

Riding Mechanic: An iOS App for Vehicle Monitoring and Analysis

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Riding Mechanic: An iOS App for Vehicle Monitoring and Analysis

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We recommend acceptance of this manuscript in partial fulfillment of this candidate's requirements for the degree of Master of Software Engineering in Computer Science. The candidate has completed the oral examination requirement of the capstone project for the degree.

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Abstract

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On Board Diagnostics II (OBD-II) was first adopted for all cars and light trucks since 1996 and lots of OBD-II products had come out in the past few years. Some early developed OBD applications did not make it very clear what problems were confronted with because most developers had little knowledge about On-Board Diagnostics systems. As time went by, newer apps had become more and more comprehensive. There are also high-performance OBD apps that provide drivers with detailed information of cars, but users need to pay for them. Therefore, my target is to develop a free mobile OBD-II application to gather detailed diagnostic information over a long period that can be used to monitor a vehicle’s operation and discover potential concerns before they became serious faults. The application can also help drivers identify the effect certain configuration changes have on their cars’ operations by recording driving behaviors from one route to another route.

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Glossary

Attention command set

Attention Command set (AT command set) is a command language used to control modems.

ELM327

The ELM327 is a programmed microcontroller produced by ELM Electronics for translating the on-board diagnostics (OBD) interface found in most modern cars [1].

Diagnostic Trouble Codes

Diagnostic trouble codes (DTCs) are alphanumeric characters saved by a vehicle's Onboard Diagnostic system to point out different types of faults.

On-board Diagnostic II Parameter IDs

Onboard Diagnostic II Parameter IDs (OBD-II PIDs) are hexadecimal codes sent to a vehicle's Onboard Diagnostic system to request data.

On-board Diagnostic II scanner

Onboard Diagnostic II scanner (OBD-II scanner) is a tool used to help getting access to the data provided by OBD system.

On-board Diagnostics

Onboard Diagnostics (OBD) is a vehicle-mounted system used to monitor the running status of engine components and working status of emission control system.

1. Introduction

In our daily life, it becomes more and more difficult to imagine life without driving. When you must go to work in a different city, go to school far away from your house, plan to travel to another state with your friends or you just want to make transportation faster and easier for you and your family, taking a car is really a good choice.

People drive every day, but they have little knowledge about cars. In that case, it is a good solution to use on-board diagnostics systems to help people get close to their vehicles. It is possible for users to use an OBD app along with an OBD scanner to read data from the car. Most OBD apps in the market can provide drivers with cars' real-time information and diagnostic trouble codes. Instead of investigating the problems themselves, those apps simply tell them what kinds of problems along with categories they belong to.

As mentioned above, my target is to develop a free mobile OBD app to gather detailed diagnostic information over a long period that can be used to monitor a vehicle's operation and discover potential concerns before they become serious faults. The app can also help drivers identify the effect certain configuration changes have on their car's operation by recording driving behaviors from one route to another route.

1.1 Onboard Diagnostic systems

On-Board Diagnostics, or "OBD," was first introduced in early 1980s. Early OBD systems were developed to remind drivers of losing control and occurring malfunctions. As time went by, On-Board Diagnostics II, an advanced version over early OBD models, was adopted mandatory for all cars and light trucks manufactured in the United States since 1996, as required by the Clean Air Act Amendments [2]. Since that time, OBD system begins to play an important role in fighting emissions of greenhouse gasses and engine failures.

On-Board Diagnostics is additional computer software that monitors the emission control and emission-related components/systems, along with certain engine components

that provide vehicle operational information [2]. OBD systems can monitor both running situations of engine and working status of emission control systems all the time. Once over standard emissions are detected, OBD systems will give alerts to users. If any systems in a car are broken, “Check Engine” or “Malfunction Indicator Lamp” light on the dashboard of the car. Meanwhile, OBD systems will store Diagnostic Trouble Codes(DTCs) which are related to those broken systems. By using a standard scan tool connected to vehicle’s OBD-II connector, an automotive technician can quickly know what the trouble is and where it occurs. This can save plenty of time for both drivers and technicians.

The biggest difference between OBD-II system and previous OBD systems is that OBD-II system is extremely strict with emissions. It can detect over standard emissions by monitoring power system and emission control system. OBD-II system also has unique features. The first one is that all data link connectors(DLC) in cars are standard 16-Pin OBD-II connectors which brings lot of convenience for people. The second one is that OBD-II DLC can help to transmit data between cars and scan tools. The third one is that OBD-II defines universal Diagnostic Trouble Codes(DTCs) and its meanings for all kinds of vehicles. The fourth one is that it has similar functions as car driving recorder (car DVR). The fifth one is that users can use scan tools to clear DTCs. The last one is that OBD-II can show those cleared DTCs. Although it is very efficient to monitor emissions by using OBD-II system, sometimes drivers do not accept or just ignore alerts from OBD-II system. For this reason, a more advanced version, OBD-III had been developed. The main purpose of OBD-III is to combine vehicle detection, maintenance and management. When over standard emissions occur, OBD-III will prevent users from keeping driving with high emissions. However, OBD-III techniques are not widely used. We may have opportunity to use OBD-III in the future.

1.2 Onboard Diagnostic II scanner

Since OBD-II scanner is a standard tool used to help getting access to the data supported by OBD system, it has been playing an important role in the process of reading

data from a vehicle. An OBD-II scanner does not make any sense when it is used as a single object. In the other words, an OBD-II scanner should always work with an OBD-II system. The OBD-II scanner can connect to an OBD-II port provided by the OBD-II system. According to United States Federal Law, every car or truck on the road manufactured since 1996 is mandatorily required to have OBD-II system and OBD-II ports. People do not need to worry about that OBD-II systems have different OBD-II ports. Since OBD-II systems are standardized after 1996, OBD-II ports had been standardized by SAE J1962. When users want to use an OBD-II scanner to connect to an OBD-II port, the OBD-II port must be plugged into an OBD-II scanner. After the OBD-II scanner plugged in, it begins to act as a special server. There are two types of OBD-II scanners so that a server usually has two types. The first type is Wi-Fi server which can provide its own Wi-Fi signal. The other one is Bluetooth which can provide its own Bluetooth signal. Connection between a mobile device and an OBD-II scanner can be built easily by simply connecting to that scanner's Wi-Fi or Bluetooth. After building connections successfully, users can use an OBD app to read data from a vehicle.

Figure 1 shows how an OBD-II scanner acts as a medium between the application and a car [3]. As shown in the picture, the OBD-II scanner has two components-one is ELM327 and another is a kind of Wi-Fi module which can send and receive Wi-Fi signals. EML327 is the core part of an OBD-II scanner and it is designed to build connections between an OBD-II port and a standard serial port. So, it almost supports all standard OBD-II protocols and it has universal serial interface.

After the scanner plugged in, it will keep sending Wi-Fi signal. A mobile device also has a Wi-Fi module which is responsible for receiving that signal. Once connection has been built, the application starts sending commands to the Wi-Fi module on the phone through Universal Asynchronous Receiver/Transmitter (UART). The Wi-Fi module on the phone receives those commands and sends them to the Wi-Fi module on the scanner by using wireless communication transfer protocol (WTCP). Then Wi-Fi module on the scanner receives those commands and sends them to the ELM327 through UART. Then the ELM327 uses those commands to interact with OBD-II system in the car through the

universal serial port. The OBD-II system can identify those commands (next part will talk how to do it) and quickly send responses to the scanner. As soon as the scanner receives responses from the car, it will send them to the application by using the same mechanism. The application will keep receiving messages. Once received, it begins to analyze those commands and transfer them into universal data used in our daily life.

The reason why choosing a Wi-Fi scanner is that users cannot connect to a vehicle's Bluetooth and a scanner's Bluetooth at the same time. Some people usually connect to the vehicle's Bluetooth to listen to music or make phone calls. Bluetooth based applications will bring them troubles. Therefore, my choice is using an OBD-II Wi-Fi scanner and developing an OBD-II app to build Wi-Fi connection.

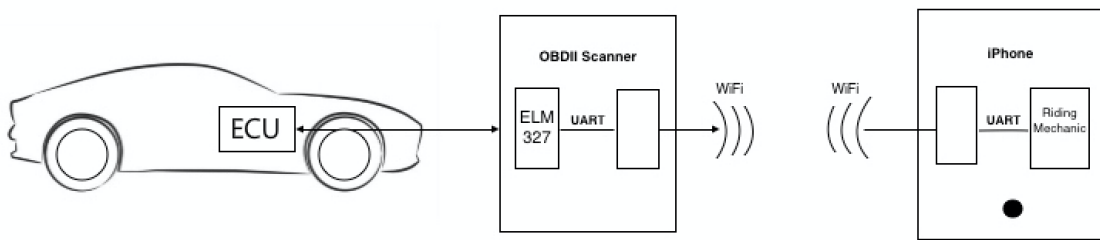


Figure 1. How to use an OBD-II scanner

1.3 Onboard Diagnostic Parameter IDs

OBD-II PIDs are hexadecimal codes sent to a vehicle's Onboard Diagnostic system to request data. SAE J1979 defines standard universal OBD-II PIDs that are used by many car manufacturers, but car manufacturers also defined their own specific PIDs to their vehicles. This application will focus on those universal PIDs instead of all OBD-II PIDs because it is hard for developers to collect self-defined PIDs from manufacturers.

As mentioned above, SAE J1979 described standard universal OBD-II PIDs. Table 1 shows ten modes of operations defined in the standard [4]. This application will read data

and diagnostic information from a vehicle. Therefore, mode ‘01’ and ‘03’ are two most important codes for this project.

Mode (hex)	Description
01	Show current data
02	Show freeze frame data
03	Show stored Diagnostic Trouble Codes
04	Clear Diagnostic Trouble Codes and stored values
05	Test results, oxygen sensor monitoring (non CAN only)
06	Test results, other component/system monitoring (Test results, oxygen sensor monitoring for CAN only)
07	Show pending Diagnostic Trouble Codes (detected during current or last driving cycle)
08	Control operation of on-board component/system
09	Request vehicle information
0A	Permanent Diagnostic Trouble Codes (DTCs) (Cleared DTCs)

Table 1. Ten modes of operation

As defined by SAE J1979, OBD-II PIDs are consist of ASCII codes. There are many kinds of PIDs under mode ‘01’ while ‘03’ does not have any subset. Table 2 shows OBD-II PIDs used in the application [4].

OBD-II PIDs	Description
0100	Get supported PIDs [01-20]
0120	Get supported PIDs [21-40]
0140	Get supported PIDs [41-60]
0105	Get engine coolant temperature
010C	Get engine RPM
010D	Get vehicle speed
0110	Get MAF air flow rate
0142	Get control module voltage
03	Get stored DTCs

Table 2. OBD-II PIDs used in the application

1.4 Diagnostic Trouble Code

DTCs are fault codes detected by the OBD-II systems and those trouble codes will be stored by the OBD-II system. Users can use query tools on the internet to get diagnostic information associated with DTCs. OBD-II DTCs are alphanumeric codes which are consist of five characters, one letter followed by four digits (e.g., P1000). The first character always describes which system has that fault. Table 3 gives specific information of each letter's meaning [5].

Letter	System
P	Powertrain (Includes engine, transmission, drive shafts, differentials and the Final Drive)
U	User Network (Wiring Bus or UART)
B	Body (Includes A/C and Air Bag)
C	Chassis (Includes ABS)

Table 3. Meanings of a DTC' prefix

The second character is a binary number that indicates whether the trouble code is an OBD-II generic code or not. If the second digit is zero, it is a generic code. If the second digit is one, it is a manufacturer specific code. The third character points out which subsystem in car has that fault. The fourth and fifth characters work together and explain that fault.

Let's use an example of C0300. The first letter C indicates a chassis problem. The zero indicates that it is a generic code. The number three indicates that the failure is in the misfire monitoring system. The last two digits indicate that it is rear prop shaft circuit malfunction.

Referring to previous argument, the application can receive diagnostic messages from a vehicle. Those messages need to be encoded to become universal DTCs. The prefix of a DTC is encoded as two bytes and the second character of a DTC is also described by another two bytes. Table 4 and table 5 show how those two character are encoded [6]. The last three digits are hexadecimal characters and each of them can be either a number (0-9) or a letter (A-F). All three characters are encoded by four bytes and they follow the rules when a hexadecimal character is converted into a binary character.

First two bytes of a diagnostic code	First DTC character
00	P- Powertrain
01	C- Chassis
10	B- Body
11	U- User Network

Table 4. How first DTC character is encoded

Following two bytes of a diagnostic code	First DTC character
00	0
01	1
10	2
11	3

Table 5. How second DTC character is encoded

1.5 AT command set

AT command set is a specific command language originally developed by Dennis Hayes for the Hayes Smartmodem 300 baud modem in 1981 [7]. As time went by, it became a commonly used command language with a series of short text strings which can be used to manage modems' behaviors. Although AT commands and OBD-II commands (OBD-II PIDs) are both sent from the application, they are totally different. Since Wi-Fi connection has been built between a vehicle and a phone, users can use the application to send AT commands to change settings of the OBD-II scanner. As mentioned above, EML 327 is the core part of an OBD-II scanner. In addition, it is fully configurable with AT commands. An AT command is firstly created by the application and then it is transferred from the phone to the scanner by using UART and WTCP. Once the scanner has received that AT command, it can tell it and know what to do next. It will also give a response to the sender to let it know whether the command works or not. In a word, AT commands are used to communicate with the OBD-II scanner and OBD-II PIDs are commands used to communicate with OBD-II systems.

