Breadboard	A tool for connection which houses the hardware components for the vehicle tracking system.

Software	Function
Arduino	This is the software application used to interface with the Arduino Uno board.
Web server	This is responsible for pushing the transmitted data to the web application and then to the database.
Database	The database is simple storage of information. The database stores the GPS data transmitted by the GSM module as well as the home location.
Web application	The main user interface of the vehicle tracking system. Responsible for displaying the location of the vehicle using Google Maps API. Also provides the user the option to track vehicle location.
SendGrid	SendGrid is a software tool that will be used to send email alerts to the user when the specified perimeter is breached.
Postman	Postman is a software tool used to test and configure APIs. For this project, it is used to test the API by sending locations. This testing method is convenient since the real-time feature would require movement.

Chapter 4: Methodology

This chapter presents into more detail the system architecture, how the various components of the system interact with one another and the software implementation of the system.

4.1 Experimental Setup

4.1.1 Arduino Uno Microcontroller

The GPS and GSM modules are connected to pins on the Arduino Uno microcontroller which interfaces with the Arduino software on the computer. The pins used for this project are 5V, 3.3V, GND, RST, 6, 8, 9, 10, 11.

4.1.2 GPS Module

To ensure that valid readings were obtained the GPS module was sent outdoors, into open space to be calibrated. Usually, when GPS modules are not properly calibrated, an error in the form of "invalid location" is encountered. This prevents the GPS module from receiving any valid data and so it was paramount that the GPS module is properly calibrated to avoid the error.

The GPS module has 4 pins namely: VCC, TX, RX and GND. Pin VCC was connected to the 5V pin on the Arduino microcontroller. TX and RX are connected to pins 9 and 8, and GND is connected to one of the GND pins on the Arduino Uno microcontroller.

4.1.3 GSM Module

The GSM module requires a SIM card to function. The AirtelTigo SIM card was used for this purpose because of the strong connection received in the current location. Unlike the GPS module, the GSM module has 5 pins namely: VCC, RST, TX, RX, and

GND. The VCC pin on the GSM module is connected to the 3.3V pin on the microcontroller. The RST pin is connected to pin 6, TX and RX are connected to pins 10 and 11, and GND shares a common connection with the GPS GND on the microcontroller.

