ASHESI UNIVERSITY

IMPLEMENTATION OF A GPS TRACKING SYSTEM AND A REMOTE CONTROL INTERFACE FOR A MINI-VEHICLE

CAPSTONE PROJECT

B.Sc. Computer Engineering

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2019

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CAPSTONE PROJECT

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

Samuel Ebenezer Bunyan

2019

Declaration

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

Supervisor's Signature:

Supervisor's Name:

Date:

Acknowledgement

I would like to extend my gratitude to all the lecturers I have encountered throughout my time in Ashesi, as their contribution towards shaping my thinking over the course of my time in Ashesi was extremely vital throughout this project. I would also like to thank my family and friends for their constant support during this project. Additionally, I would like to express my sincerest gratefulness to my supervisor, Dr. Kenobi Morris for his continuous support and advice throughout the course of the project. Most importantly, I would like to thank God for his guidance throughout the project.

Abstract

Car theft has become prominent all over Ghana in recent years. Despite its growing prominence throughout the country, measures to promptly recover stolen vehicles have often proved tedious and futile. To tackle this problem, this project aims to develop a remote control system and a model of a GPS tracking system which would together help vehicle owners swiftly recover their vehicles should the need arise. This was achieved by developing a mobile application to serve as an interface for remote control circuit integrated with a mini-vehicle. The developed interface provides an effective means of controlling the vehicle. To further improve upon this project, a WIFI module can be used to increase the range of control, while an ultrasonic sensor can be integrated into the vehicle to help avoid obstacles when controlling the vehicle remotely.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background

The advancement of technology in the past two decades has steered a new wave in society today. Today, technology has significantly transformed many aspects of our society, from the way we work to the way we socialize and everything in between [1]. This domination of technology over our everyday lives has reformed society such that life has been simplified in a variety of ways. Despite the enhancement of our everyday activities due to the upsurge in the use of technology, recent developments have also led to several adverse effects in society pertaining to health, privacy, and security, among others. The rise in the use of technology in developing countries has seen a similar rise in the theft cases involving these technology. Now, more than ever, guarding expensive technology has become more and more important.

One prime example of the growing necessity to protect technology is the steady rise in carjacking in Ghana. Carjacking can be described as the intentional and unlawful theft of a vehicle by force or threat of force [2]. Although carjacking is a worldwide phenomenon, reports in Ghana over the past five years suggest that it is on the rise due to the economic hardships experienced in the country. Per police reports, carjackers typically take advantage of alienated locations and hide in bushes while waiting for an appropriate time to strike before forcibly removing the passengers out of the car [3]. Other more sophisticated techniques, include drink spiking and posing as interested persons for cars on sale [4]. These newly deployed techniques make it more and more difficult for vehicle owners to resist carjacking. In one carjacking operation, the criminals involved approached a taxi rank and pretended to be interested in hiring the service of a taxi. After obtaining the driver's service and making a stop at the Mall, the criminal offered a drink to the unsuspicious driver. The drink was spiked causing the driver to pass out, and then the vehicle was stolen accordingly [5].

To further highlight this problem, a report emerging from Daily Guide in 2018, revealed that eleven carjackers were apprehended by the police from their various hideouts in Accra and Tamale [3]. From this apprehension, the police retrieved eleven vehicles, seven of which were identified by their original owners [3] after several months of investigations. This failure to retrieve all the vehicles, despite spending months on investigations, emphasizes the need for a mechanism to retrieve these lost vehicles.

In stark contrast to the technological shift in developed countries which has caused crime rates (such as those involving car crimes) to drop dramatically in the past 20 years [6], many developing countries like Ghana currently still face challenges with combatting crime. With Ghana lagging behind in technological integration, where police in developed countries have often thrived by harnessing technology to improve their effectiveness, the lack of availability of surveillance videos, fingerprint technology and DNA evidence has ultimately made it difficult for the police department in the country to operate optimally.

As such, this project aims to develop a remote control interface and a GPS tracking system that can be easily retrofit on vehicles to aid in the recovery of stolen vehicles. For the effective implementation of this system, this project was carried out as a collaboration between the author of this paper and Wilfred Amoo-Gottfried, a mechanical engineering student. The author of this paper is responsible for developing the GPS tracking system and the remote control interface, while Mr. Amoo-Gottfried's role in this project is to develop a steering system mechanism to help achieve the remote control interface.

1.2 Related Works

This section presents information gathered from existing research in preparation for the project. Consequently, the topic area explored was the history surrounding the invention of cars and the development of smart vehicles in recent years.

As revealed in the preceding chapter, technology has developed significantly in recent decades causing tremendous improvements in society today**.** The first full-scale self-propelled mechanical vehicle or car was designed and constructed by Nicholas-Joseph Cugot in 1769 and was unable to carry a passenger [7]. Although this represented the first step in the development of cars, this invention had issues with water supply and maintaining water pressure. With this inspiration, many steam powered vehicles dominated the early parts of the 19th Century. Before long, the development of the world's first internal combustion engine in 1807 led to a new model of a vehicle powered by this new engine technology [8]. Overtime, the development of the cars significantly evolved to incorporate more improved mechanisms. Karl Benz is generally credited with being the inventor of the modern car [9]. The invention of the modern car was shortly followed by the first road trip by a car which was undertaken by Benz's wife, Bertha Benz to prove the road-worthiness of the new car invention [9].

By the 20th Century, large-scale, production line manufacturing of affordable cars had become the dominant routine used in the automobile industry. As a result of this new development in the industry, cars came off the production line much more rapidly than in previous methods, increasing productivity significantly, while using less manpower [10]. This new turn in the industry caused the automobile industry to make waves around the world and meant that automobile companies that failed to adopt the new technique in mass production, risked going broke. By 1930, as many as 250 companies that had not adopted mass production had disappeared [10].

In response to the rise of new technologies all over the world, controls in respect to cars have also evolved with a similar rise in the use of electric cars, the integration of mobile communication into vehicles and the growing development of autonomous cars. An electric car is a plug-in electric automobile that is propelled by one or two electric motors, using energy typically stored in rechargeable batteries [11]. From its inception in the 19^{th} Century, electric cars have gradually gained influence in the car industry due to the growing concerns of oil prices and a desire to reduce greenhouse gas emissions, which pose a threat to the environment. Unlike the electric car, autonomous (self-driving) cars are a more recent development in the industry. An autonomous car is best described as a vehicle that is capable of sensing its environment and moving with little or no human input [12]. Typically, autonomous vehicles combine a variety of sensors (such as radar, GPS, sonar, odometry, among others) to recognize their surroundings. Although fully autonomous vehicles already exist in prototype, there is still more room for progress before they are in general use.

As mentioned above, autonomous vehicles move with little or no human input. As such, although these vehicles cannot be directly described as remote controlled vehicles, both modes of vehicles largely employ the same principles; which is the capability of controlling a vehicle without human input. Consequently, the understanding of the concept behind the development of autonomous vehicles is a particularly key aspect in the implementation of this project.

1.3 Problem Description and its Significance

In Ghana today, the absence of surveillance cameras in most parts of the country as well as a poorly managed database of citizens in the country has made the efforts of the police in solving crimes quite futile. To place the issue into further perspective, the typical approach and arguably the only means of investigating crime in the country is by relying solely on eye witnesses. Consequently, for many crimes committed in alienated areas, it is often next to impossible for the police to solve. Therefore, steps need to be taken to bridge the gap between the use of technology in solving crimes and the police department in the country.