Every AT command used by modem begins with "AT" or "at" and following characters are different. In this project, the application will use AT commands to communicate with an OBDII- scanner. Table 6 shows some AT commands used in the application [8].

Version	Command	Description	Group
1.0	@1	Display the device description	General
1.3	@2	Display the device identifier	General
1.3	SP 00	Set protocol to auto and save it	OBD
1.0	Z	Reset all	General

Table 6. AT commands used in this application

1.6 Thesis outline

Thesis outline simply talks about the contents of following chapters.

- Chapter two shows how to analyze users' requirements from different perspective. Functions that can be performed by users are described in detail in functional requirements. Non-functional requirements are related to system qualities.
- Chapter three describes both goals and constraints of system architecture design. Then it gives an overview of what the application will look like when it is completed. It also points out some key issues and its solutions.
- Chapter four presents detailed system design including database table design and use of UML diagrams to analyze user scenarios, relationship between classes and interactions between each component in the system.
- Chapter six shows implementation of main functions. It uses advantages of pseudocode to make logic of each process clear.
- Chapter seven presents testing strategies and how they are used in testing. It also shows the process of testing and testing data included in each kind of testing.

2. Requirements analysis

This section lists specific requirements for Riding Mechanic. Requirements are divided into the following sections:

1. User requirements. These are requirements written from the point of end-users and they describe the functions that the product must have. User requirements are usually expressed in user stories.
2. Functional requirements. These are detailed specifications describing the basic functions the system must have. Functional requirements are defined by developers to satisfy user requirements.
3. Non-functional requirements. These are requirements defining characteristics the system should have. Non-functional requirements are also called system features (e.g., Usability).

2.1 User requirement analysis

In section one, we briefly talked about why OBD apps are needed in our daily life. This part will describe the requirements in detail from end-user's perspective. A smart vehicle can optimize its performance to reduce fuel consumption, show the best with considering current external conditions and detect errors in the engine. It is a little bit hard for users to maintain the performance of cars because users can only view some basic information (e.g., speed) which gave users little help to improve the performance. What people should do if they want to get familiar with their cars without going to the auto shop? As mentioned above, users can use an OBD-II adapter to read information from a car's OBD-II system. However, to handle all kinds of data form OBD-II device users still need OBD-II apps to figure those categories out. The question is what capabilities users want those apps to have.

To communicate with a car, the very first step for users is to connect to an OBD-II scanner through Wi-Fi or Bluetooth. Users want an OBD app to help them get access to the car. After building connection successfully, users can communicate with the car

through the scanner. It is necessary for users to think about what kinds of information are needed so that users can take advantage of those information to help them. To improve driving habits, the best way is to analyze driving records to draw conclusions. Users want the app to have functions of recording driving information. All data in driving records must be specific and accurate to guarantee correctness of those conclusions. Speed and RPM are two kinds of significant information in driving records. Although users can easily view speed and RPM on the dashboard of a car, they are not specific. Users want the app to have specific speed and RPM in driving records. In addition, driving time and driving distance are very important for users to know how long and how far they have been driving. Users want the app to count time and distance in records. Besides, average speed can help users to identify comfortable diving speed in different situations. Users need that information in records. What's more, real-time MPG can let users know how fuel consumption depends on road conditions and average MPG can help users assess fuel consumption of a car. Therefore, real-time MPG and average MPG are both needed in driving records. Moreover, fuel consumption and fuel cost give user intuitional feelings of how much a car cost. Those two kinds of information should be included in records. Furthermore, engine coolant temperature can help user identify if a car is at risk of damage from overheating and control module voltage can help user identify if a car is at normal voltage level. Users want engine coolant temperature and control module voltage to be included in records. At last, driving records should contain bad driving habits like sharp acceleration times and sharp braking times. Users want those two kinds of information to help them overcome bar driving habits.

When users are driving on the road, bad driving habits or unknown malfunctions may result in accidents. Users may want the app to remind them of those bad driving habits or unknown malfunctions. Users want to set up speed limit to build over speed protection. Meanwhile, users also want to limit driving hours in case of tired driving. In addition, users also want to set up water temperature limit to remind them of high engine temperature. Besides, users want to set up fuel price to help them calculate how much they will pay for a journey. What's more, different users used different units of

measurement. They want to find their familiar units of measurement in the app. Because users want to record all kinds of driving information, they need to register accounts and then using them to log into the app. Meanwhile, they want the app to memorize their accounts at very first time so they did not need to type username and password again and again. Only when users want to log out function will they be required to type username and password for next time's login.

Once users have multiple driving records, they may want to search records for a date and got total fuel consumption, total fuel cost and total driving distance on that day. The app should show all records on that day. Besides, total fuel consumption, total fuel cost and total driving distance on that day should be included. Another important requirement for users is to make full inspections of cars. Users want to check their cars to find if there exist problems in cars. External problems (e.g., headlight malfunction) are easily to find and internal problems are hard to be detected without using professional tools. Users need the app to help them identify those malfunctions.

2.2 Functional requirements analysis

This section will analyze user requirements from developers' perspectives. It indicates the functions that they system must have to satisfy user requirements. The format used in this section is taken from one of my classes [9]. Index is used for functional requirements retrieval. Name represents the name of the function. Purpose indicates the purpose to design this function. Input parameters are input data required by this function and Output parameters are output data created by this function. Action indicates constrains and scenarios of this function. Exceptions are those wrong operations that will have influence on this function. Remarks remind developers of something important. Cross-references refer to another function's index which is related to this function. Following functional requirements are taken from functional requirements specification [10].

Index: Access.1

Name: Register

Purpose: To register an account for Riding Mechanic.

Input parameters: Username, password, confirm password

Action: Ensure that username doesn't exist in the system.

Ensure that password and confirm password should not be empty.

Ensure that password and confirm password are same.

Show information of registering an account successfully.

Output parameters: None

Exceptions: Username has already existed.

 Password or confirm password is empty.

 Password and confirm password are different.

Remarks: Application should show proper error message when users make mistakes.

Cross-references: None

Index: Connection.1

Name: Connect to a car

Purpose: To connect to a car.

Input parameters: None

Action: Ensure that an OBD-II adapter has already plugged into a car.

Ensure that Riding Mechanic is using the OBD-II adapter's Wi-Fi.

Jump to main screen and change status to connected.

Output parameters: None

Exceptions: The OBD-II adapter hasn't plugged into a car.

Riding Mechanic is not using the OBD-II adapter's Wi-Fi.

Remarks: Let users perform actions step by step.

Cross-references: Access.2

Index: Get.1

Name: Get supported PIDs

Purpose: To get supported OBD-II PIDs of a car.

Input parameters: None

Action: Ensure that Riding Mechanic has already connected to a car

Store those information into database.

Output parameters: None

Exceptions: Riding Mechanic hasn't connected to a car.

Remarks: Perform this activity in background.

Cross-references: Connection.1

Index: Save.1

Name: Save driving information

Purpose: To save driving information

Input parameters: None

Action: Ensure that Riding Mechanic has already connected to a car

Ensure that Riding Mechanic has already got supported PIDs.

Ensure that Riding Mechanic is keeping reading data from the car.

Choose to stop reading data and save it.

Output parameters: None

Exceptions: Riding Mechanic hasn't connected to a car.

Riding Mechanic hasn't got supported PIDs.

Riding Mechanic is not keeping reading data from the car.

Remarks: Give users choice to save or not save.

Cross-references: Get.2

Index: Search.1

Name: Choose specific date

Purpose: To choose a specific date for searching

Input parameters: None

Action: Ensure that users have already logged in.

Output parameters: None

Exceptions: Users haven't logged in.

Remarks: None

Cross-references: Access.2

Index: Check.1

Name: Check a car

Purpose: To check a car to find malfunctions

Input parameters: None

Action: Ensure that users have already logged in.

Ensure that Riding Mechanic has already connected to a car.

Start checking and show results.

Output parameters: Malfunctions

Exceptions: Users haven't logged in.

Riding Mechanic hasn't connected to the car.

Remarks: Give hint if no malfunctions occur.

Cross-references: Connection.1

Index: Alert.1

Name: Set up alert

Purpose: To close or open an alert for Riding Mechanic

Input parameters: None

Action: Ensure that users have already logged in.

Open or close an alert.

Output parameters: None

Exceptions: Users haven't logged in.

Remarks: None

Cross-references: Access.2

Index: Set.1

Name: Set up fuel price

Purpose: To set up fuel price to calculate fuel cost

Input parameters: Fuel price

Action: Ensure that users have already logged in.

Enter valid fuel price.

Output parameters: None

Exceptions: Users haven't logged in.

Fuel price is invalid.

Remarks: None

Cross-references: Access.2

2.3 Non-functional requirements analysis

This section will discuss non-functional requirements for this application from following aspects.

The first one is platform constrain. Because this application is developed for iOS users, it can only be installed and run successfully on an iPhone. Meanwhile, this application has used some application programming interfaces(APIs) supported by Apple Inc. and those APIs are only included in software development kit (SDK) whose iOS version is equal to version 8.0 or higher than 8.0. If users want to use this application without having any troubles, they need to upgrade their iPhones' system to iOS 8.0 or higher.

The second one is operating constrain. Users need to register an account for this app and then used the account to login. The third one is accuracy and precision. This application will show real-time information of a car. Some of real-time data comes from the car and the other data is decided by developers. Therefore, the accuracy and precision of the data is in allowable error scope. The fourth one is reliability. In case of system failure, this application will give proper error message to users when they have unexpected operations.

The next one is security. This application will read data from a car. Taking data protection into consideration, the application will allow users use their personal accounts to login. The last one is usability. This application will give users appropriate message

when users go to a different screen. Users can easily know what functions this screen has and how to go to other screens. What's more, this system will allow users perform functions step by step instead of giving all functions at very beginning.

3. System architecture design

This section will firstly identify goals and constraints of architecture. Then, it will focus on figuring key scenarios out. After that, it will overview whole application including architecture, tools and technologies used in this project. Finally, it will identify key issues that may occur during implementation and talk about how to deal with those issues.

3.1 Goals and constraints of architecture

One of the most important goals is to build a prototype for this project which can help users to understand developers' suggestions for the final product. Meanwhile, users can easily describe and prove requirements that have not been considered and then communicate with developers to figure issues out. This system has used incremental model and by the help of incremental prototyping the time gap between user and software developer has reduced a lot. During development, Dr. Elliott Forbes, advisor of this project, played a role of a customer and met with me very week to give his advice for each development phase in this project. Users have opportunities to provide feedback while some components are still in development. In addition, that way can influence the outcome of further development.

Another important goal is to identify key technical risks. The first key technical risk is to identify how to connect to a car through a mobile application. This process may involve hardware issues and will take some time to make it clear. After building connection successfully, another key technical risk is to identify how to read data from a car which will take long time to figure out both sending requests to a car and receiving data from a car. The next key technical risk is to guarantee accuracy of the data read from the car. The last key technical risk is to take thread safety into consideration. While the application is running, both UI changing and communication between a car and the application must be executed in different threads and those threads should not have conflicts with each other.

As mentioned in proposal, this application will use an OBD-II Wi-Fi scanner to read data from a car. In the other word, users must use a Wi-Fi type scanner to get access to the car and cannot connect to normal network. This is the biggest constraint in this project. The second constraint is that the application doesn't have enough storage to keep data and it should be saved in server database. The last constraint is that users need to buy an OBD-II Wi-Fi adapter and then they can use this application. There is no way to connect to a car directly without using any hardware products.

3.2 Key scenarios

A scenario is a broader and more encompassing description of a user's interaction with the system, rather than a path through a use case [11]. Key scenarios in this system included registering for an account, logging in, resetting password, connecting to a car, reading data from a car, saving data into database and searching history data.

When a user wants to register for an account, he or she should go to registration screen and enter username and password and confirm password. Both username and password should not be empty. In additional, username should be email address and should not be same with any usernames stored in database. After a user complete those steps, he or she will register for accounts successfully.

When a user wants to login, he or she is required to enter username and password. Username should be email address and be same with one of usernames stored in database. Meanwhile, username should match with password. After account verification, a user can login and perform functions in the system.

When a user forgets password, and wants to reset password, he or she is required to enter username. Username should be email address and be same with one of usernames stored in database. The system should automatically generate a password for that username and send it to that user. Meanwhile, server database should update that account.

When a user wants to connect to a car, he or she should have logged in. The first step is to open device's Wi-Fi in connection screen. Then an OBD-II Wi-Fi scanner need to be

plugged into an OBD-II port on the car. Finally, connecting to OBD-II scanner's Wi-Fi. A user must finish those actions step by step.

When a user wants to read data from a car, he or she is required to connect to the car first. After building connections successfully, the application will keep reading data from the vehicle and show it to the user. The user can click stop button in the screen if he or she wants to go back main screen.