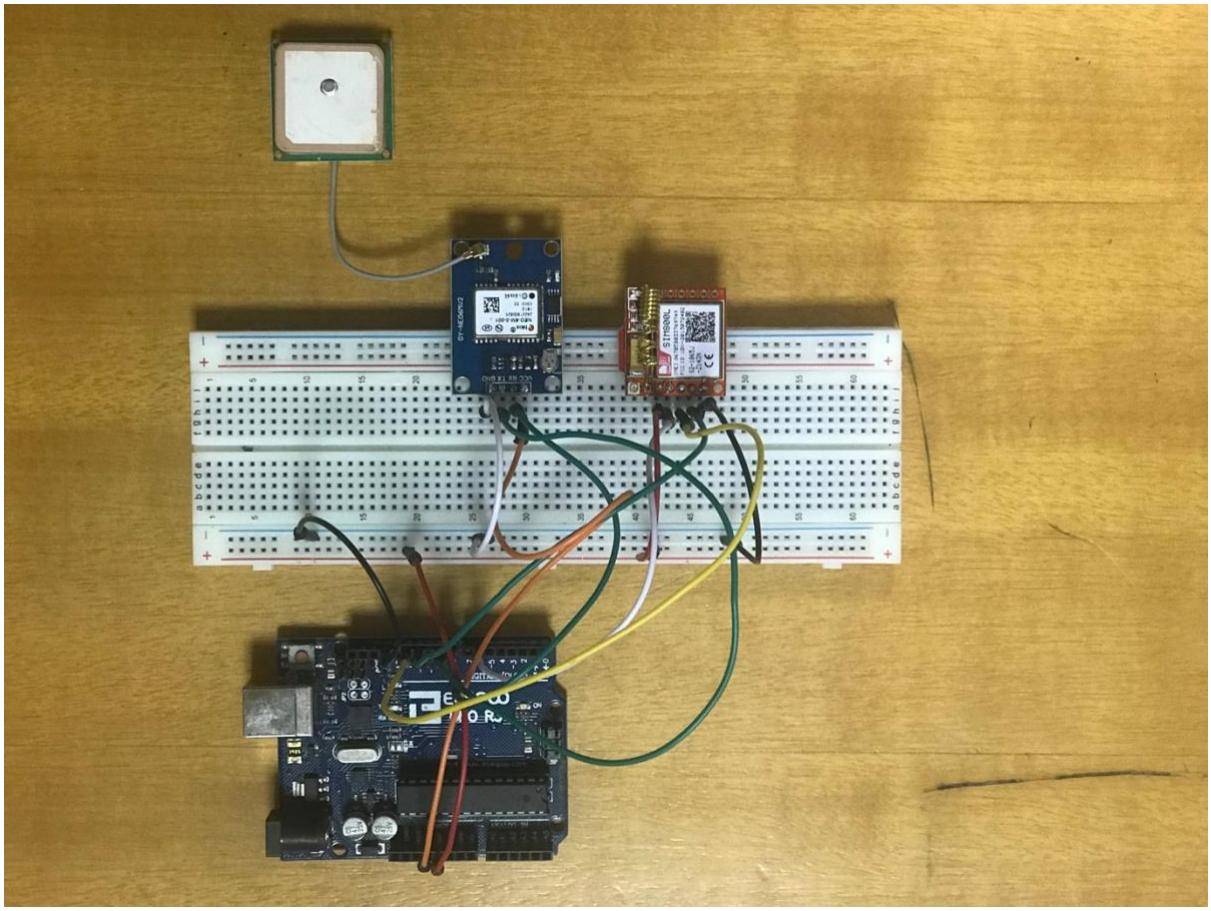

Figure 4-1: Vehicle tracking circuit showing the connection of the main components

4.2 Method

4.2.1 Arduino

The Arduino software is used to interface with the Arduino Uno microcontroller. The code is configured to send GPS data to the listening web server via the GSM module.

4.2.2 Web Service

Tracking of the Location of a car (Arduino) is achieved with a Web Service Created using C#, and ASP.Net Core

The Web Service acts as Mediator between the hardware, the database, and the web application. The Web Service (API) runs SignalR, which is a real-time messaging and notification framework. The SignalR Code is triggered in the controller by a POST request being sent by the Arduino. This request contains the latitude and longitude information of which is then sent to the Web Application using a SignalR Hub connection. SignalR sends data using various mean, WebSocket's, Long Frames, etc. The Hub Connection to the Web Application using SignalR is set to the default settings. This uses the best and available connection available on the device to establish a connection.

The Web Service also performs computations and calculations, to determine the right coordinates or the correct range or distance the car finds itself in at a given time.

```
using Microsoft.AspNetCore.SignalR;
using System.Threading.Tasks;

namespace Gps.Api.Service
{
    public interface ILocationHubService
    {
        Task PinpointLocation(string lat, string lon);
    }

    public class LocationHub : Hub<ILocationHubService>
    {
    }
}
```

Figure 4-1: SignalR hub interface

4.2.3 Database

The database was implemented using Visual Studio's Local Database. The database created using a Code First Approach. C# classes were made that mirror table in SQL. Based on the Name of the classes and the fields in each table, database migrations were running using an object-relational mapper (ORM), entity framework core, to run database migrations. Migrations are when an ORM parses language-specific objects and classes and create SQL table scaffoldings that represent the same structure of the database schema design using language classes and objects. For the purpose of the project, 3 tables were needed, namely the home location table, location table, and the users table.

Home Location Table

This table stores the permanent location of the central location (center point of circle) set as the default location.

Location Table

The location table contains, latitude and longitude which represents the location of the respective car at given time periods, and a foreign key, User Id, which will serve as a form of restriction on data access when the system is implemented for multiple cars and Users.