This paper seeks to demonstrate how the development of a GPS tracking system and a remote control interface would help recover stolen vehicles efficiently. Due to how widely used mobile phones are, this GPS tracking system is developed as a mobile application. In addition to the development of a GPS tracking system, a remote control interface is modelled on a mini-vehicle to test its effectiveness in order to analyze its potential influence on quick recovery of hijacked vehicles in the near future. Consequently, the development of the GPS tracking system will improve the security of vehicles all over the country.

1.4 Objective

This project seeks to explore the incorporation of mobile technology into a mechanical design by creating an efficient smart vehicle system modelled on a mini-vehicle. Through this development the project aims to model the recovery of a vehicle by using GPS technology and a remote control interface. The GPS technology would identify the location in which a vehicle is at a particular point in time, while the remote control interface would enable the user to steer the vehicle to him or herself.

1.5 Overview of Remaining Chapters

This project paper is segmented into five main chapters and is outlined as following. The first chapter presents the project to the reader, highlighting the motivation behind the project and providing some background information to the project. Chapter two then describes the design, emphasizing the various components of the project as well as the assumptions and constraints involved with coming up with an appropriate design. Chapter three is a chapter on the implementation and focuses on the procedure adopted in completing the project. The fourth chapter gives a detailed account of the results obtained from the implementation and analyses the results accordingly. The paper would then conclude in a final chapter containing the limitations of the project and highlights suggestions for future areas of development in the project.

Chapter 2: Requirements and Design

2.1 Overview

This section on design introduces the chapter with an outlined purpose and a brief summary of what this chapter entails.

2.1.1 Purpose

This chapter describes how the mobile application in addition to the control system described in the preceding chapter are designed and implemented. The design presented in this chapter provides a detailed view of the mobile application architecture to enable an engineer to build the system according to the requirements specified.

2.1.2 Summary

This chapter features an elaborate description of all the aspects that encompass the successful design of parts of the system that played a key role in implementation. The chapter also discusses the processes carried out in selecting an appropriate design. These processes would demonstrate the design considerations after thoughtful deliberations throughout the course of the project.

2.2 Requirements Specification

2.2.1 Scope

This project designs and implements a mobile application to facilitate the control and tracking of a mini-vehicle. To successfully make the application functional, a hardware system was constructed to enable the interaction between the vehicle and the mobile application. As such, a remote control circuit and a GPS tracking circuit consisting of all the necessary components were developed.

The various components of the system are explained below:

- **Remote Control Circuit:** The remote control circuit would provide a vehicle owner with the ability to control his/her vehicle from a distance. This control is achieved by re-configuring the steering mechanism (carried out by Mr. Amoo-Gottfried) on a vehicle and incorporating the remote control circuit into it. The remote control circuit would then consist of a stepper motor, powered by a motor driver that is responsible for controlling the direction in which the vehicle moves as intended by the vehicle owner. Two DC motors are also embedded in the circuit to control the forward and backward motion of the vehicle.
- **GPS Tracking Model:** The GPS tracking model would aid the vehicle owner in monitoring a vehicle as and when he/she chooses to. This model of a GPS tracking system would provide a representation of a tracking system that can be developed further enhanced in the future to aid in the recovery of vehicles. For this project, the GPS Tracking is executed as a mobile app interface to simply allow a vehicle owner to locate his/her vehicle in the midst of a very packed parking space. This is achieved by employing the use of the location services provided on an Android Operating System driven mobile phone.
- **Mobile Application:** The mobile application would provide a user interface for a vehicle owner to navigate the control of his/her vehicle. It would also provide an avenue for the owner to monitor the location of the vehicle at every given point in time. The mobile application is developed using MIT App Inventor 2 and is constructed using the Android operating system and would be available

to Android users. The application would have two screens, one for the remote control and one for the GPS tracking.

- **Vehicle Steering System and Rear Wheel Drive:** The design of the vehicle steering system and rear wheel drive would provide a means of integrating the remote control circuit with a prototype vehicle. To achieve this, the steering system was constructed as a rack and pinion steering system, and driven by a stepper motor. This aspect of the system was designed by Mr. Amoo-Gottfried.

2.2.2 Overall Description

This section provides a detailed overview of the requirements of the system requirements. The context diagram in Figure 2.1 provides a high-level description of the system and its various components. The main actor in the system controls the steering of the vehicle using a mobile phone. This is illustrated in the diagram, in addition to his/her interaction with the system.

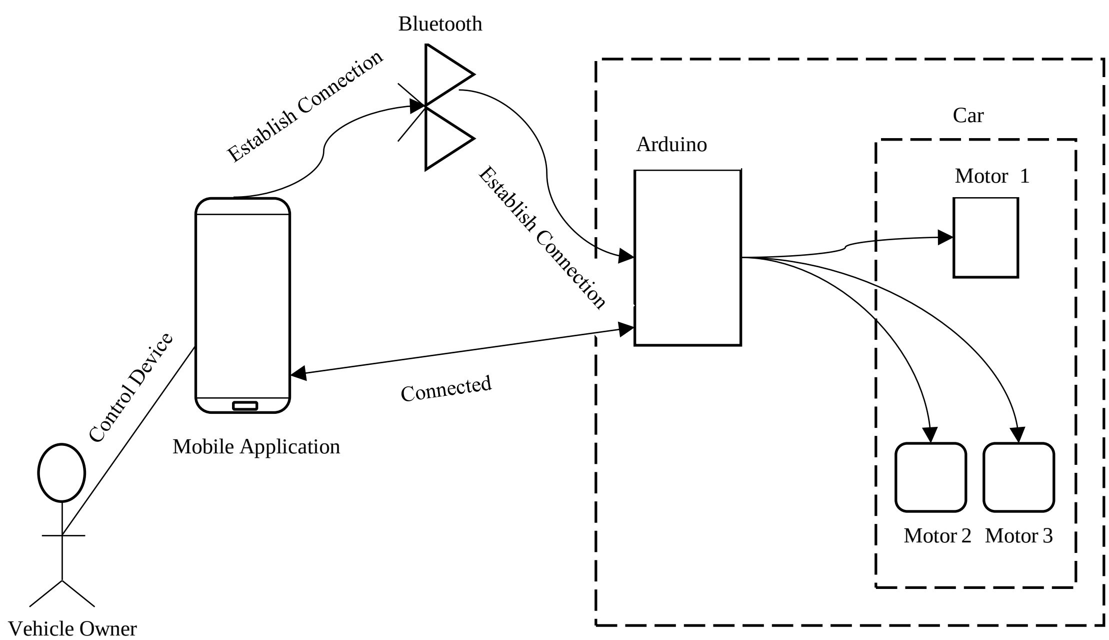

Figure 2.1: Context Diagram of System

2.2.3 Product Functions

The primary functions of the system with a brief description of each are listed below:

- **Remote Control:** This function enables the user to remotely control a vehicle within a 100 meter radius by pressing the desired directional buttons on a mobile application.
- **GPS Tracking**: This function enables the user to record the location of the vehicle when getting out of the car. As such, when parked in a congested area, a vehicle owner can easily locate his car by accessing the mobile application.

2.2.4 Specific Requirements

The functional requirements of the system have been segmented based on the major product functions of the system. Functional requirements are statements that specify the services that a system is expected to provide, how the system should react to particular inputs, and how the system should behave in particular situations [13]. Essentially, functional requirements define the specific facilities to be provided by the system. The functional requirements for this project are outlined in the following subsections; Remote Control and GPS Tracking. A summary of these functional requirements are provided below:

- The mobile application shall allow users to connect to Bluetooth.
- Users can view location of paired vehicles.
- User can steer movement of a paired vehicle with the mobile application.
- User can stop the movement of a vehicle.
- System must store location of vehicle in a database.