When a user wants to save data into database, he or she should have stopped reading data from a car and the system will remind them of saving data. The system will save data into temporary database instead of server database because network is unavailable when the user has connected to a car through an OBD-II Wi-Fi scanner. Temporary database will upload data to server database after login.

When a user wants to search history data, he or she is required to go to trip analysis screen. Temporary database will request data from server database according to that account after login. The user can select specific date to search run history. If the user does not select any date, system will automatically show current date's trip information.

3.3 Application overview

This section will create an overview of what the application will look like when it is completed. As mentioned in capstone proposal, this software is designed to be a mobile application and will have a server database. The biggest deployment constraint is that this application cannot have access to the server database while it is running on an iPhone. Some running data can only be stored in temporary database. Fetching and saving data must be executed between after login.

This application will use a combination of architecture styles. It will involve a separate server system and multiple clients. When a client sent one or more requests, the client will receive those requests and send corresponding responses to the client. There are two main benefits to use the client/server architectural style. The first one is higher security. Because all data is stored on the server, it is easy for admin to get a better

control of security than client machines. The second one is ease of maintenance. Roles and responsibilities of a computing system are distributed among several servers that are known to each other through a network [11]. Another important architecture style is object-oriented architectural style which will divide system responsibilities into individual objects. Each individual module will take responsibilities for separate functionalities which can be used by other modules by providing corresponding interfaces. There are several advantages to use objective-oriented design. The first one is reusable. Some classes can be used by other classes through polymorphism and abstraction. The second one is testable. Encapsulation of classes can help users to do both unit testing and integration testing. The last one is highly cohesive. By locating only related methods and features in an object, and using different objects for different sets of features, you can achieve a high level of cohesion [11].

This software is a mobile application running on iPhone. The programming language used for client part is objective-c and the integrated development environment is Xcode. As for the server part, the main programming language is Node.js and the integrated development environment is Visual Studio Code. This product will use MySQL as server database and use MySQL Workbench to manage the database.

3.4 Key issues and solution

It is meaningful for developers to identify key issues based on quality attributes where problems often occur when designing an application.

The first quality attribute is system quality which will analyze the whole system from supportability and testability. This product cannot run individually without using an OBD-II Wi-Fi scanner. This is hardware restriction and cannot be solved in software development. Besides, this product is required to run on an iPhone. There may exist unknown problems when users launch it on an iPad. As for testability, it is not too hard for developers to do functional testing, unit resting, integration testing and system testing because this product will take object-oriented architecture design.

The second quality is run-time quality which will analyze the system from manageability, performance, reliability, scalability and security. Manageability describes how easy it is for system administrators to manage the application. This system will take client/server architecture design to make it easy to manage the server database. Performance is an indication of the responsiveness of a system to execute any action within a given time interval [11]. In general, system should give proper message when the system is downloading data or uploading data. Some actions which took tens of seconds or a few minutes will be executed in the background instead of keeping users waiting for a long time. Reliability defines how stable the system is when it is running. The system should give corresponding error message instead of breaking down suddenly whenever users make mistakes. Scalability is the ability to create a more advanced version of the system. This product will use generic OBD-II PIDs which can only request some basic information from a car. More functionalities can be designed if developers have access to manufactures specific OBD-II PIDs. Usability defines how well the application meets the requirements of the user and consumer by being intuitive, easy to localize and globalize, providing good access for disabled users, and resulting in a good overall user experience [11]. This product will use incremental model which can help users communicate with developers directly. Users have more information about the product while it is under development.

Another important key issue is thread safety. This application will send multiple standard OBD-II PIDs to the vehicle but the car cannot receive more than two commands at the same time. The main thread of the application will take charge of updating UI and background threads will be responsible for sending OBD-II PIDs. The orders of sending different OBD-II PIDs should be sent based on their priorities. Next chapter will talk how to implement it.

As mentioned in users' requirements, a user can use this application to record vehicle information for a journey. Some information, such as speed and RPM, can be easily retrieved by sending corresponding OBD-II PIDs. But other information like driving distance cannot be read directly from the vehicle. So, this kind of information will be

handled by developers. Next chapter will describe how the system dealt with that kind of information.

As for communication between server side and client side, the system uses the Hypertext Transfer Protocol (HTTP) to send request. Figure 2 shows a high-level design for this application. Both information from server side and information from client side must be configurable to be meaningful. What's more, the server side should give client side proper response whenever a client submitted an HTTP request to the server. For example, if a client sends a request to do account verification, the client receives that request and deals with that request. If no such account exists, the server will respond no such account existed. If network crashes suddenly, the server will respond internet occurred error. If a request is in wrong format, the server will respond method is not supported. If that account exists in database, the server will give response together with that account information to the client.

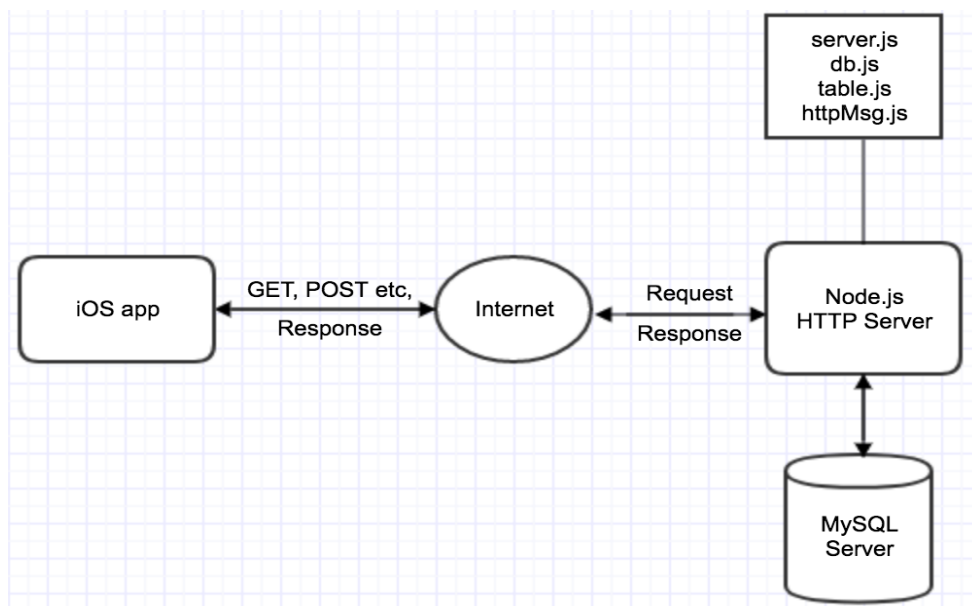


Figure 2. High-level architecture

4. Detailed system design

Detailed design focuses on all implementation details necessary to implement the architecture that is specified. Detailed system design is a low-level design and the main goal of it is to prepare a blue print of a system that meets the goals mentioned in system architecture design. This section described procedures and methods which will be used in detailed system design. According to the requirements of Rational Unified Process (RUP) [13] and Unified Modeling Language (UML) [14], detailed system design will define the behavior of each architectural component in detail. This section will take advantage of use case diagram to give a graphic overview of the actors involved in a system, different functions needed by those actors and how these different functions are interacted. Class diagram will be used to shows internal classes in the system, attributes and operations of each class and the relationship between each class. Sequence diagram will be used to show interactions between objects, functions taken by each object and sequence of messages sent or receive by each object.

4.1 Database design

4.1.1 Database table design

A well-structured database can save disk space by eliminating redundant data, maintain data accuracy and integrity and provide access to the data in useful ways [15]. The first step in database design is to find out “entities” which exist in four kinds: people, things, events, and locations. Everything people can want to put in a database fits into one of these categories. In this project, user is absolutely one of the entities. Another entity is trip which contains information of a car during this trip.

The next step is to determine the relationships between the entities and to determine the cardinality of each relationship. In this project, a user can record a trip or multiple trips. Multiple users cannot record the same trip.

The third step is to find out “attributes” which will be saved as data elements for each entity. For user table, it uses auto-increment id as primary key. Unique “username” and

“password” are also needed. Besides, “totalAlertSwitch” should be one of the “attributes” because it can determine if a user wants to open or close alert during a trip. In addition, “speedLimit” and “speedAlertSwitch” are also “attributes” because “speedLimit” determines the warning speed value and “speedAlertSwitch” determines if a user wants to open speed limit alert or not. Similarly, we can get “attributes” like “tiredDrivingHour”, “tiredDrivingAlertSwitch”, “waterTemperatureLimit” and “waterTemperatureAlertSwitch”. What’s more, “fuelPrice” should be one of the “attributes” because users can use it to calculate fuel cost. “unit” should also be one of the “attributes” because users should be able to change unit of measurement. About a trip, it should use auto increment id as primary key and uses “userID” as a foreign key. In addition, it should have “startDateTime” and “endDateTime” to represent when users recorded the trip. Besides, “drivingDistance”, “averageMPG”, “averageSpeed”, “fuelCost”, “sharpAccelerationTime” and “sharpBrakingTime” are also “attributes” because they are necessary information for users to analyze a trip.

After finishing above steps, Entity Relationship Diagram (ERD) can be easily retrieved. ERD gave a graphical overview of the database. Figure 3 shows ERD for this project.

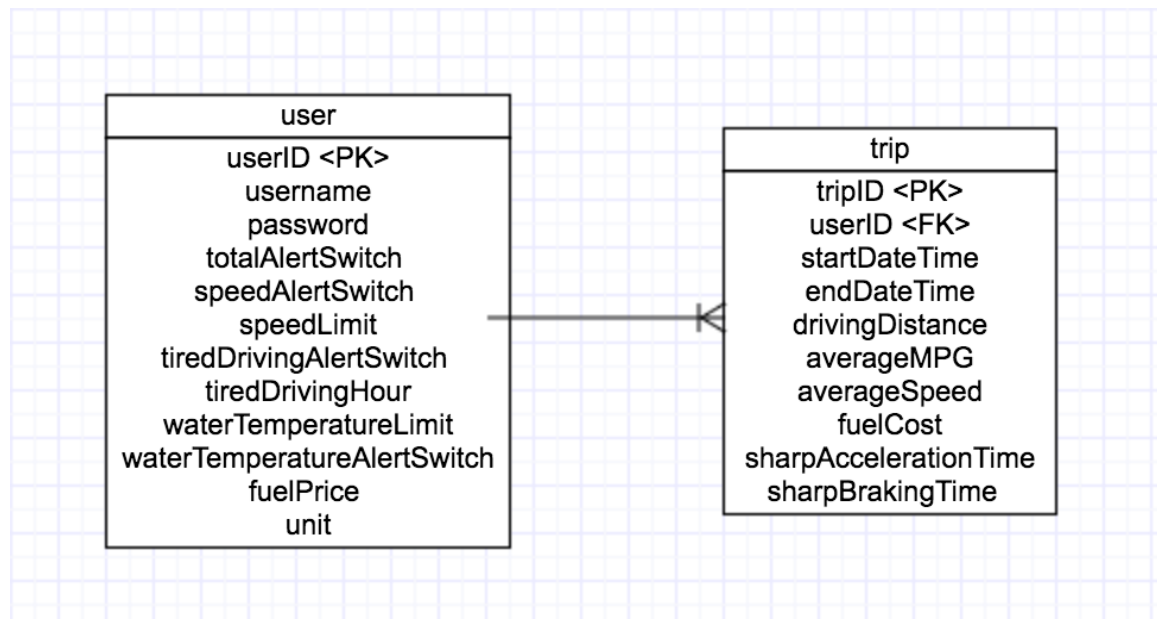


Figure 3. Entity relationship diagram

The final step is to define attribute's data type. There are a lot of different data types. This project will use MySQL as a server database, so all types of data are defined by MySQL. For user table, all attributes should not be null. "userID" should be unique positive self-increasing integer. Type of "username" and "password" are "VARCHAR" and "username" should be unique. "totalAlertSwitch", "speedAlertSwitch", "tiredDrivingAlertSwitch", "waterTemperatureAlertSwitch" and "unit" have the same type. The type is "TINYINT" which is equal to Boolean type. The reason to use "TINYINT" instead of using "Boolean" is that MySQL did not have internal "Boolean" data type. "speedLimit", "tiredDrivingHour", "waterTemperatureLimit" and "fuelPrice" used the type of "Double" because all of them are float values. For table trip, "tripID" should be unique positive self-increasing integer. It used "userID" as foreign key and "userID" should be not null and unique. Besides, "startDateTime" and "endDateTime" represented specific date and time so their type is "DATETIME". "drivingDistance", "averageMPG", "averageSpeed" and "fuelCost" are float values and their type is "DOUBLE". "sharpAccelerationTime" and "sharpBrakingTime" record how many times users have sharp acceleration and sharp braking, so their type is "INT".

After those steps finished, we can build the database through MySQL Workbench. Figure 4 shows user table and figure 5 shows trip table.

