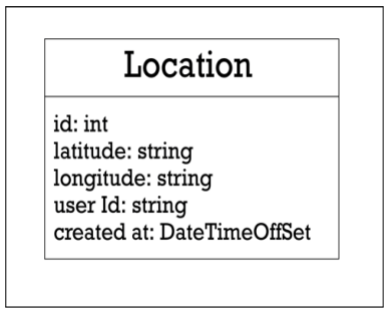

Figure 4-2: UML Diagram of location table in database

```
[Table("Location")]
public class Location : EntityBase
{
    //Hide the actual Id value from users by encoding is
    [NotMapped]
    public string EncodedId => IDService.Encode("loc", Id);

    [Required]
    public string Latitude { get; set; }

    [Required]
    public string Longitude { get; set; }

    [Required]
    public double Distance { get; set; }

    [Required]
    public int UserId { get; set; }
}
```

Figure 4-3: Location table object which holds the frequently changing location info

User Table

This table contains the basic information of a User. It is used to authenticate users and identify a specific user to their car information.

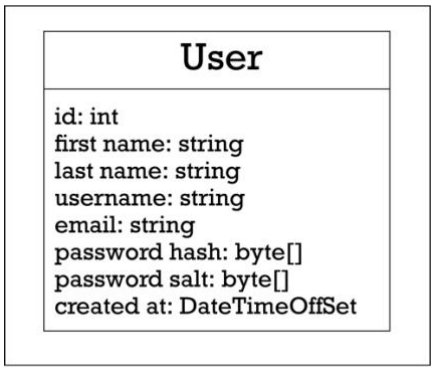

Figure 4-4: UML Diagram of the user table in the database

For Security reasons, passwords are hashed before stored using HMACSHA 256 hashing. Also, the Actual id of a table is never exposed to the User Interface of the Web Application or the cars (Arduino) system. Rather this value is Encoded before used.

4.2.4 Web Application

The Web Application in this project is used as a dashboard to monitor information about the vehicle. This was implemented using Angular 7, which uses the typescript Language. Typescript is a language derived from JavaScript, which allows developers to utilize strongly typed language capabilities, it was developed and managed by Microsoft. [5]. To enable users to track the location of their car. The google maps API was used. A map was embedded on the dashboard of the web application. This map is fed with live location data from the Arduino via SignalR.

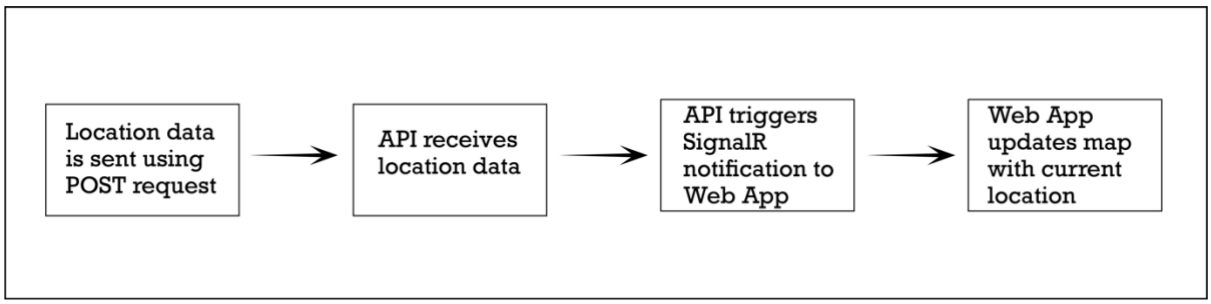

Figure 4-5: Illustration of web application operation

```
connect(accessToken) {
  if (!this.connection) {
    this.connection = new signalR.HubConnectionBuilder()
    .withUrl(CONFIGURATION.baseUrls.server +
        'location')
    .build();

    this.connection.start().then(() => {
      console.log('Hub connection started');
      this.connectionEstablished.next(true);
    }).catch(err => console.log(err));

    this.connection.on('PinpointLocation', (latitude, longitude) => {
      console.log('Received', latitude, longitude);
      this.locationCordinates.next({ latitude, longitude });
    });
  }
}
```

Figure 4-6: SignalR connection from Web Application

4.2.4.1 Location Restriction

To find the circle distance, also known as orthodromic distance, the Haversine formula is used. The steps in calculating the distance are shown in the table below:

Find the value of the latitude in radians: Value of Latitude in Radians, lat = Latitude / (180/pi) OR Value of Latitude in Radians, lat = Latitude / 57.29577951 Find the value of longitude in radians: Value of Longitude in Radians, long = Longitude / (180/pi) OR Value of Longitude in Radians, long = Longitude / 57.29577951 To find the distance between the two points: Distance, d = 3963.0 * arccos[(sin(lat1) * sin(lat2)) + cos(lat1) * cos(lat2) * cos(long2 – long1)]

Any time the Arduino/postman sends its location (which happens every 10 seconds using the Arduino), to the API on the server receiving the coordinates sent, it will need to first verify if the current location has violated the Home location boundaries. When it receives the location, it fetches the home location data from the database. This data contains the default home location coordinates and the specified distance. The distance is the radius around the home location coordinate that the vehicle is permitted to travel. This range is displayed on the web application as a red circle. By default, the distance is set to 300 meters.