2.2.4.1 Remote Control Interface

This section elaborates on the remote control interface requirement and provides a use case depicting the behavior of the remote control interface. A scenario is also provided, after which a detailed breakdown of the functional requirements is then listed and discussed.

2.2.4.1.1 Description

This is the key feature of the system and allows the user to steer the vehicle in his/her desired direction. The use case diagram in Figure 2.2 describes the user's interaction with the system in respect to this requirement.

2.2.4.1.2 Use Case Diagram: Remote Control

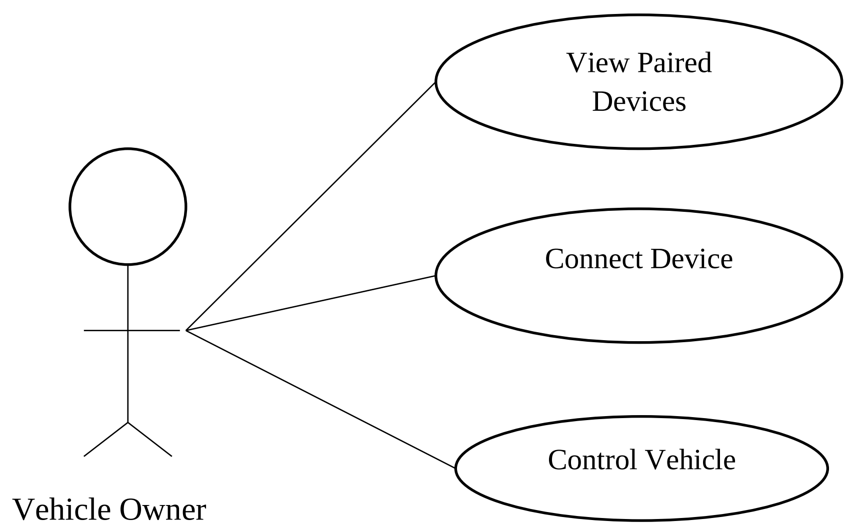

Figure 2.2: Use case diagram for remote control interface

2.2.4.1.3 Requirement Scenario: Remote Control

Mr. Baah is a vehicle owner who lost his car in a carjacking incident. After several days of investigations to aid in the recovery of his car, Mr. Baah spots his car. Not certain of the location of the thief that stole the vehicle, Mr. Baah chooses to control the vehicle from a distance to himself in order to ensure his safety. He then accesses the vehicle control application on his phone and connects to the vehicle via his mobile phone. Now with this connection established, Mr. Baah directs his vehicle to himself by clicking on the directional buttons.

2.2.4.1.4 Functional Requirements

REQ-RC-1: A user should be able to see a list of all the external devices paired with the mobile phone.

Table 2.1: Table of Requirements for REQ-RC-1

Description	A user should be able to see a list of all the devices that have been paired with the mobile phone via Bluetooth.
Inputs	Selects the Bluetooth icon
Source	N/A
Outputs	User can view all the external devices that have been paired with the mobile phone.
Destination	The list of paired devices would be viewed on the user's interface.
Action	At the click of the Bluetooth button, a screen showing the list of paired devices must come up.
Pre-condition	The user has put the Bluetooth on his/her phone on. The user has paired external Bluetooth devices with the mobile phone.
Post-condition	Pop up screen with list of paired devices, if any
Side-effects	None

REQ-RC-2: A vehicle owner should be able to connect his/her mobile phone with the vehicle.

Table 2.2: Table of Requirements for REQ-RC-2

Description	A user should be able to connect his/her mobile phone to the vehicle to enable control.
Inputs	None
Source	N/A
Outputs	Communication established between vehicle and mobile phone. User receives feedback on change in connection state.
Destination	The feedback is shown on the mobile application interface to indicate to the user that connection has been established.
Action	User selects the vehicle's Bluetooth to connect.
Pre-condition	Constructed remote control circuit must be powered. Bluetooth connection on phone must be enabled.
Post-condition	Communication established between vehicle and mobile phone
Side-effects	None

REQ-RC-3: A vehicle owner should be able to control his/her vehicle remotely using the mobile application.

Table 2.3: Table of Requirements for REQ-RC-3

Description	With communication established between the vehicle and the mobile phone, user should be able to control his/her vehicle using the application interface.
Inputs	Right Directional Button Left Directional Button Forward Directional Button Reverse Directional Button
Source	N/A
Outputs	Vehicle turns right Vehicle turns left Vehicle moves forward Vehicle reverses
Destination	N/A
Action	User clicks the directional buttons of his/her choice.
Pre-condition	Remote Control circuit is powered up. Mobile phone is connected to vehicle via Bluetooth.
Post-condition	Vehicle in desired position
Side-effects	None

2.2.4.2 GPS Tracking

This section details out the GPS Tracking Interface requirement and provides a use case diagram illustrating the behavior of the interface. A scenario is also provided, after which a detailed breakdown of the functional requirements is then listed and discussed.

2.2.4.2.1 Description

This feature of the system allows the user to record the location of the vehicle when he/she parks in a congested parking lot. The use case diagram in Figure 2.3 describes the user's interaction with the system in respect to this requirement.

2.2.4.2.2 Use Case Diagram: GPS Tracking

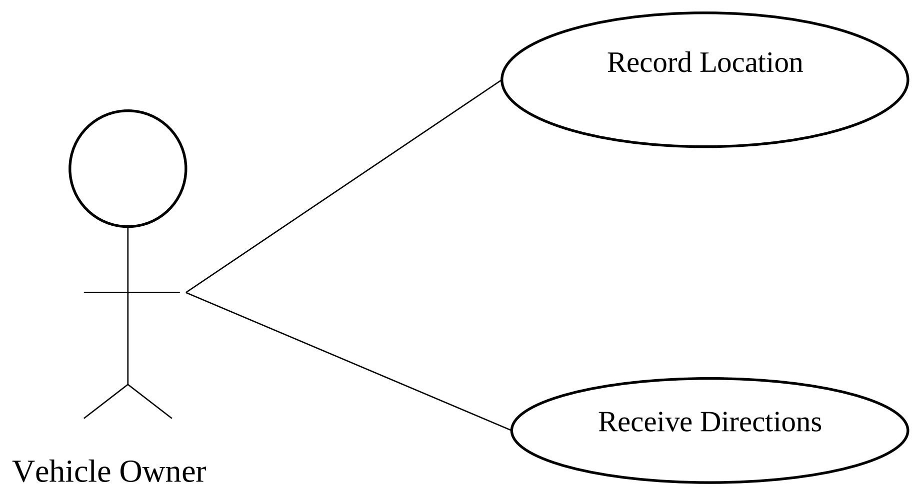

Figure 2.3: Use Case Diagram for GPS Tracking

2.2.4.2.3 Requirement Scenario: GPS Tracking

Mr. Baah arrives at the market to buy some goods for his household. Upon arrival at the market Mr. Baah notices that the car park is really huge and yet completely filled up with cars. Not sure whether he would be able to locate his car when he is done shopping at the market, Mr. Baah presses the record location button on the vehicle application interface. When done shopping, Mr. Baah conveniently selects directions to the last stored location. With the directions displayed on the application, Mr. Baah follows the map closely and easily returns to his vehicle.

2.2.4.2.4 Functional Requirements

REQ-GT-1: A vehicle owner must be able to store the current position of his/her vehicle.