Column	Datatype	PK	NN	UQ	BIN	UN	ZF	AI	G	Default / Expression
 userID	INT(11)		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
 username	VARCHAR(100)		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
 password	VARCHAR(100)		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
 totalAlertSwitch	TINYINT(4)		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'1'
 speedAlertSwitch	TINYINT(4)		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'80'
 speedLimit	DOUBLE		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'1'
 tiredDrivingAlertSwitch	TINYINT(4)		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'1'
 tiredDrivingHour	DOUBLE		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'4'
 waterTemperatureAlertSwitch	TINYINT(4)		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'1'
 waterTemperatureLimit	DOUBLE		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'220'
 fuelPrice	DOUBLE		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'2.39'
 unit	TINYINT(4)		<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	'1'

Figure 4. User table in database

Column	Datatype	PK	NN	UQ	BIN	UN	ZF	AI	G	Default / Expression
tripID	INT(11)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
userID	INT(11)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
startDateTime	DATETIME	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
endDateTime	DATETIME	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
drivingDistance	DOUBLE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
averageMPG	DOUBLE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
averageSpeed	DOUBLE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
fuelCost	DOUBLE	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
sharpAccelerationTime	INT(11)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL
sharpBrakingTime	INT(11)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	NULL

Figure 5. Trip table in database

4.1.2 Database password encryption and decryption

Password encryption is designed to grantee account safety. When a user has created an account for this application, the password will be encrypted when it is insert into server database table. This technology is supported by MySQL. The encryption method is “AES_Encypty (password, key)”. By using this method, the password in the table will be a messy code and no one can read useful information form that messy code. The key of password worked as an index. The application can only find the password through the key. This project will use unique username as the key of the password.

It is easy for developers get the password which is not encrypted. Once it has been encrypted, the most important thing is decryption. The decryption method is “AES_Decypty (password, key)”. This decryption key should be same with the key for encryption. As mentioned above, it is the username. It is not enough to get the real password because the password will be converted into binary value after using that method. So, another method, “cast (AES_Decypty (password, key)”, AS CHAR)”, should be used after initial decryption. So, the first step of decryption is to convert a messy code into binary value by using “AES_Decypty (password, key)”. The second step is to convert that binary value into char value by using “cast (AES_Decypty (password, key)”, AS CHAR)”. Then, the real password can be retrieved.

4.2 Use case diagram

All use cases are retrieved from user requirements and the use case diagram gives an overview of usage requirements for a system. Figure 6 shows the use case diagram of this project.



Figure 6. Use case diagram

4.3 Class diagram

Class diagram is the core part of UML diagram and it describes the structure of a system by modeling its classes, attributes, operations, and relationships between objects. There are several benefits by using class diagram. It can help developers to illustrate data models for information systems and have a good understanding of a general overview of system. In addition, it provides an implementation which contains independent description of types used in a system and passed between its components. Figure 7 shows the class diagram of this project.

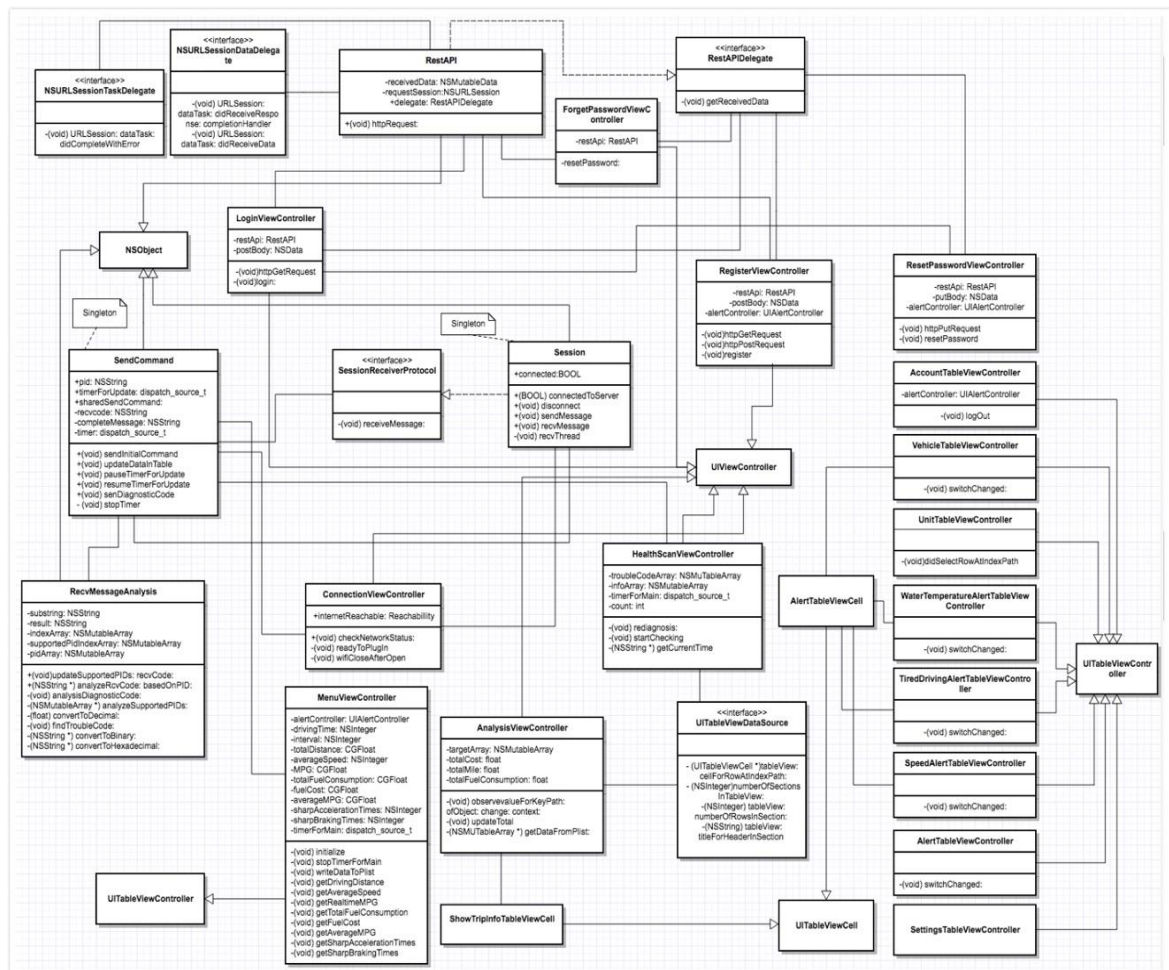


Figure 7. Class diagram

4.4 Sequence diagram

This section will mainly show the sequence diagrams of some important activities in this application. By using sequence diagram, we can clearly see how different components interact with each other and how messages passed between components in different activities.

Figure 8 shows sequence diagram of login, it describes login scenario; Figure 9 shows sequence diagram of registration, it describes registration scenario; Figure 10 shows sequence diagram of resetting password, it describes a user forgets password and uses the system to reset password; Figure 11 shows sequence diagram of connection, it indicates the scenario to connect to a car; Figure 12 shows sequence diagram of reading data from a car; Figure 13 shows sequence diagram of searching data for a specific date; Figure 14 shows sequence diagram of checking a car; Figure 15 shows sequence diagram of sending initial OBD-II PIDs to get supported OBD-II PIDs.

While the system is sending OBD-II PIDs to the car to get real-time information, it is very important to decide the order of sending different OBD-II PIDs because the OBD-II system can only receive and give response to one OBD-II PID each time.

The application will receive message and deal with that message every half second. In the other word, the application can only receive two kinds of message each second which meant the application can only send two kinds of message each second. Table 7 shows the frequency of sending each kind of OBD-II PIDs.

	1s	2s	3s	4s	5s	6s	7s	8s	9s	10s	Rule
0105 (Coolant Temperature)										√	Time% 10==0
010C (RPM)	√		√		√		√		√		Time is odd
010D (Speed)	√	√	√	√	√	√	√	√	√	√	Time% 1==0

0110 (MAF Air flow rate)		√		√				√			Time is even and! Time%10==0 and! Time%6==0
0142 (Control module voltage)						√					Time%6==0