After fetching the home location data, it needs to check for breaches in the safe area. It does this in the following steps:

1. Calculate the distance between the points on the map using the Haversine formula

2. Compare the resultant distance Magnitude. If the resultant distance is larger than the home location distance, it means there is a violation.

In the case of a violation, the home location distance is subtracted from the resultant distance between the two points. An email is sent to the user using the SendGrid API to the vehicle owner. The information is then posted to the web application using SignalR. SignalR then does its calculations using the same Haversine formula and process and displays it on the map.

```
public static class DistanceService
{
    private const int RE = 6371; // Radius of the earth

    //Method that returns results of distance voilation
    public static string CalculateDistanceVoilation(double radius, double homeLat, double homeLon, double lat, double lon)
    {
        if (radius - CalculateDistance(homeLat, homeLon, lat, lon) < 0)
        {
            return string.Format(@"You are {0}
            meters out of the safety range", CalculateDistance(homeLat, homeLon, lat, lon) - radius);
        }
        return string.Empty;
    }

    //Implementation of Halfsine formular
    private static double CalculateDistance(double homeLat, double homeLon, double lat, double lon)
    {
        var dLat = deg2rad(lat - homeLat);
        var dLon = deg2rad(lon - homeLon);
        var a =
              Math.Sin(dLat / 2) * Math.Sin(dLat / 2) +
              Math.Cos(deg2rad(homeLat)) *
              Math.Cos(deg2rad(lat)) *
              Math.Sin(dLon / 2) * Math.Sin(dLon / 2);

        var c = 2 * Math.Atan2(Math.Sqrt(a), Math.Sqrt(1 - a));
        return RE * c * 1000; // distance, d = RE * c, (distance in kilometers so multiplied by 1000)
    }

    //Helper method to convert degrees to radians
    private static double deg2rad(double deg) => deg * (Math.PI / 180);
}
```

Figure 4-7: Implementation of Haversine formula in C#

4.2.4.2 Email Alert

The email alert feature was implemented using SendGrid's API. To use the service, an account must be created with SendGrid to get an API key. A SendGrid object is created, and the API is inserted is added to the dependency injection container, so it can be used in the whole application. The dependency injection container is how ASP.Net Core feeds applications with objects that are initialized at runtime. When the GPS location is posted from the Arduino, it runs checks on the information being received and compares with the home location specified in the database. The home location is a place that is set as the GPS location, with a specified radius of about 300m around that point. Any violation of the radius around the home location checks the distance violation and send email alerts the user using the SendGrid object created.

Chapter 5: Results

5.1 Hardware

The readings captured by the GPS module is transmitted to the web server via the GSM module. The data transmission occurs every 10 seconds to make the tracking close to real-time as possible. Figure 5-1 is a sample of the GPS module readings as seen in the serial monitor of the Arduino software.