Table 2.4: Table of Requirements for REQ-GT-1

Description	With communication established between the vehicle and the mobile phone, user should be able to control his/her vehicle using the application interface.
Inputs	Right Directional Button Left Directional Button Forward Directional Button Reverse Directional Button
Source	N/A
Outputs	Vehicle turns right Vehicle turns left Vehicle moves forward Vehicle reverses
Destination	N/A
Action	User clicks the directional buttons of his/her choice.
Pre-condition	Remote Control circuit is powered up. Mobile phone is connected to vehicle via Bluetooth.
Post-condition	Vehicle in desired position
Side-effects	None

REQ-GT-2: A vehicle owner should be able to view directions to the last stored location of the vehicle.

Table 2.5: Table of Requirements for REQ-GT-2

Description	The user should be able to access the directions to the last stored location of the vehicle using Google Maps.
Inputs	Coordinates of Last Stored position of vehicle. Coordinates of vehicle owner's current position.
Source	N/A
Outputs	Google Maps View direction from current position to last stored vehicle location.
Destination	None
Action	Select button to view directions to car.
Pre-condition	Position of vehicle was recorded.
Post-condition	View of map
Side-effects	None

2.2.5 Non-Functional Requirements

Unlike functional requirements, non-functional requirements are not directly concerned with the specific services delivered by the system to its users [13]. Rather, they are constraints on the services or functions offered by the system. Additionally, non-functional requirements typically apply to the system as a whole instead of the individual system. The non-functional requirements for this project are provided below:

- Availability: The mobile application shall be accessible on all mobile phones that utilize the Android operating system.
- Performance: The mobile application should not crash after it has been opened.
- Reliability: The GPS tracker in the system must accurately record and store the location of the vehicle.

- Safety: Users must not be allowed to control the vehicle if they do not have the pin code for the vehicle.
- Maintainability: Vehicle control must be constantly available.

2.3 Design Specification

2.3.1 Applied Project Design Objective

In order to demonstrate the skills and knowledge acquired throughout the course of studying as a computer engineering student, the design in this applied project aims to demonstrate:

1. The author's understanding of electronic circuits.
2. The importance of electronic circuits in controlling a system.
3. The ability to combine the knowledge acquired from studying computer engineering with enhancing a mechanical device.

2.3.2 Design Decisions

This section provides a breakdown of the decision making process undertaken to design a remote control system and a GPS tracking system for a mini-vehicle, both of which would be accessible on an Android mobile application. This decision making process was enhanced through the use of a Pugh Matrix.

2.3.2.1 Pugh Matrix

The Pugh matrix shown in the table below was used to choose a suitable means of executing the control and GPS tracking interfaces for the mentioned project. The list of criteria was drawn based on key factors that ensure an effective control interface for a toy car while maintaining an appropriate level of difficulty for a capstone project. The design options were then compared on a five-point scale (+2 – much better than, +1 – better than, 0 – equal to, -1 – worse than, -2 – much worse than) using the criteria chosen for comparison.

Table 2.6: Pugh Matrix for Selecting an Appropriate Control Interface

		Baseline	**Weight**	**A**	**B**	**C**
Criteria	**Criteria Description**					
1	Cost of Implementation	0	1	0	-1	-1
2	Response Time	0	3	+1	+2	+2
3	Compatibility with variety of software	0	4	0	-1	-2
5	Implementation Difficulty	0	2	-1	+2	+2
6	Better form of Control	0	5	+1	+2	+2

The following table represents the key for the elements represented in the Pugh matrix in table 1.

Table 2.7: Description of keys in the Pugh Matrix

Key	**Description**
Baseline	Infrared Remote Control
A	Joystick Control
B	Mobile Phone (Android OS)
C	Mobile Phone (iOS)

An Infrared Remote Control was selected as the baseline. This baseline was chosen because of its compatibility with most of the existing mini-vehicles. Modern day mini-vehicles for toddlers are developed using infrared remote controls. Consequently, a more appropriate remote control interface was sought to improve the control of these mini-vehicles. Other control interfaces considered to replace the infrared remote control include a joystick controller, a mobile phone with an Android Operating System (OS) as well as a mobile phone with the iOS designed by apple. The Pugh matrix is updated in table 3 by applying the weights of the criteria.

Table 2.8: Updated Pugh Matrix

		Baseline	**Weight**	**A**	**B**	**C**
Criteria	**Criteria Description**					
1	Cost of Implementation	0	1	0	-1	-1
2	Response Time	0	3	+3	+6	+6
3	Compatibility with variety of software	0	4	0	-4	-8
5	Implementation Difficulty	0	2	-2	+4	+4
6	Better form of Control	0	5	+5	+10	+10

Based on the Pugh Matrix in table 3, the option B (mobile phone with Android interface) was selected as the control interface for the mini-vehicle. Option B was most closely matched by option C (mobile phone with iOS) with 15 vs 11. The key differential in both modes of control interface was their respective compatibility with a variety of software. This is a key aspect as it could pose a strain on the development of the interface within the set time period.

2.3.3 System Architecture

This section provides a conceptual model that describes the structure and behavior of the system developed. Figure 2.4 illustrates the various components that make up the system and the category under which each component falls under.

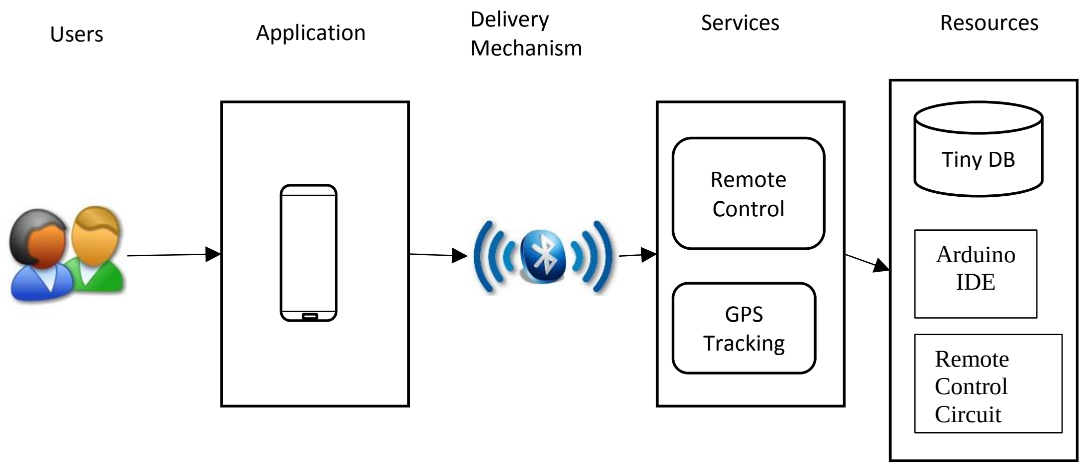

Figure 2.4: System Architecture

The users depicted in Figure 2.4 represent vehicle owners who seek to control their vehicle using the mobile application. The mobile application is available on android, while delivery mechanism of the system is Bluetooth and provides the user with an opportunity to access the remote control service. The resources used to achieve the remote control and GPS tracking are represented under the resources section in Figure 2.4. These resources are;

- **Tiny DB** – a database used to handle the storage of the coordinates of position for the vehicle.
- **Arduino IDE** – a software application used to construct code to control the stepper motor and dc motors.
- **Remote Control Circuit** – used to provide a means of response based on the direction the user has provided on the mobile application.

Chapter 3: Implementation

3.1 Overview

This chapter presents the tools, libraries and components and their role in executing this project. It also focuses on the two aspects of implementation; hardware and software, and provides an elaborate description of the two aspects of implementation. The chapter also provides evidence of the implementation of the project, breaking the project into its components.

3.2 Tools, Components, Libraries, and Frameworks Employed

This section presents the tools, components, libraries and frameworks used in executing this project. These are presented with descriptions of their functions and the role they play in the execution of this project.