Table 7. Frequency of sending different OBD-II PIDs

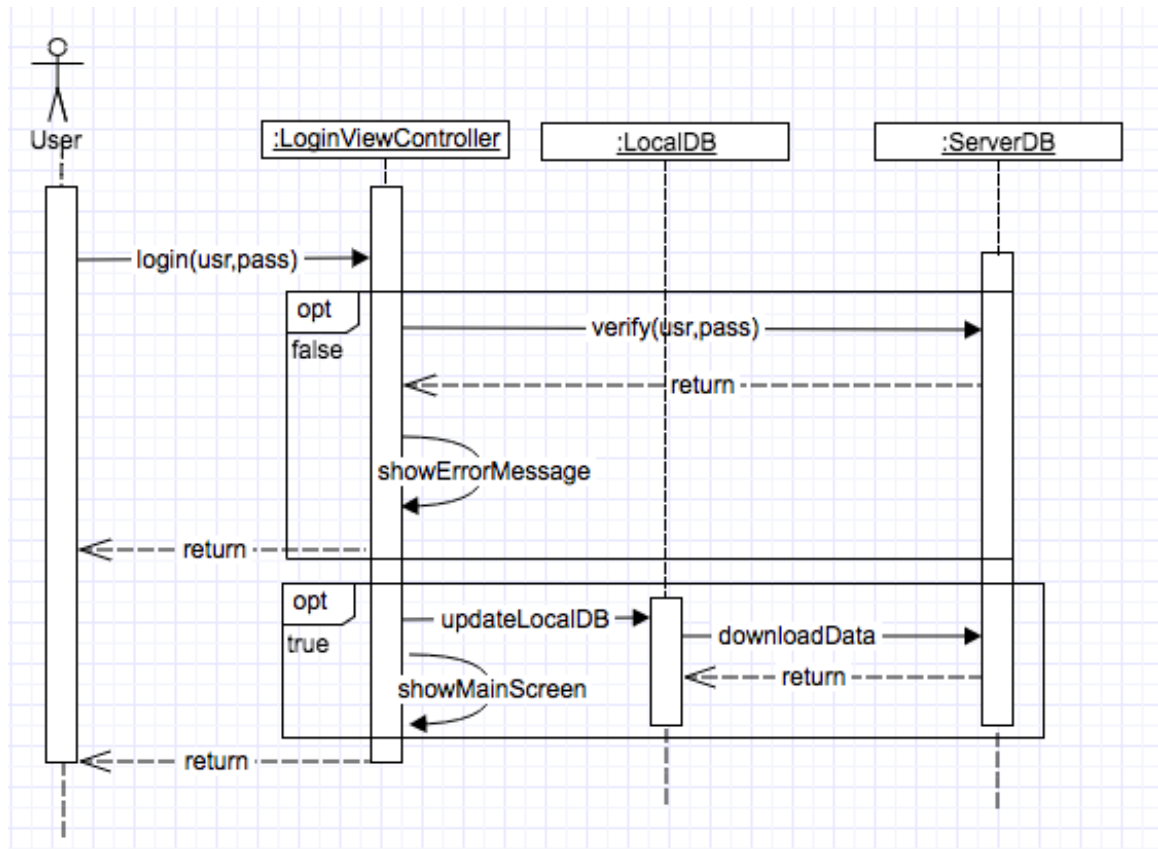


Figure 8. Sequence diagram of login

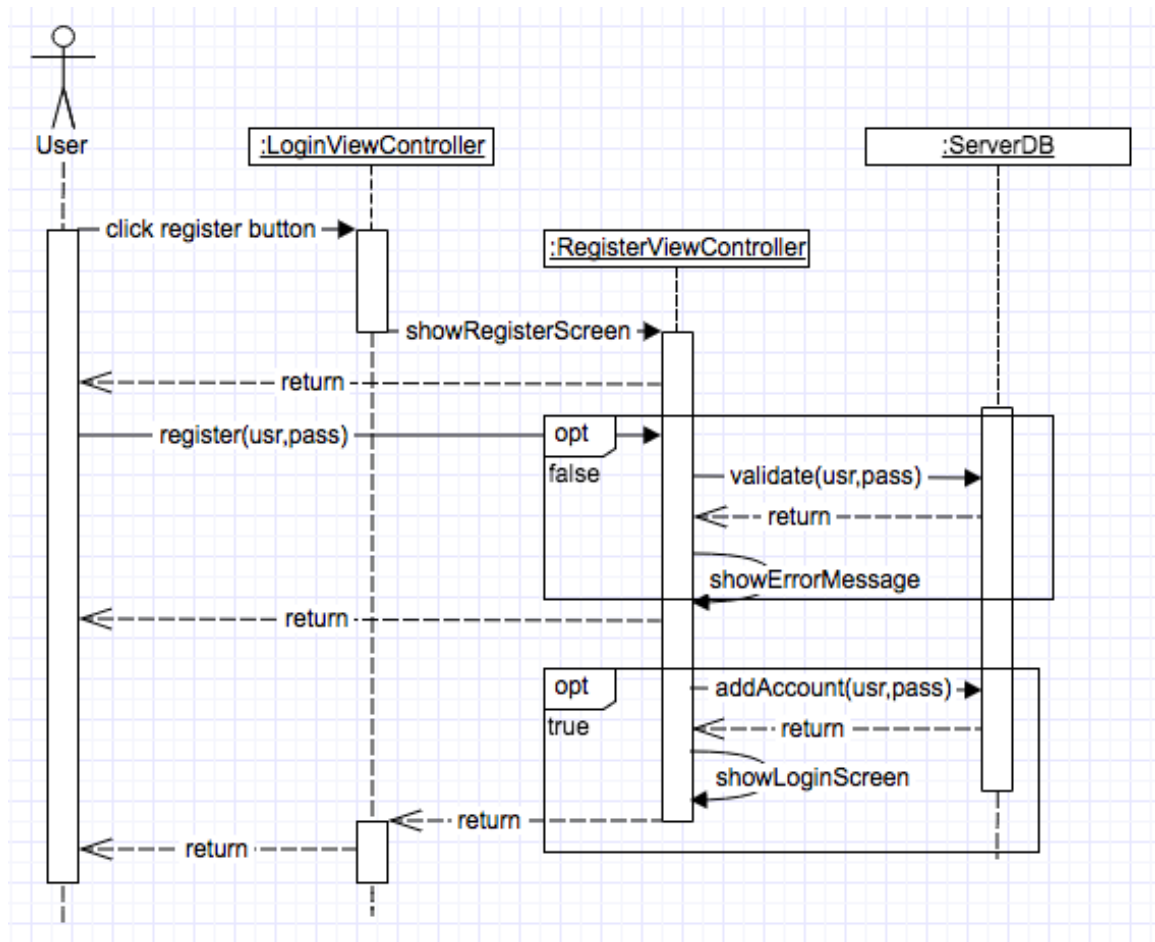


Figure 9. Sequence diagram of registration

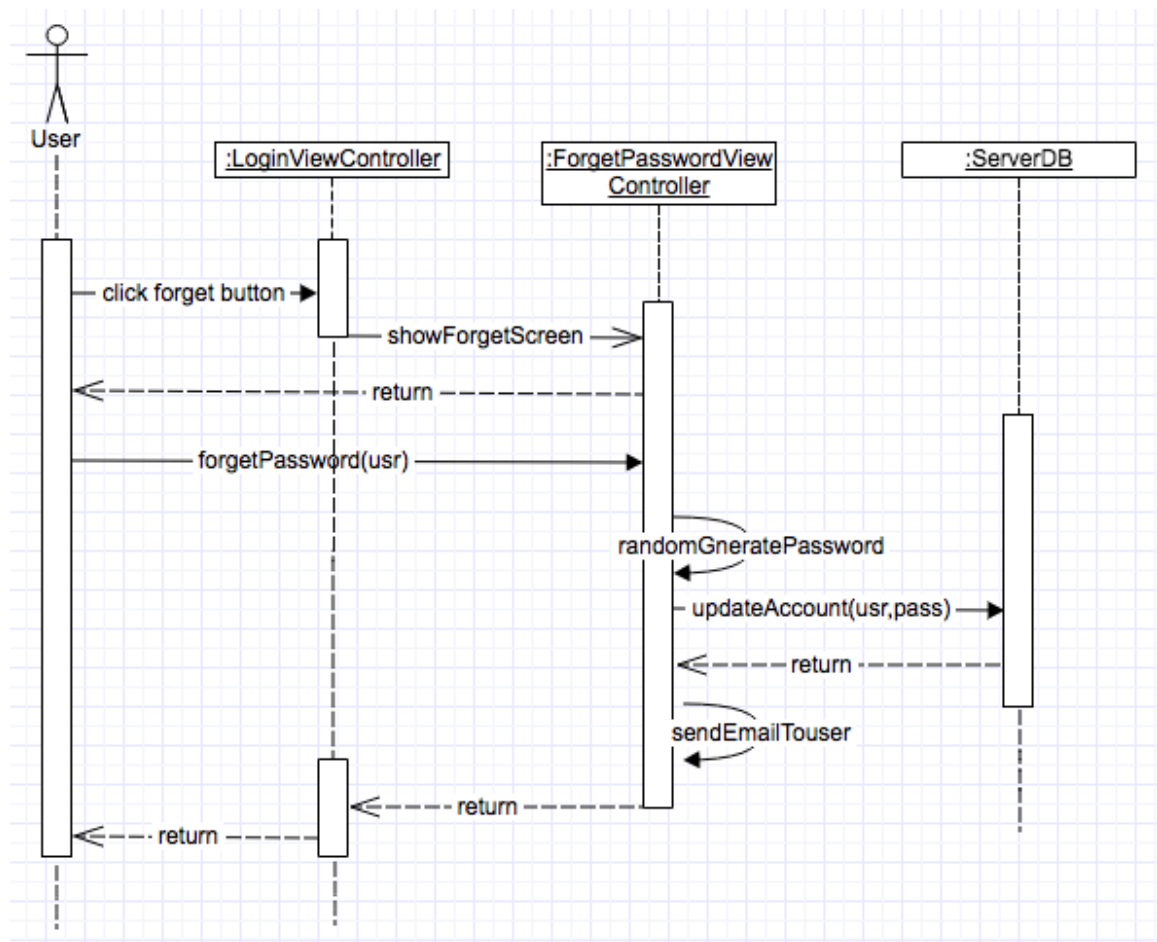


Figure 10. Sequence diagram of resetting password

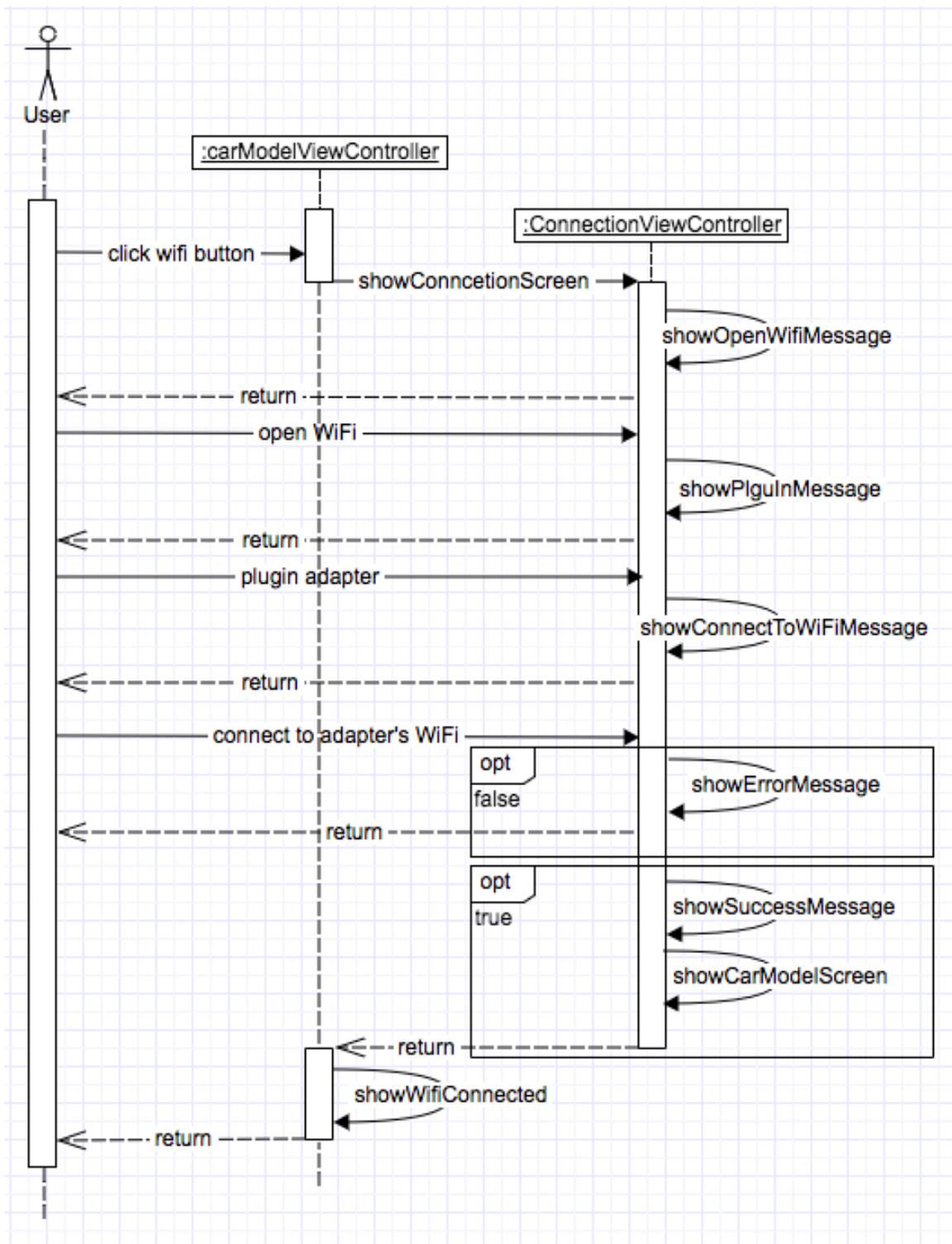


Figure 11. Sequence diagram of connection

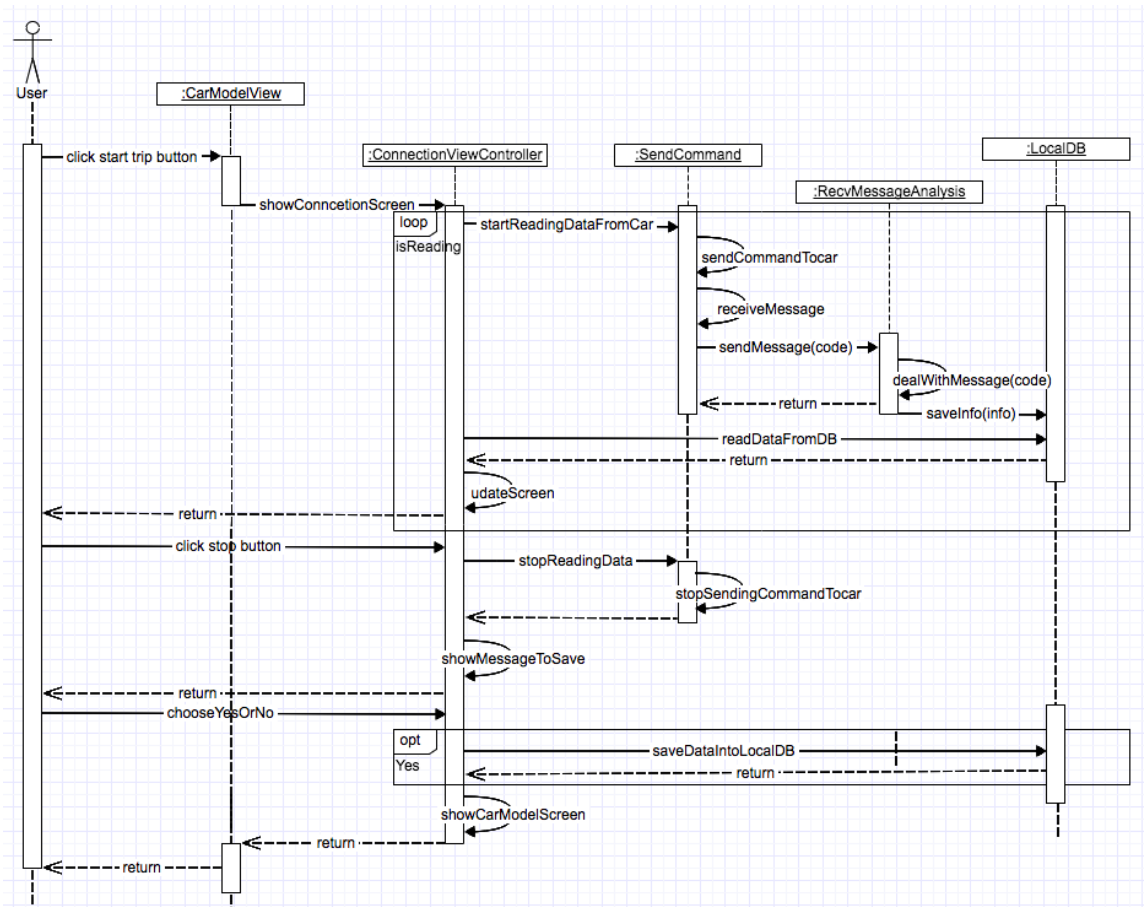


Figure 12. Sequence diagram of reading data

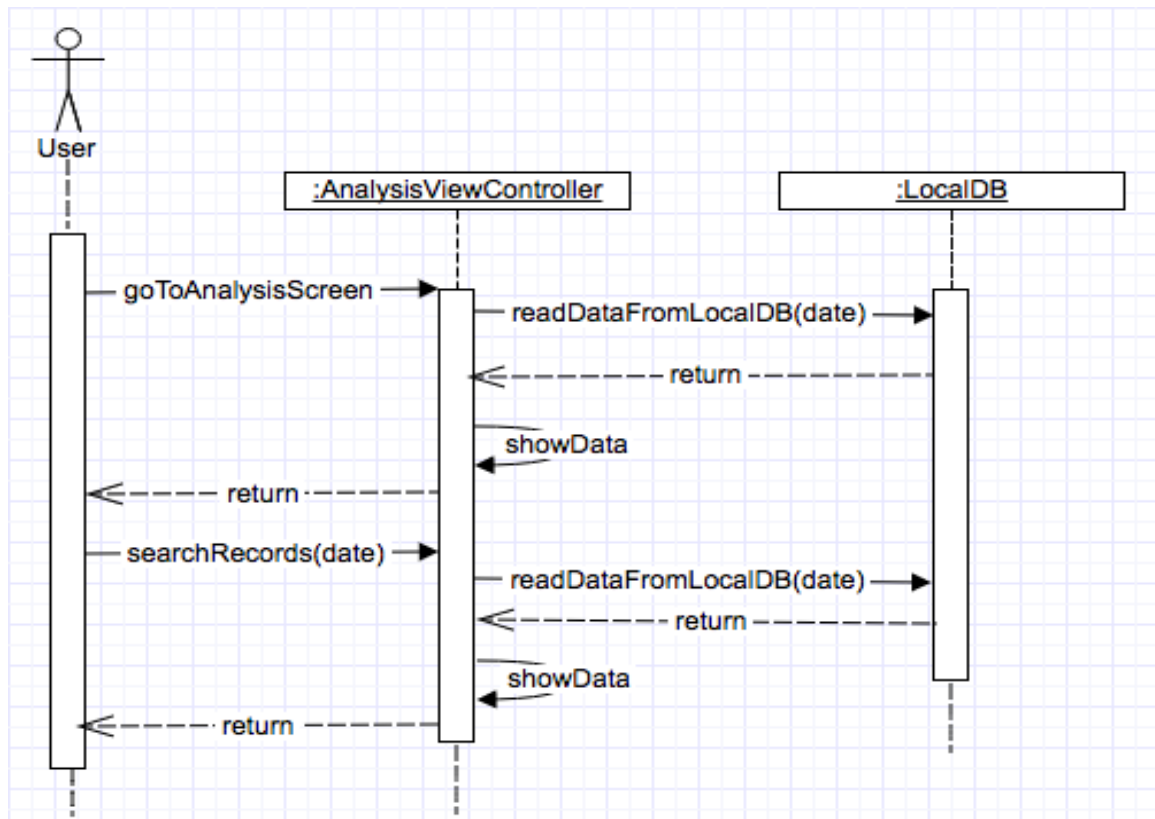


Figure 13. Sequence diagram of searching a trip

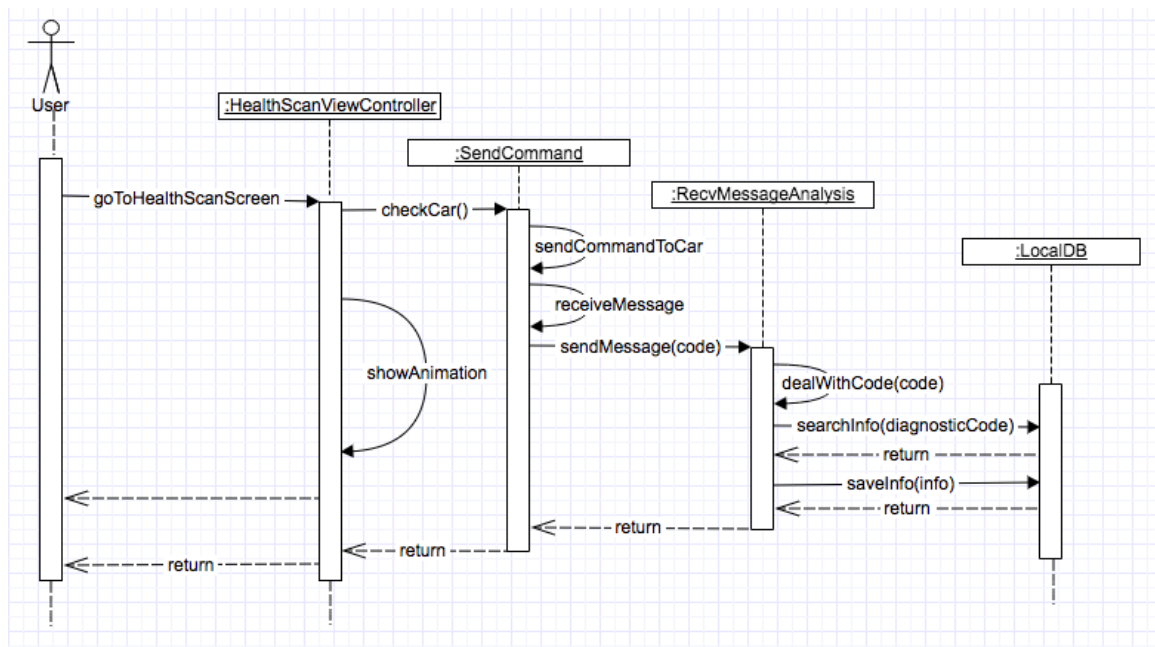


Figure 14. Sequence diagram of checking a car

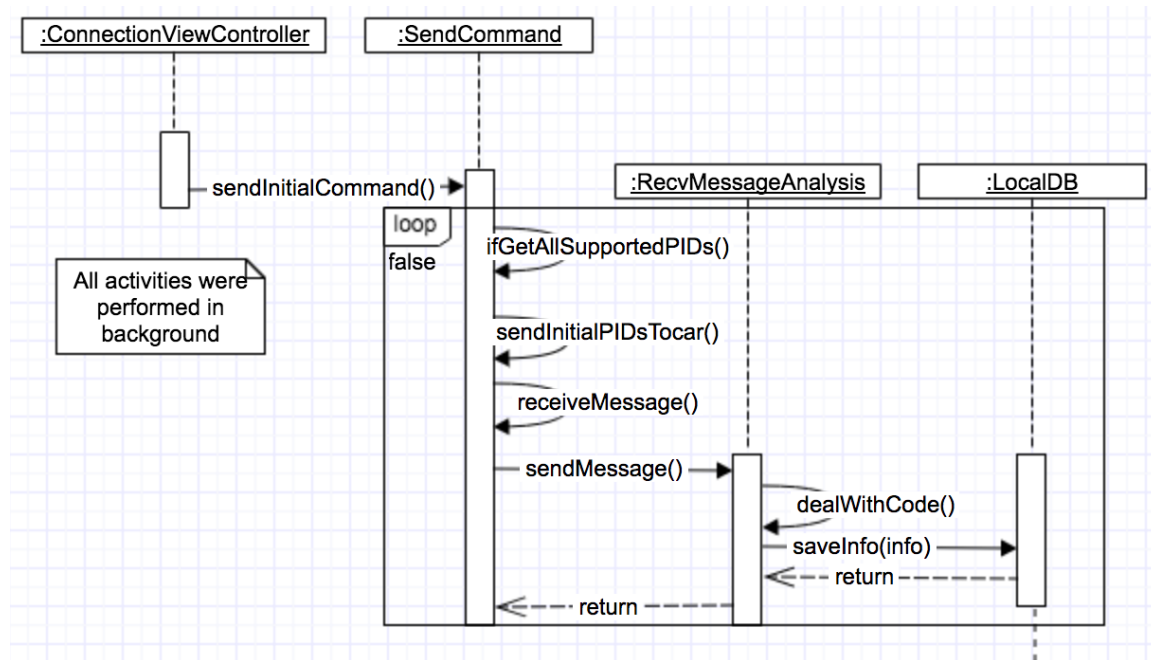


Figure 15. Sequence diagram of sending initial commands

4.5 How driving distance is calculated

As mentioned above, some information of a journey cannot be read directly from the vehicle and that kind of data will be worked out by the system. This part will describe the process of calculating the driving distance. Physics formulas has taught us distance is equal to elapsed time plus average velocity. We can apply it into calculating driving distance. The elapsed time can be worked out by just counting elapsed time. The system can also read the current speed form the vehicle every second. By using the theory of differential calculus, the error of the distance will be reduced by using smaller time interval and the smallest time interval for reading current speed is one second.

The first step for calculating distance is to get average speed in one second. For example, the speed of the third second is ten miles per hour and the speed of the fourth second is twenty miles per hour, so the average speed between the third second and the fourth second is fifteen miles per hour. Then, the second step is to calculate the distance

in one second by using the physics formula ($s=v*t$). The last step is to add every second's distance together to get total distance.

4.6 User interface design

As we know, user interface design is one of the most important parts in software development. The quality of user interface has huge influence on user experience of the product. A good GUI (graphical user interface) not only catches a first-time user's eye but also motivates the user to use the product again. I will introduce four principles of UI design which come from a paper [10] that I have read.

The first one is reading gravity. The second one is minimization of cognitive load. The third one is using pre-existing mental models. The last one is use of color to direct attention. In addition, I also have my own GUI designing experience which come from Professor Kasi's class. The first one is that GUI should be usable to as many as possible. The second one is that GUI must report appropriate error messages at the right time. The third one is that providing appropriate help at the right time and motivate the user to continue. The last one is that try to protect the users from introducing errors into the system (error prevention). Those UI design principles will be used as references to design UI of this product.