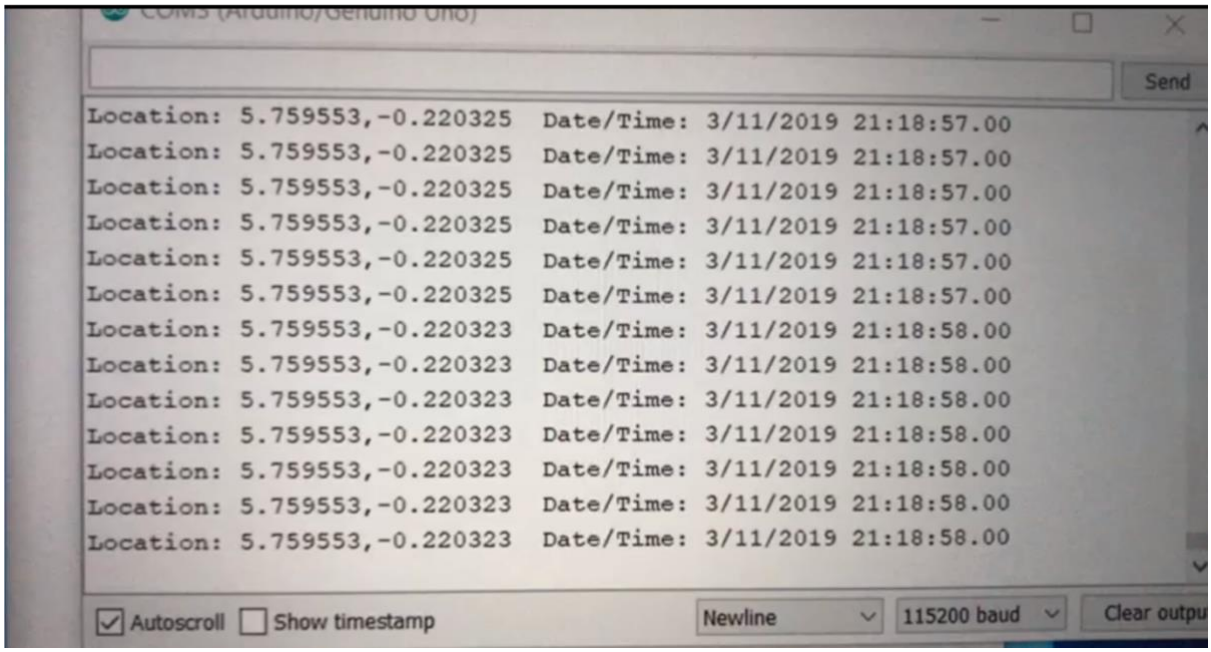

Figure 5-1: Sample GPS data as seen in the Serial monitor of the Arduino software

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5.2 Server Side

When the GPS data is sent to the server, it compared the coordinates to the home location to determine whether the received coordinates fall within the specified perimeter. This calculation is done using the half-sine formula stored in the API.

5.3 Web Application

The web application is deployed on the local host. GPS data is received from the web server to update the location on the map.

5.3.1 Location Tracking

As seen from Figure 5-1 and Figure 5-2, a perimeter, indicated in red, has been specified. The google maps API provide the option of viewing the map in Satellite and terrain mode. The blue pin seen on the map represents the home location. Currently, the home location is the present location. A small radius was used for testing purposes When the coordinates were changed to a location outside the specified perimeter (indicating the vehicle had gone beyond the specified radius), the user received an email alert. The results from the email alert function are described in the next section.