3.2.1 Arduino Nano

Figure 3.1: Arduino Nano

The Arduino Nano is a small, complete board, similar to the Arduino Uno based on the ATmega328. It is an open-source microcontroller board developed by Arduino and has the same functionality as the Arduino Uno [14] albeit in a different more compact package. Arduino boards are typically used in projects where automation is an essential part of the system. For this project, the Arduino board is used for enabling the control of the stepper motor and the dc motors, which together drive the movement of the vehicle. The Arduino Nano is also used to provide connection to an Android driven mobile phone via a Bluetooth connection. The Arduino is also used to enable the GPS tracking of the vehicle as well. The specifications of the Arduino Nano is in the appendix of the paper.

3.2.2 Stepper Motor

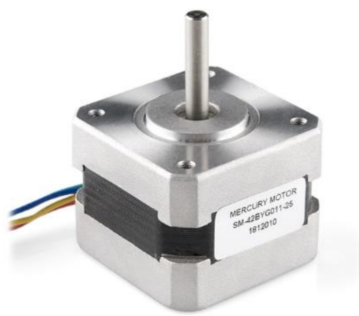

Figure 3.2: Stepper Motor

A stepper motor is a brushless, synchronous electric motor that converts digital pulses into mechanical shaft rotation [15]. Each revolution of the stepper motor is distributed into a discrete number of steps [15]. Due to the fact that each rotation causes the motor to rotate at a precise angle, the motor's movement has the ability to be controlled without any feedback mechanism. With any increase in frequency of the digital pulses, the step movement changes into continuous rotation, with the speed of rotation directly proportional to the frequency of the pulses [15]. For this project, the stepper motor was used to control the movement of the gear on the rack and pinion system. The movement of this gear in an anti-clockwise motion and a clockwise motion is ultimately what determines the direction of movement of the vehicle.

3.2.3 Motor Driver – L298N

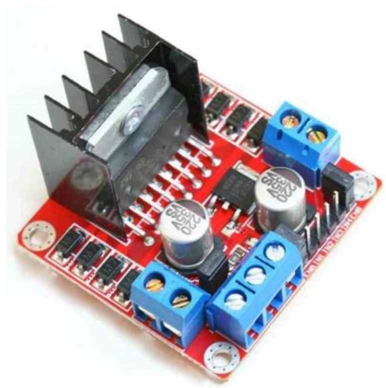

Figure 3.3: L298N Motor Driver

Although the stepper motor and the DC motors are ultimately responsible for the motion of the vehicle in this system, the microcontroller cannot control the motors on its own. This is because the microcontroller operates on very low voltage and current which is much less than is required for driving the motors. As such, the L298N motor driver is a little current amplifier that supplies the microcontroller with the required levels of current and voltage needed to power the motors in the system. The pin configuration for the L298N is shown in the appendix.

3.2.4 DC Motor

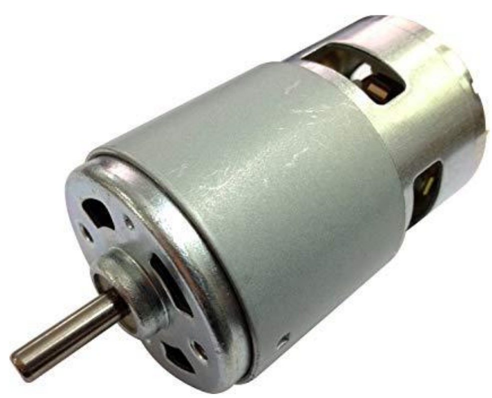

Figure 3.4: DC Motor

A DC motor is a class of rotary electrical machines that convert direct current electrical energy into mechanical energy. DC motors are one of the most widely used motors and can be powered from existing direct-current lighting power distribution systems. For this project two DC motors are attached to the back tires; one at each back tire. The goal of this design is to develop a means of directly controlling the tires via the DC motors attached which move the tires in the direction in which they rotate. The specifications for the DC motors used in this system is provided in the appendix.

3.2.5 Bluetooth Module

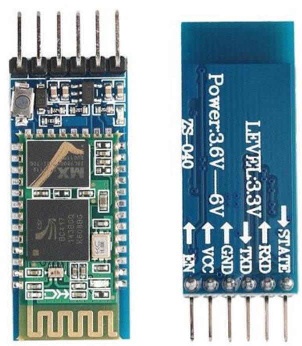

Figure 3.5: HC-05 Bluetooth Module

The HC-05 Bluetooth module is a simple Serial Port Protocol (SPP) module that is designed for transparent wireless connection setup. It can be used in both a master and slave configuration which makes it ideal for wireless communication. For this project, the HC-05 Bluetooth module is used to enable communication between an Android mobile phone and the Arduino Nano used for the project. This is key to driving the motors which the Arduino is responsible for. The pin configuration and the technical specifications of the HC-05 Bluetooth module is in the appendix.

3.3 How the System Works

To meet the requirements of the system, the mobile application was developed to provide a means of controlling the vehicle. As such, the application is a user interface that allows a vehicle owner to steer the vehicle in the direction he or she wants. A GPS tracking interface is also provided on the application to aid the vehicle owner in locating his vehicle in a congested parking space. A Bluetooth module is used to establish communication between the phone and the Arduino which enables the control of the vehicle.

3.4 Evidence of Implementation

This section demonstrates evidence of the implemented system. This includes evidence of the implemented hardware, the implemented software and the installation of the remote control circuit on the mini-vehicle.

3.4.1 Hardware

Figure 3.6 shows the connected remote control circuit with all the necessary components required for controlling the motor which in turn controls the steering mechanism and the rear wheels of the vehicle. The image represents the initial implementation on a breadboard. After this initial implementation, tests were conducted to ensure that the circuit worked as desired before installation on the mini-vehicle. From the mobile application, the stepper motor can be controlled.

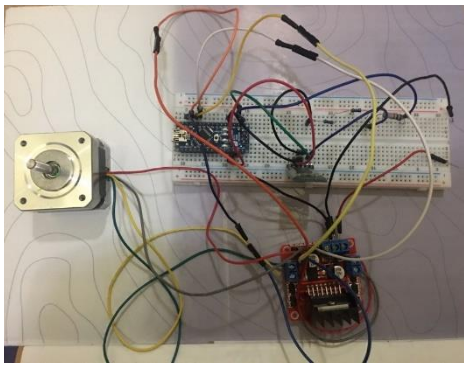

Figure 3.6: Remote Control Circuit

3.4.2 Software

The following screens demonstrate the implemented mobile application and the features available for a vehicle owner to aid in the recovery of his/her vehicle should it get lost. The demonstration comes in two aspects. One aspect illustrates the functionality of the GPS Tracking Model and one aspect illustrates the functionality of the Remote Control System.

3.4.2.1 View of Application

Although the mobile application has not been launched on the Android play store, it is accessible on Android mobile phones by downloading the Tahoe QR scanner code application (shown in Figure 3.7) from the play store and scanning the QR code from the implemented application on MIT App Inventor. The resulting downloaded application is the third icon shown in Figure 3.7.

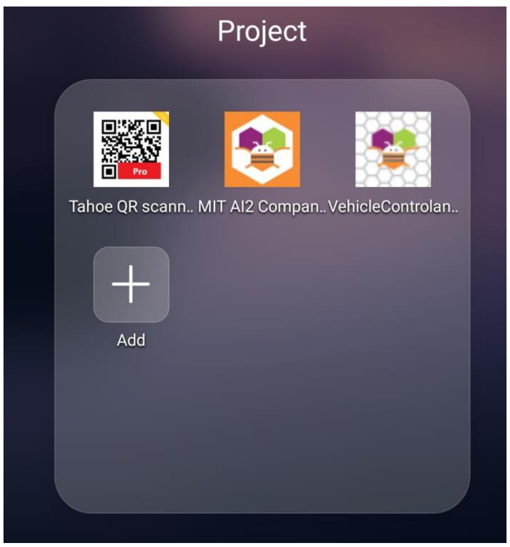

Figure 3.7: View of Application

3.4.2.2 Landing Page

Before delving into the GPS Tracking model and the remote control system, a home interface was developed to enable users of the application to choose which feature of the application he/she would want to use at any given point in time. The landing page is shown in Figure 3.8.