I will first introduce some basic patterns for mobile navigation. Tab bar pattern is one of the most frequently used patterns in mobile applications. Many popular applications, like Facebook, Instagram and Twitter, using tab bar pattern in their design. It is originally from desktop design. The tab bar usually put navigation icons at the bottom of a screen to fit finger touch. Users can navigate directly to the screen associated with the item. By using tab bar navigation pattern, users can easily have access to all main functionalities without multiple touches; In addition, users can know where they are and what to do when they are using the application. In this product, all main functions are represented by bottom icons in tab bar. Figure 16 shows an example.

Another popular UI design pattern is navigation bar. Almost all popular mobile applications have navigation bars. In general, a navigation appeared between the status bar and an app screen. Users can view the status and application screens without having any troubles. A navigation bar usually has title, back button and control button. Back button is always associated with previous screen and appears on the left side of the bar. Title always shows information of current screen and appears on the middle of the bar. As for control button, it is related to a Cancel or Done button and mainly used to manage users' actions. This product has used lot of navigation bars. Figure 17 shows an example.

In addition to UI design patterns mentioned above, some popular UI elements are also frequently used in famous mobile applications. For example, Messenger used table view to show contract list. The table view is used to manage data which has similar data structure or belongs to similar category. Table view can help us to show additional contents by scrolling with it. Some table views also have headers and footers which can make it easy to tract a long table. Figure 18 shows an example in this product.

Alert is another important UI element in mobile application design. Many applications used alerts to remind users of something important. An alert usually contains a title and optional information. The title indicated what that the alert's meaning and optional information told users what they can do. A widely-used example for using alert is AMBER Alert. Almost all people can view that information immediately once an AMBER Alert occurred. From this example, we can easily find out the advantages of using alerts in mobile application. Figure 19 shows an example in this product.