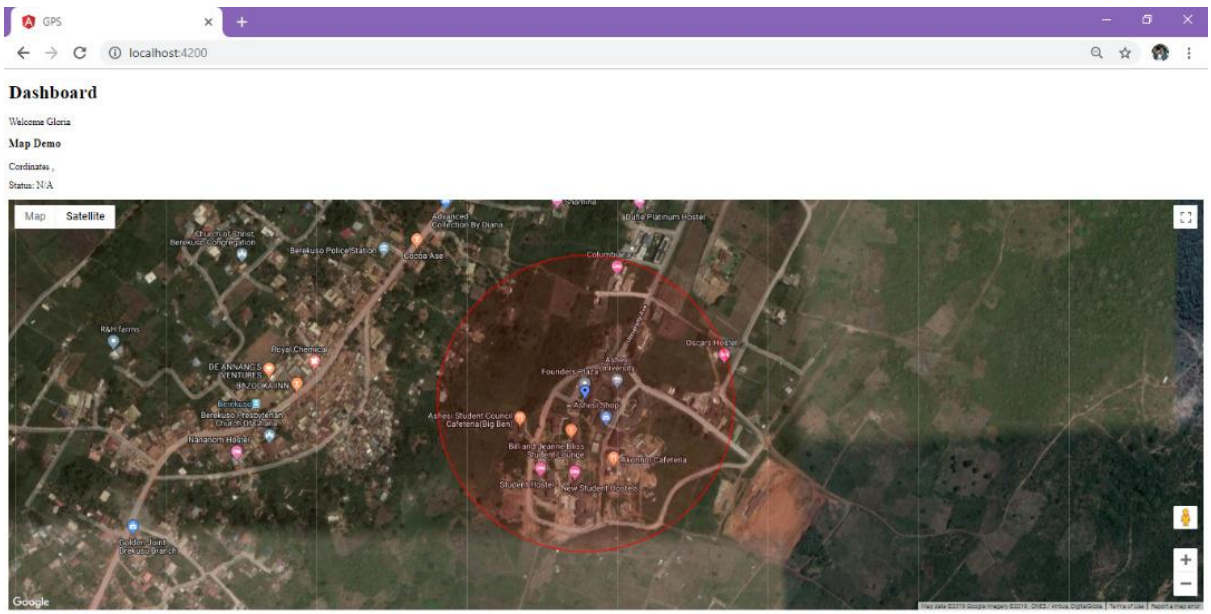

Figure 5-1: Web application interface in satellite view mode

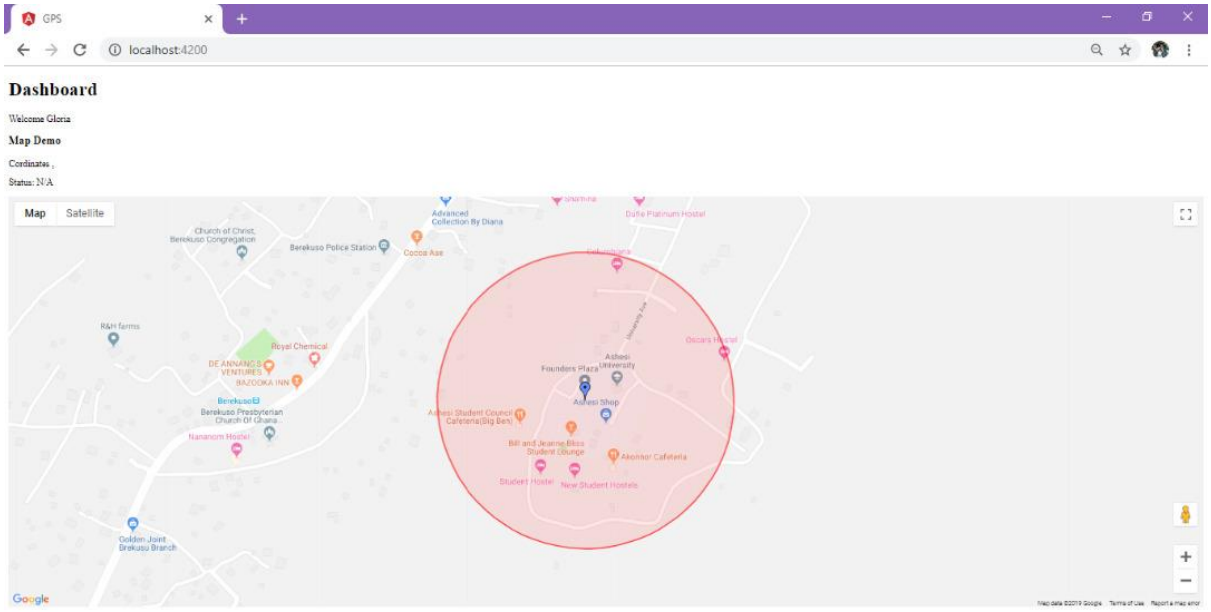

Figure 5-2: Web application interface in Terrain view mode

5.3.2 Email Alert

In Figure 5-3, it can be seen that there are now two pinpoints, a red, and a blue pin. The blue pin indicates the home location and the red pin indicates the current location. It is also seen that the red pin is outside the specified range. Postman has used to send coordinates that fell outside the range, indicating the vehicle had gone beyond the specified perimeter. The status above the map changes from "N/A" to "You are 345 meters out of the safety range". Samples of email alerts that were received as different coordinates outside the range were tested are seen in Figure 5-4. These were received immediately the specified range was violated.