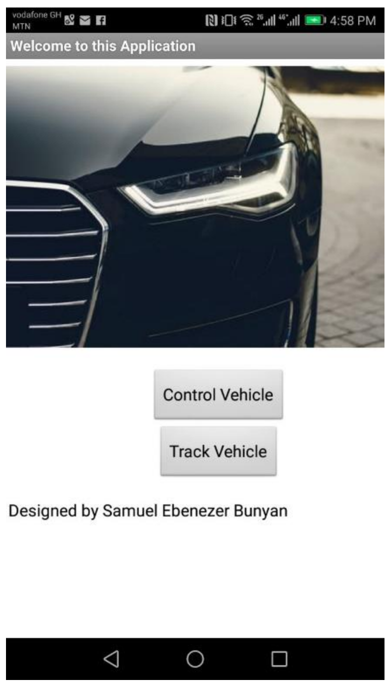

Figure 3.8: Landing page of mobile application

As shown in Figure 3.8, upon clicking the application, there are two buttons accessible depending on what feature of the application the user desires access to. By clicking the "Control Vehicle" button, the user would be directed to a second screen with an interface for controlling the vehicle. By clicking the "Track Vehicle" button, the user would be directed to a third screen with the GPS tracking interface. The navigation to the various screens by the click of the button was implemented using the block code shown in Figure 3.9.

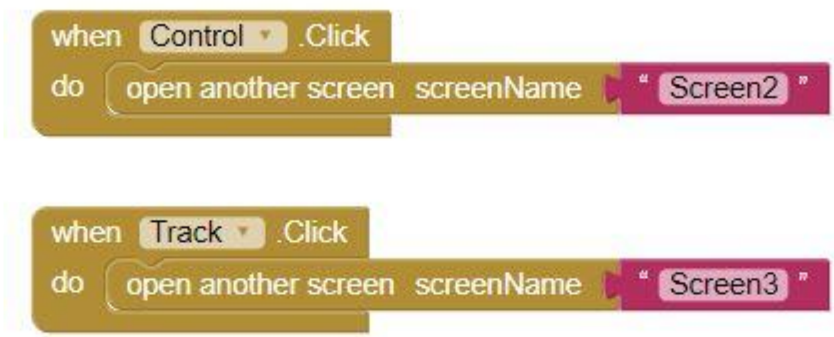

Figure 3.9: Block code for navigating to screens for control and tracking

3.4.2.3 Remote Control System

This section provides evidence of the implemented remote control system. This remote control interface is accessible after clicking the "Control Vehicle" button on the first page. The resulting interface is shown in Figure 3.10.

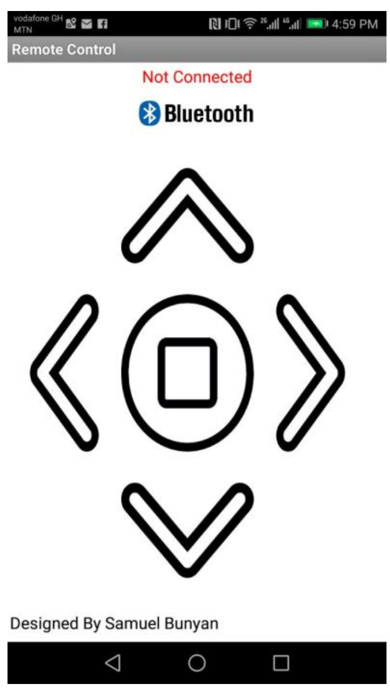

Figure 3.10: Remote Control Interface

Figure 3.10 presents the remote control interface for a vehicle owner. The "Not Connected" illustrates that the vehicle has not been connected with the mobile phone. To establish connection between the vehicle and the mobile application, the user has to click the Bluetooth icon underneath the "Not Connected" label. Upon clicking the icon, a list of the devices (shown in Figure 3.11) that have been paired with the mobile phone appears.

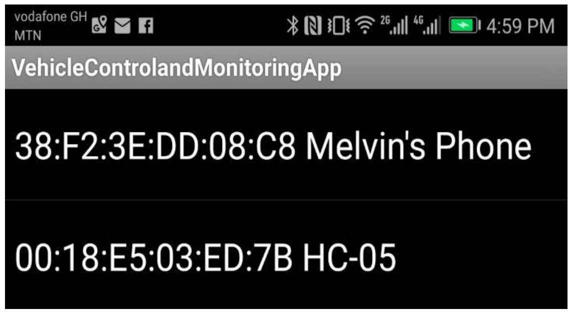

Figure 3.11: List of Paired devices

To connect to the vehicle, it has to be selected to gain connection. Once connection has been established, the "Not Connected" changes to "Connected" as shown in Figure 3.12.

Figure 3.12: Connection Status

This change in color to indicate connection status is achieved by implementing the block code shown in Figure 3.13.

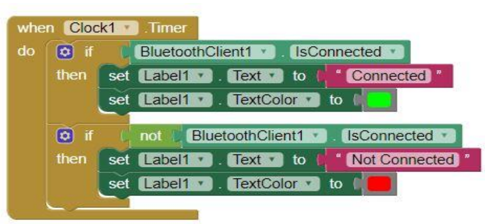

Figure 3.13: Block Code to implement Connection Status

Once connection status has been change to “Connected”. This indicates that communication has been successfully established between the mobile phone and the vehicle. This was implemented using the block code shown in Figure 3.14.

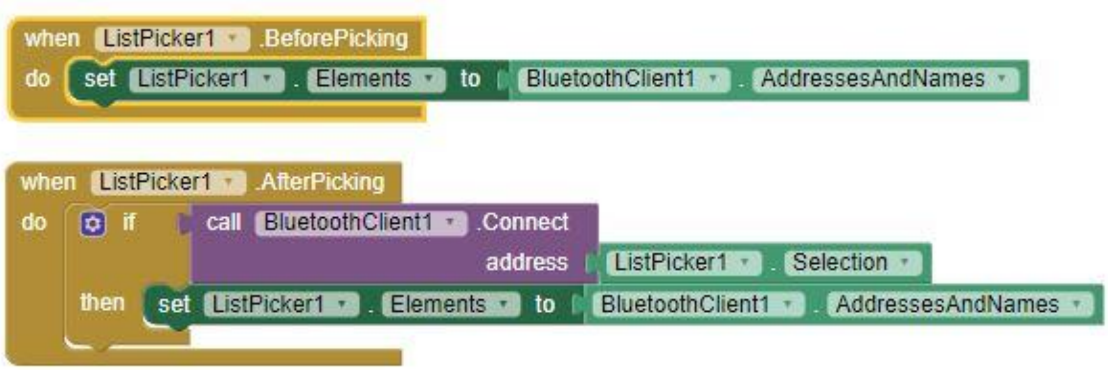

Figure 3.14: Implementation of Bluetooth connection

The directional buttons displayed on the interface are used to control where the vehicle is directed to when the button is pressed. The middle button is used to halt the vehicle. This control is achieved as shown in Figure 3.15.