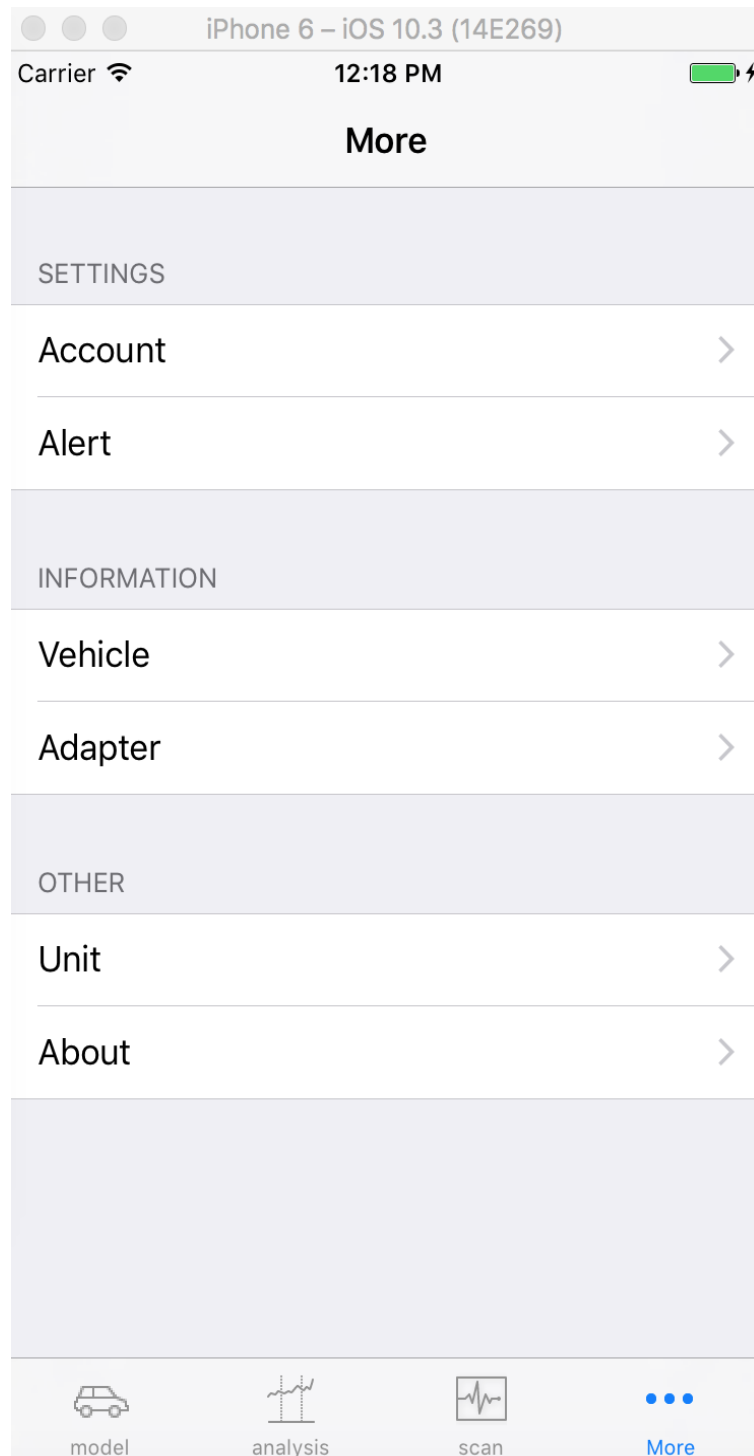


Figure 16. Example of using a tab bar

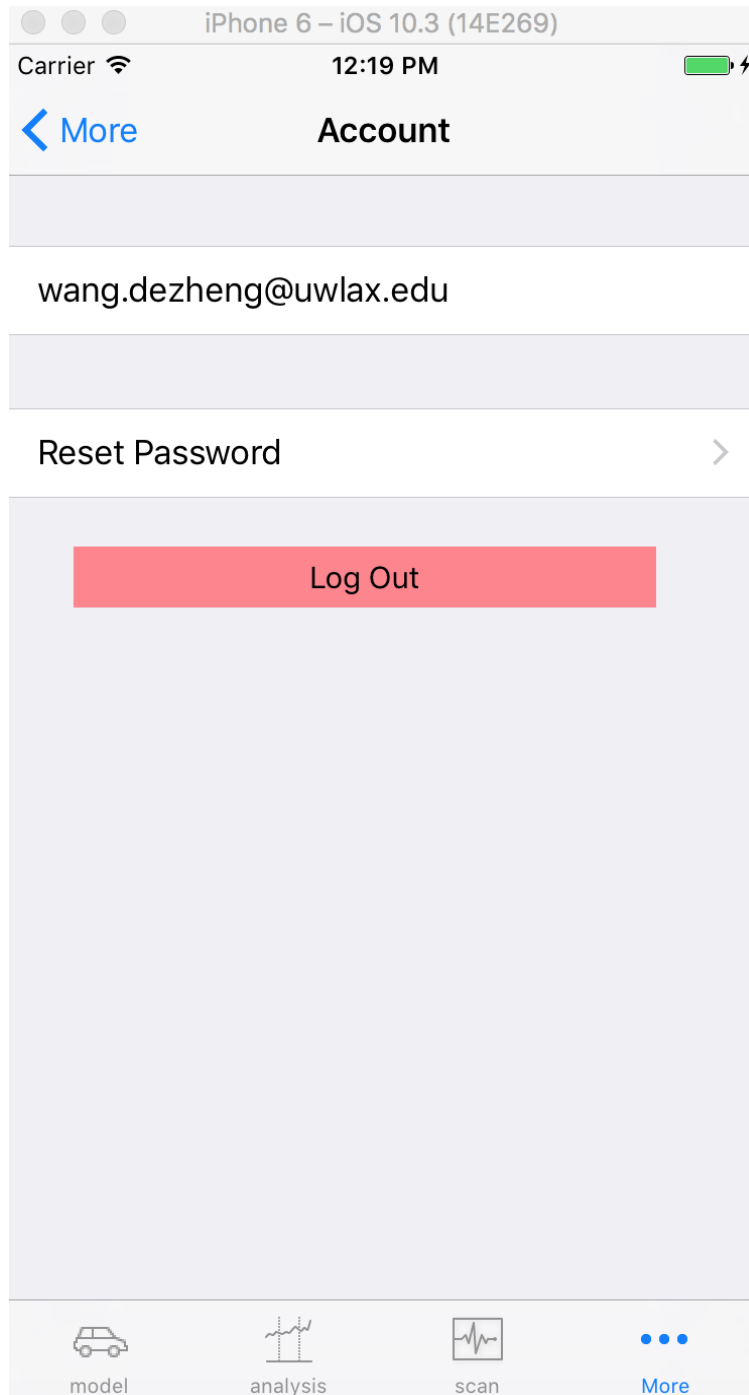


Figure 17. Example of using navigation bar



iPhone 6 – iOS 10.3 (14E269)		
Carrier 	12:37 PM	
Trip Information		Stop
Driving Time	6	s
Driving Distance	0.00	km
Speed	0.0	km/h
Average Speed	0.0	km/h
RPM	0	rmp
Realtime MPG	0.00	mpg
Total Fuel Consumption	0.00	gal
AverageMPG	0.00	mpg
Fuel Cost	0.00	gal
Engine Coolant Temperature	0	°C
Control Module Voltage	0	V
Sharp Acceleration	0	time
Sharp Braking	0	time

Figure 18. Example of using table view

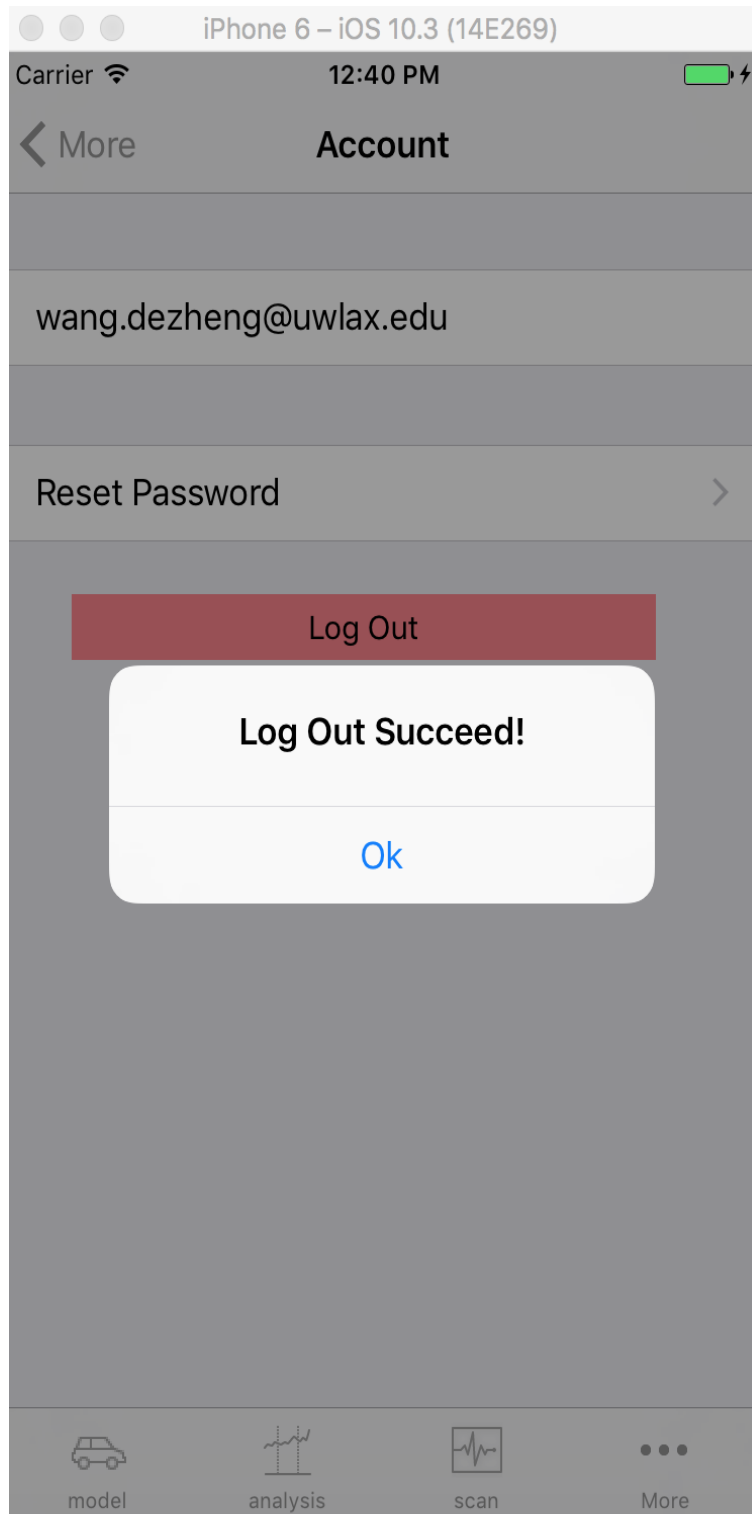


Figure 19. Example of using an alert

5. System implementation

Instead of using objective-c codes, this section will use pseudocode to talk about the main algorithm and logic in this application. Pseudocode can be understood by most people.

5.1 Login module

This part used pseudocode to describe the login procedure. It involved following functions: Login (), SetInitialStatus (username), SetUser(username), SetTrip (userID).

```
1. If username and password had been memorized
2. Go to main screen
3. Else if users click login button
4.     Login () //User click login button will call this function
5. Else if users click register button
6.     Go to register screen
7. Else
8.     Go to forget password screen
9.
10. Login () {
11.     Set username to username text field value
12.     Set password to password text field value
13.     If username or password is empty
14.         Alert "Username or password should not be empty"
15.     Else
16.         Send get request to the server //request body contains username
17.         Query password based on username in user table
18.         If return value is empty
19.             Alert "Incorrect username or password"
20.         Else if return value is not equal to password
21.             Alert "Incorrect username or password"
22.         Else if return value is equal to password
23.             Store username, password, userID in local database
24.             SetInitialStatus (username) // background thread
25.             Go to main screen
26. }
27.
28. SetInitialStatus (username) {
29.     SetUser(username) // upload local data (update local database if needed)
30.     SetTrip (userID) // upload local data (update local database if needed)
31. }
32.
33. SetUser (username) {
34.     If user table is empty in local database
35.         Send get request to the server //request body contains username
36.         Query all related information based on username in user table in server
37.         Set a delay // need time to download data
38.         Set userInfo to return value
39.         Update user table in local database based on userInfo
```



```

40. Else
41.     Query all related information based on username in local database
42.     Set userInfo to return value
43.     Send put request to the server // request body contains userInfo
44.     Update user table in server database based on userInfo
45. }
46.
47. SetTrip (userID) {
48.     If new trip table is empty in local database
49.         Send get request to the server //request body contains userID
50.         Query all related information based on userID in trip table in server
51.         Set a delay // need time to download data
52.         Set tripInfo to return value
53.         Update trip table in local database based on tripInfo
54.     Else
55.         Query all related information based on userID in new trip table in local
56.         Set newTripInfo to return value
57.         Send post request to the server // request body contains newTripInfo
58.         Add newTripInfo to trip table in server database
59. }

```

5.2 Registration module

This part used pseudocode to describe the registration procedure. It involved following functions: Verify ().

```

1. If users click submit button in register screen
2.     Verify () //User click submit button will call this function
3. Else users choose to go back login screen
4.     Go to login screen
5.
6. Verify () {
7.     Set username to username text field value
8.     Set password to password text field value
9.     Set confirm to confirm password field value
10.    If username is not in email format
11.        Alert "Username should in email format"
12.    Else if password or confirm is empty
13.        Alert "Password or confirm password should not be empty"
14.    Else if password is not equal to confirm
15.        Alert "Passwords must match"
16.    Else
17.        Send post request to the server // request contains username and
password
18.        Insert username and password into user table
19.        If return value is false
20.            Alert "Sorry, this username had been used!"
21.        Else
22.            Alert "Register Succeed"
23.            Go to login screen
24. }

```

5.3 Forget password module

This part used pseudocode to describe how to reset password when a user forgot his password.

```
1. Set username to username text field value
2. If username is empty
3.     Alert "You must enter username"
4. Else
5.     Send get request to the server //request body contains username
6.     Query that username in user table in server database
7.     If return value does not have content
8.         Alert "Username does not exist"
9.     Else
10.        Set newPassword to random six-digit number
11.        Send email to username // username is in email format
12.        Send put request to the server
13.        Update user table in server database based on username and newPassword
14.        Go to login screen
```

5.4 Device connecting module

This part used pseudocode to describe the procedure of connecting to an OBD-II Wi-Fi scanner. It involved flowing functions: SendInitialCommand (), ReceiveMessage ().

```
1. while Wi-Fi is open
2. Do
3.     Show plug in button
4.     Users click plug in button
5.     Show connecting to Wi-Fi button
6.     If device is connected to adapter's Wi-Fi
7.         Set wifiStatus to connected
8.         Store wifiStatus in local database
9.         SendInitialCommand () // this method comes from SendCommand class
10.        Go back main screen
11.    Else
12.        Alert "Connection failure"
13.
14. SendInitialCommand () {
15.    Create timer
16.    Set timer priority to background
17.    Timer:
18.        If last command had not been sent
19.            Use Session class
20.            Session send commands
21.            ReceiveMessage ()
22.        Else
23.            Stop timer
24. }
25.
```

```

26. ReceiveMessage () {
27.     Set message to receive message
28.     Use regular expression to deal with message
29.     Analyze message and get value// value represents vehicle supported command
30.     Store that value in local database
31. }