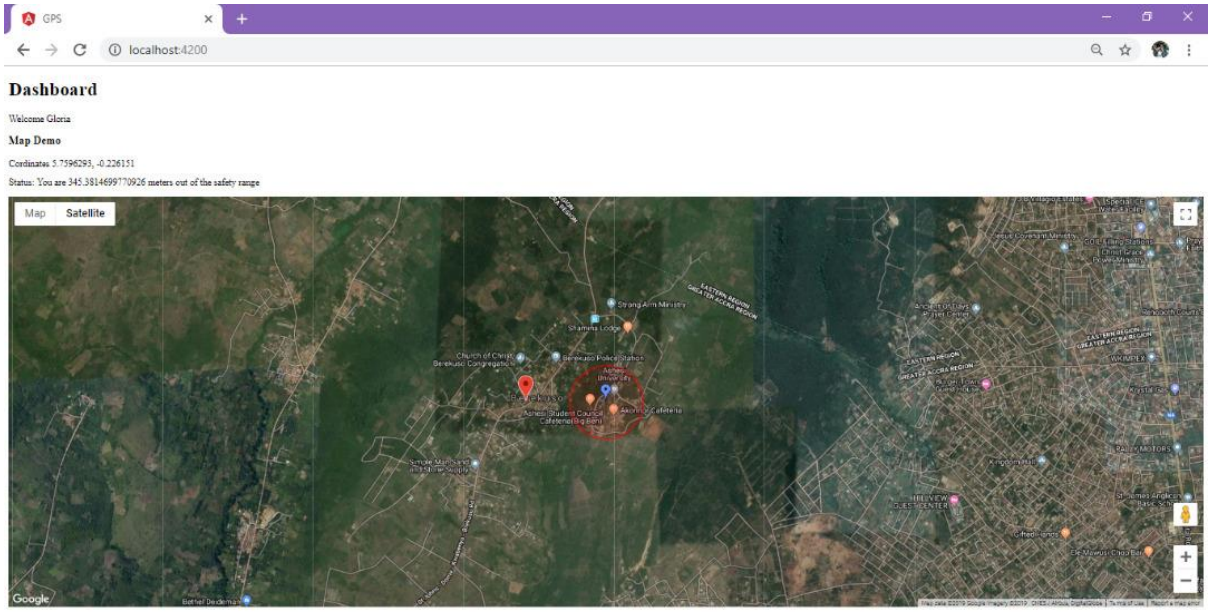

Figure 5-3: Map showing location outside the specified range.

Figure 5-4: User's inbox showing email alert messages.

Chapter 6: Conclusion

6.1 Discussion

In this project, I have presented a detailed description of the design and implementation of a low- cost vehicle tracking system. After the successful completion of this project, the following benefits are realized by parents and other vehicle owners for whose use this system is intended for:

- Effective real-time vehicle tracking
- Information on vehicle location history over a period of time
- Quick email alert when the vehicle goes beyond the specified perimeter

The system has proven to be effective and it is hoped that more people will adopt the use of vehicle tracking due to these new features added to the traditional vehicle tracking devices sold on the Ghanaian market. It is believed that child kidnapping, car theft and other dangers mentioned in the motivation behind the topic can be greatly reduced with the adoption and use of this vehicle tracking system.

6.2 Limitations

During testing, a major limitation that was initially overlooked in the planning stage was encountered. The GSM module operates on mobile data and since it was continually transmitting data to the web server, data was constantly being used. This required that data was purchased several times during testing, and so will become a major problem in the actual implementation of the system. Another limitation was in the testing of the hardware circuit. Real-time required movement to test the circuit.

6.3 Future Work

Based on the success of the project, more features can be added to augment the system. Research can be done on how to bypass the data issues of the GSM module discussed earlier in section 6.2. For testing purposes, the perimeter was fixed. Future implementations will allow the user the option of modifying the range whenever it's desired. A mobile application can also be developed to provide more convenience in terms of the usage of the app. With the mobile application, user can receive notifications and alerts whether online or offline. Sensors can be incorporated in the circuit to provide additional features. The use of a gas sensor can be used to detect when there is a leakage in the vehicle. The use of an accelerometer can be used to detect the speed at which the vehicle is moving. An alcohol sensor can also be included to check whether the driver is sober or has had some alcohol intake. All these sensor readings will be displayed on the web application. The research will need to be made on how to incorporate these new components in the circuitry in such a way that it will be in close proximity to the driver while also serving all its expected functions.

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