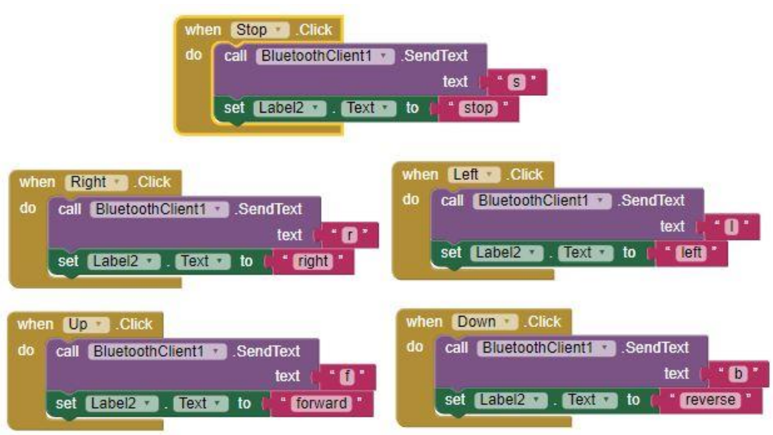

Figure 3.15: Directional Control

3.4.2.4 GPS Tracking System

This section provides evidence of the implemented GPS Tracking model. This GPS Tracking interface is accessible after clicking the “Track Vehicle” button on the first page. The resulting interface is shown in Figure 3.16.

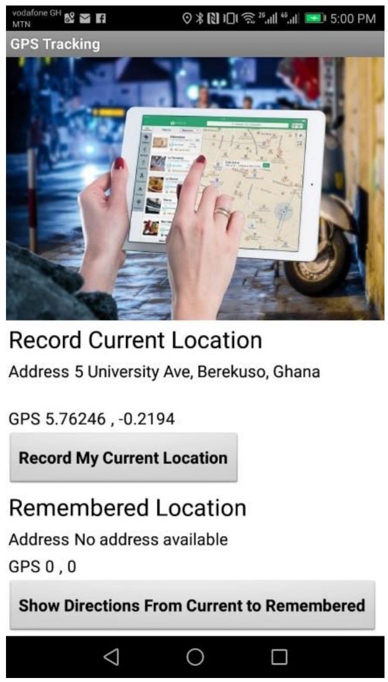

Figure 3.16: GPS Tracking Interface

Upon opening the application, the features of the application are accessible and can be used accordingly. As shown in Figure 3.16, the functions provided on the tracking application enables a vehicle owner to store the location of the vehicle any time he/she is leaving the vehicle. Upon hitting the “Record My Current Location” button, the coordinates of the vehicles current location are stored. Consequently, should the vehicle owner struggle to locate his/her vehicle in a congested parking space, the vehicle owner can use the mobile application to obtain directions to the last stored location by clicking the “Show Directions From Current To

Remembered” button, which would then provide a map view directing the vehicle owner to his/her vehicle. This is shown in Figure 3.17.

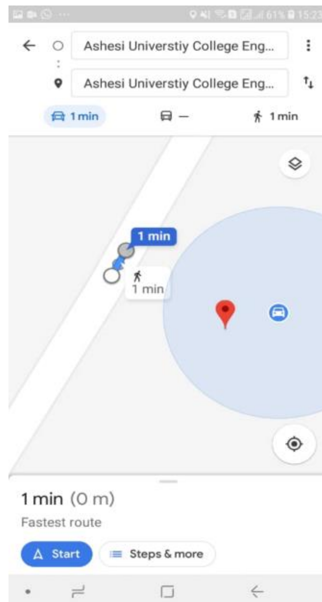

Figure 3.17: Map view showing directions from current location to last stored location

3.4.3 Installation of Remote Control Circuit on Mini-vehicle

After the completed implementation of the hardware for controlling the vehicle as well as the software which provides an interface for accessing this control, the circuit was installed on the mini-vehicle. This installation is shown in Figure 3.18

Figure 3.18: Integrated mini-vehicle with control circuit

As shown in Figure 3.18, the stepper motor was connected to the pinion gear which rotates in a clockwise and an anticlockwise direction. This rotation is controlled by the developed mobile application interface by the right and left buttons. Connected to the rear tires are two DC motors which together steer the vehicle forward and backwards.

Chapter 4: Testing and Results

4.1 Overview

This chapter discusses the tests that were carried out on the developed system and the corresponding results from these tests. These tests were undertaken to certify whether the project successfully meets all the requirements as outlined when carrying out the project.

4.2 Unit Testing

The first part of the testing process; unit testing, was undertaken to verify that each unit of the system meets its required specification. For this aspect of testing, the connection of the mobile application to a Bluetooth device was tested, in addition to the response of the Stepper Motor and the DC motors to the directional buttons in the mobile application. This information is represented in the following subsections; Bluetooth Connection and Motor Control, under the Unit Testing section.

4.2.1 Bluetooth Connection

A key element of enabling control of the vehicle is establishing connection between the mobile device and the vehicle. For this project, this connection was established using Bluetooth. Consequently, before control of the vehicle is accessible, the mobile device must first be paired with the vehicle. With the successful pairing of the mobile device to the vehicle, the user can then establish connection at a given point in time via the application. A summary of the results is shown in Table 4.1.

.

Table 4.1: Summary of unit test results for Bluetooth connection.

Functionality	**Expected Result**	**Actual Result**
Hit Bluetooth Button	List of devices paired to the phone shows up	List of devices paired to the phone shows up
Connect to Bluetooth	"Connected" display in green writing.	"Connected" display in green writing.
Disconnect from Bluetooth	"Not Connected" display in red writing.	"Not Connected" display in red writing.

4.2.2 Motor Control

4.2.2.1 Stepper Motor

With the system designed, the stepper motor is responsible for controlling the rack and pinion which is provides a means of steering the system in the desired direction. This was tested by using the mobile application to validate whether the stepper motor turns in the expected direction when the direction is selected on the interface. This result is shown using the serial monitor of the Arduino IDE to show the response when the left and right buttons are selected.

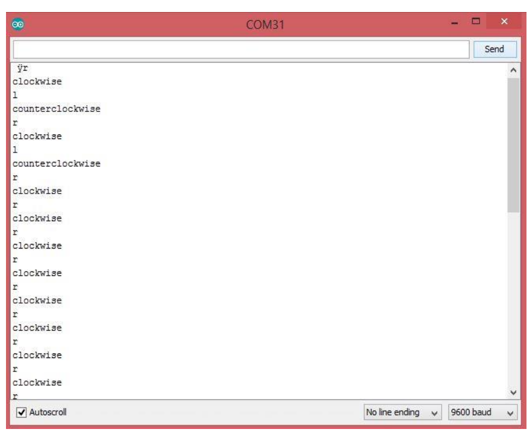

Figure 4.1: Serial Monitor when right and left button is clicked

As observed in Figure 4.1 when the right button is selected on the mobile application the stepper motor turns in a clockwise direction. On the other hand, when the left directional button is selected, the motor turns in an anticlockwise direction. A summary of the results when testing the control of the stepper motor is provided in Table 4.2.

Table 4.2: Summary of unit test results for the stepper motor

Functionality	**Expected Result**	**Actual Result**
Right Button	Rotates the stepper motor in a clockwise direction	Rotates the stepper motor in a clockwise direction.
Left Button	Rotates the stepper motor in an anti-clockwise direction.	Rotates the stepper motor in an anti-clockwise direction.

4.2.2.2 DC Motors

With the system designed, the DC motors are responsible for controlling rear wheels of the vehicle which provides a means of steering the system in a forward or backward motion. This was tested by using the mobile application to validate whether the DC motors turn in the expected direction when the direction is selected on the interface. This result is shown using the serial monitor of the Arduino IDE to show the response when the left and right buttons are selected.

Table 4.3: Summary of Unit Test results for DC motors

Functionality	**Expected Result**	**Actual Result**
Forward Button	Rotates the two DC motors in a clockwise direction.	Rotates the two DC motors in a clockwise direction.
Reverse Button	Rotates the two DC motors in an anti-clockwise direction.	Rotates the two DC motors in an anti-clockwise direction.

4.3 System Testing

At the testing level, the technical aspects of the system were tested as a whole to validate whether the system meets the adequate requirements as stated during its development.

4.3.1 Functional Testing

For the mobile application to be useful to the user, all the functions of the application must work as indicated on the interface. To validate this, the various parts of the landing page, the remote control interface and the GPS tracking interface were tested. All the functions on the mobile application worked as expected.

4.3.2 Response Testing

To ensure that the mobile application is meaningful to the user, the application must not take too long to load. Additionally, the actions indicated by the buttons must respond in a timely manner so that not much time is wasted trying to load the application. Although, this response time was not measured as it would have required additional hardware, the instantaneous response of the vehicle illustrated that the system met the desired requirement for response time.

4.4 User Testing

The application was tested by a vehicle user. The user, who is an android user described the user friendly and was excited about the interface of the application. With respect to the remote control screen of the mobile application, the user commented on the style of the buttons and indicated that he would have ideally preferred smaller buttons. In line with the functionality of the remote control interface, the user was generally impressed that the mobile application was able to control the vehicle. Finally, although the user expressed his appeal to the GPS tracking interface, the user pointed out that struggling to locate vehicles in congested parking lots was not a common occurrence in the country. As such, the user would have preferred to see the GPS tracking interface provide live updates of the location of the vehicle at every given point in time.

Chapter 5: Conclusion

5.1 Summary

This mobile application developed in line with the remote control circuit and the GPS tracking model to meet the requirements recorded in the build up to implementing the project. The mobile application is available to only Android users and allows the user to locate his/her vehicle in a congested parking space. The application also provides the user with an avenue for controlling the vehicle to steer it to where the user desires.

5.2 Limitations

Although this system meets the functional requirements stated in the document, some limitations posed a strain on the development of the system and ultimately caused the system to not be as effective as desired. These limitations are highlighted below:

- The system is restricted to Bluetooth connectivity and so the control of the vehicle is limited to a relatively small range. As such, the mobile phone has to be within 100 meters of the vehicle which is being controlled.
- Security concerns may arise from the use of the mobile application. This is because the application does not use a secure server. However, since Google Maps is integrated with the application and requests access from the user, the location access can be exploited maliciously and used for dubious means.

5.3 Lessons Learnt

Throughout the project, there were a number of valuable lessons learned which would shape my life as an engineer. The lessons learned are outlined below.

- A key component of engineering is adequate planning. Adequate planning provides a clear path for the execution of any project and ensures that all the necessary factors are taken into consideration to avoid minor setbacks.
- Engineering is a discipline that occasionally requires improvisations in order to meet the intended target. These improvisations typically involve the tools used in carrying out the project.
- Carefully underlining the design considerations helps select the most suitable design option for implementing a project.

5.4 Future Work

To develop the system further into a more sustainable and useful system, a number of functionalities can be added to the system. These include the following:

- Develop the application on an IOS driven mobile phone as well as on the Windows driven phone. Additionally, a web platform should also be developed to improve accessibility to both the tracking of the vehicle and control of the vehicle.
- Rather than using a Bluetooth module, a WIFI module should be explored. This would require installing a means of constantly connecting the vehicle to internet access. The use of a WIFI module would enhance the availability of the interface and the capability of accessing vehicle control from distances further apart from the vehicle.
- Ultrasonic Ping sensors can be embedded into the project to aid in avoiding obstacles that may come in the way when controlling the vehicle. This is a very

vital aspect when controlling from longer range distances as it would be impossible to tell from the map view should the vehicle risk colliding with another vehicle or a human being.

- A solar panel can be used to keep the battery constantly charged so that the battery does not run down at crucial points, especially when control of the vehicle is desired.
- An allocation for increasing the speed of the vehicle via the remote control must be provided to tailor the mobile application to the needs of a vehicle owner.
- A lock system must be employed to ensure that the control of the vehicle from the mobile application overrides any manual control. This would make it a more effective means of recovering any stolen vehicle.

Appendix

Appendix A: Arduino Nano Pin Configuration

Source: Adapted from [16]

Pin Category	Pin Name	Description
Power	Vin, 3.3V, 5V, GND	Vin – input voltage to Arduino when using external power source (6-12V) 3.3V – supply generated by on-board voltage regulator. Maximum current draw is 50mA 5V – regulated power supply to control microcontroller and other components on the board GND – ground pins
Reset	Reset	Resets the microcontroller
Analog Pins	A0 – A7	Measures analog voltage in the range 0-5V
Input / Output Pins	D0 – D13	Used as input or output pins. 0V and 5V.
Serial	Rx,Tx	Receives and transmits Time-to-live (TTL) serial data
External Interrupts	D2, D3	Triggers an interrupt
Pulse Width Modulation (PWM)	D3, D5, D6, D9, D11	Provides 8-bit PWM output
Serial Peripheral Interface (SPI)	D10 (SS), D11 (MOSI), D12 (MISO), D13 (SCK)	Used for SPI Communication
Inbuilt LED	D13	Turns on inbuilt LED
I2C	A4 (SDA), A5 (SCA)	Used for TWI communication
Analog Reference	AREF	Provides reference voltage for input voltage

Appendix B : Arduino Nano Technical Specifications

Source: Adapted from [17]

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage	7 – 12 V
Analog Input Pins	8
Digital Input / Output Pins	14
DC current on I/O pins	40 mA
DC current on 3.3V pins	50 mA
Flash Memory	32 KB (2kB used for Bootloader)
SRAM	2 KB
Clock Speed	16 MHz

Appendix C: HC-05 Bluetooth Module Pin Configuration

Source: Adapted from [18]

Pin Number	Pin Name	Description
1	Enable / Key	This pin is used to toggle between Data mode (set low) and AT command mode (set high). Default is in Data mode.
2	Vcc	Powers the module. Connect to +5V Supply voltage
3	Ground	Ground pin of module. Connect to system ground.
4	TX – Transmitter	Transmits serial data. Everything received via Bluetooth will be given out by this pin as serial data.
5	RX – Receiver	Receive Serial Data. Every serial data given to this pin will be broadcasted via Bluetooth
6	State	The state pin is connected to on board LED, it can be used as a feedback to check if Bluetooth is working properly.
7	LED	Indicates the status of Module • Blink once in 2 sec: Module has entered Command Mode • Repeated Blinking: Waiting for connection in Data Mode • Blink twice in 1 sec: Connection successful in Data Mode
8	Button	Used to control the Key/Enable pin to toggle between Data and command Mode

Appendix D : HC-05 Bluetooth Module Technical Specifications

Adapted from [18]

Operation Voltage	4-6V (Typically 5V)
Operating Current	30mA
Range	<100m
Protocol	IEEE 802.15.1 standardized protocol
Operation Mode	Master, Slave, Master-Slave
Interface Access	Laptop, Mobile Phones
Supported Baud Rates	9600,19200,38400,57600,115200,230400,460800

Appendix E: DC motor technical specification

Voltage	12V DC
RPM:	200
Reversibility:	Reversible
Speed:	5000r/min
Length of Motor(including spindle):	76mm
Diameter:	37mm
Shaft length:	15 mm
Shaft diameter:	6mm

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