```

5.5 Trip information module

This part used pseudocode to describe how to read real-time information from a vehicle. It involved following functions: UpdateDataInTable (), ReceiveMessage ().

```

1. while Wi-Fi status is connected && users don not click stop button
2. Do
3.     UpdateDataInTable () //this method comes from SendCommand class
4.     Create timer
5.     Set timer to priority to main
6.     Timer:
7.         Read data from local database
8.         Analyze and compute data to get other data
9.         Show data in table view
10.        Reload table
11.    If users click stop button
12.        Alert ("Save trip information? Yes: No")
13.        If users select yes
14.            Save those data and date in new trip table in local database
15.            Go back main screen
16.
17. UpdateDataInTable () {
18.     Create timer
19.     Set timer priority to background
20.     Use Session class
21.     Timer:
22.         Get supported commands from local database
23.         Session send supported commands
24.         ReceiveMessage ()
25. }
26.
27. ReceiveMessage () {
28.     Set message to receive message
29.     Use regular expression to deal with message
30.     Analyze message and get corresponding value // value represents vehicle data
31.     Store that value in local database
32. }

```

5.6 Health scan module

This part used pseudocode to describe how to read fault codes from a vehicle and show corresponding diagnostic information to users. It involved following functions: SendDiagnosticCode (), ReceiveMessage ().

```

1. // this method will be executed automatically when users go to health scan screen
2. StartChecking () {
3.     SenDiagnosticCode ()
4.     Set timer to priority to main
5.     Timer:
6.         If timer ends
7.             Read diagnostic information and code from local database
8.             Show diagnostic information and code in table view
9.             Show rediagnostic button
10.        If users click rediagnostic button
11.            Set rediagnostic button and table view to hidden
12.            StartChecking ()
13.        Else
14.            Update UI to let users wait for scanning
15. }
16.
17. SenDiagnosticCode () {
18.     Create timer
19.     Set backgroundTimer to priority to background
20.     backgroundTimer:
21.         Session send diagnostic commands
22.         ReveiveMessage ()
23. }
24.
25. ReveiveMessage () {
26.     Set message to receive message
27.     Use regular expression to deal with message
28.     Analyze message and get corresponding value//value is diagnostic code
29.     Search diagnostic information in fault code table based on diagnostic code
30.     Store diagnostic information and diagnostic code in local database
31. }

```

6. Testing

Software development always involves software testing which is the process of evaluating correctness, integrity and quality of the software. In the other word, software testing is the process of fixing bugs to satisfy user requirements. Software is usually planned earlier and it is performed only after coding. This section will talk about each phrase in software testing in detail.

6.1 Testing plan

In unit testing, testing strategy is to test server side and client side separately. For server side, it will use Postman to send different kinds of requests and check response. After bugs fixed in server side, it will use UI testing in Xcode to test each individual user interface. Compared to other UI testing framework, the major benefit of UI testing in Xcode is that it can record developers' operations to the system. In the other words, developers can perform all kinds of operations in each user interface to test all kinds of situations and then UI testing will memorize those operations and transfer them into testing codes which can be executed automatically. In a word, UI testing in Xcode is a kind of scene simulation and can bring lots of convenience to testers. Integration testing will also use UI testing in Xcode to testing the whole system including server side and client side. As for system testing, it will mainly test data accuracy. A tester will use this application to record plenty of data. Another tester will use recording functions in the car to get plenty of data. Then a tester will use graphs to make comparisons and then get conclusions.

6.2 Unit testing

6.2.1 Testing for server module

This part is responsible for testing different requests which are sent from the client side to the server side. Test cases are generated based on requests which have been used in the application. Other types of requests will not be taken into consideration. Table 8

shows details of each test case. Scenario indicates the testing environment. URL represented all kinds of requests occurred in the application. Return value is message from the server side. Status indicates whether the test case passed or not.

Test case #	Scenario	URL	Return value	Status
1	User table has this account	138.49.101.87:9000/userSettings/wang.dezheng@uwlax.edu Method: GET	All user information related to username 'wang.dezheng@uwlax.edu'	Passed
2	User table doesn't have this account	138.49.101.87:9000/userSettings/wang.dezheng@uwlax.edu Method: GET	[]	Passed
3	Trip table has this trip	138.49.101.87:9000/tripInfo/1 Method: GET	All trip information related to userID '1'	Passed
4	Trip table doesn't have this trip	138.49.101.87:9000/tripInfo/1 Method: GET	[]	Passed
5	Add a new user to user table	138.49.101.87:9000/userInfo requestBody: {username: yuan.zhihao@uwlax.edu , password :123} Method: POST	'true'	Passed
6	Add an existed user to user table	138.49.101.87:9000/userInfo requestBody: {username: yuan.zhihao@uwlax.edu , password :123} Method: POST	'false'	Passed

7	Add a new trip to trip table	138.49.101.87:9000/tripInfo requestBody: {trip information} Method: POST	'true'	Passed
8	Update a user's information	138.49.101.87:9000/userInfo requestBody: {updated user information} Method: PUT	'true'	Passed

Table 8. Test cases for the server side

6.2.2 Testing for client module

Testing for client module will be divided into five parts. The first part is to test the session module which is responsible for sending commands and receiving messages from the car. The second part is to test login module. The third part is to test registration module. The fourth part is to test resetting password function. The last part is to test searching history trips module.

Table 9 shows all test cases for testing session module. Test cases are generated based on those OBD-PIDs which have been used in this application. Each test case has three kinds of return messages and all three are right. The reason why one OBD-II PID has three return values is that the frequency of the system receiving messages will have influence on message sent by the OBD-II system. Some message cannot be sent during that time interval and it will be sent during next time interval.

Test case #	Scenario	Command	Return message	Status
9	To get supported PIDs from 0101-0120	0100	"0100\r"	Passed
		0100	"41 00 BF 9F A8 93 \r\r>"	Passed
		0100	"0100\r 41 00 BF 9F A8 93 \r\r>"	Passed

10	To get supported PIDs from 0121-0140	0120	“0120\r”	Passed
		0120	“41 20 80 07 F1 19 \r\r>”	Passed
		0120	“0120\r 41 20 80 07 F1 19 \r\r>”	Passed
11	To get supported PIDs from 0141-0160	0140	“0140\r”	Passed
		0140	“41 40 FE F0 00 00 \r\r>”	Passed
		0140	“0140\r 41 40 FE F0 00 00 \r\r>”	Passed
12	To get engine coolant temperature	0105	“0105\r”	Passed
		0105	“41 05 88 \r\r>”	Passed
		0105	“0105\r 41 05 88 \r\r>”	Passed
13	To get engine RPM	010C	“010C\r”	Passed
		010C	“41 0C 09 92 \r\r>”	Passed
		010C	“010C\r 41 0C 09 92 \r\r>”	Passed
14	To get vehicle speed	010D	“010D\r”	Passed
		010D	“41 0D 00 \r\r>”	Passed
		010D	“010D\r 41 0D 00 \r\r>”	Passed
15	To get MAF air flow rate	0110	“0110\r”	Passed
		0110	“41 10 01 1B \r\r>”	Passed
		0110	“0110\r 41 10 01 1B \r\r>”	Passed
16	To get control module voltage	0142	“0142\r”	Passed
		0142	“41 42 36 41 \r\r>”	Passed
		0142	“0142\r 41 42 36 41 \r\r>”	Passed

Table 9. Test cases for session module

Testing for registration module will use UI testing form Xcode. Firstly, it will try to register for an existed account to see if the system will give error message. Then it will use a new username. It will try to have inconsistent passwords in password field and

confirm password field to see if the system will give error message. Then it will use consistent password to register for a new account. Following codes are testing codes for registration module.

```
1. -(void)testRegisterFunction {
2.     XCUIApplication *app = [[XCUIApplication alloc] init];
3.     [app.buttons[@"Register"] tap];
4.     XCUIElement *emailAddressTextField = app.textFields[@"Email address"];
5.     [emailAddressTextField tap];
6.     [emailAddressTextField typeText:@"793013053@qq.com"];
7.     XCTAssert(app.staticTexts[@"Sorry, this email had been used!"].exists);
8.
9.     [app.buttons[@"Clear text"] tap];
10.    [emailAddressTextField typeText:@"w793013053@gmail.com"];
11.    XCTAssert(!app.staticTexts[@"Sorry, this email had been used!"].exists);
12.
13.    XCUIElement *passwordSecureTextField = app.secureTextFields[@"Password"];
14.    [passwordSecureTextField tap];
15.    [passwordSecureTextField typeText:@"123"];
16.    XCUIElement *confirmPasswordSecureTextField = app.secureTextFields[@"Confirm
password"];
17.    [confirmPasswordSecureTextField tap];
18.    [confirmPasswordSecureTextField typeText:@"12"];
19.    XCUIElement *submitButton = app.buttons[@"Submit"];
20.    [submitButton tap];
21.    XCTAssert(app.alerts[@"Error!"].exists);
22.
23.    [app.alerts[@"Error!"].buttons[@"OK"] tap];
24.    [confirmPasswordSecureTextField tap];
25.    [confirmPasswordSecureTextField typeText:@"123"];
26.    [submitButton tap];
27.    XCTAssert(app.alerts[@"Register Succeed"].exists);
28.    [app.alerts[@"Register Succeed"].buttons[@"OK"] tap];
29. }
```

Testing for login module will also use UI testing. Firstly, it will try to login with correct username and incorrect password to see if the system will give error message. Then it will incorrect username and correct password to see if the system will give error message. Finally, it will use correct username and password to login.

```
1. -(void) testLoginFunction{
2.     XCUIApplication *app = [[XCUIApplication alloc] init];
3.     XCUIElement *emailAddressTextField = app.textFields[@"Email address"];
4.     [emailAddressTextField tap];
5.     [emailAddressTextField typeText:@"w793013053@gmail.com"];
6.
7.     XCUIElement *passwordSecureTextField = app.secureTextFields[@"Password"];
8.     [passwordSecureTextField tap];
9.     [passwordSecureTextField typeText:@"123456"];
10.    XCUIElement *loginButton = app.buttons[@"Login"];
```

```

11.     [loginButton tap];
12.     XCTAssert(app.staticTexts[@"Incorrect username or password"].exists);
13.
14.     [emailAddressTextField tap];
15.     [app.buttons[@"Clear text"] tap];
16.     [passwordSecureTextField tap];
17.     [app.buttons[@"Clear text"] tap];
18.     [loginButton tap];
19.     XCTAssert(app.staticTexts[@"Incorrect username or password"].exists);
20.
21.     [emailAddressTextField tap];
22.     [emailAddressTextField typeText:@"w7930130533@gmail.com"];
23.     [passwordSecureTextField tap];
24.     [passwordSecureTextField typeText:@"123"];
25.     [loginButton tap];
26.     XCTAssert(app.staticTexts[@"Incorrect username or password"].exists);
27.
28.     [emailAddressTextField tap];
29.     [app.buttons[@"Clear text"] tap];
30.     [emailAddressTextField typeText:@"w793013053@gmail.com"];
31.     [passwordSecureTextField tap];
32.     [app.buttons[@"Clear text"] tap];
33.     [passwordSecureTextField typeText:@"123"];
34.     [loginButton tap];
35.
36.     XCTAssert(!emailAddressTextField.exists);
37.     XCTAssert(!passwordSecureTextField.exists);
38.     XCTAssert(!loginButton.exists);
39.     XCTAssert(!app.buttons[@"Register"].exists);
40.     XCTAssert(!app.staticTexts[@"Incorrect username or password"].exists);
41. }

```

Testing for resetting password module will also use UI testing in. Firstly, it will try to enter wrong username to see if the system will give error message. Then it will click reset button without having any username to see if the system will crash. Finally, it will enter correct username and click reset button. The tester should also check the email to ensure new password has been sent. The new password should be same with password value stored in database.

```

1. -(void)testForgetPasswordFunction{
2.     XCUIApplication *app = [[XCUIApplication alloc] init];
3.     [app.buttons[@"Help"] tap];
4.     XCUIElement *emailTextField = app.textFields[@"Email address"];
5.     XCTAssert(emailTextField.exists);
6.
7.     [emailTextField tap];
8.     [emailTextField typeText:@"w7930130533@gmail.com"];
9.     XCUIElement *resetButton = app.buttons[@"Reset"];
10.    [resetButton tap];
11.    XCTAssert(app.alerts[@"Error!"].exists);
12.

```

```

13.     XCUIElement *okButton = app.alerts[@"Error!"].buttons[@"OK"];
14.     [okButton tap];
15.     XCUIElement *clearTextButton = app.buttons[@"Clear text"];
16.     [clearTextButton tap];
17.     [resetButton tap];
18.
19.     XCTAssert(app.alerts[@"Error!"].exists);
20.     [okButton tap];
21.     [emailTextField typeText:@"w793013053@gmail.com"];
22.     [resetButton tap];
23.
24.     XCTAssert(!resetButton.exists);
25. }

```

Testing for resetting connection module will also use UI testing in. Firstly, it will login. Secondly, it will go the connection screen. Thirdly, it will plug the OBD-II scanner in. Finally, it will connect to scanner's Wi-Fi and users can start recording trip information.

```

1.  XCUIApplication *app = [[XCUIApplication alloc] init];
2.  XCUIElement *emailAddressTextField = app.textFields[@"Email address"];
3.  [emailAddressTextField tap];
4.  [emailAddressTextField typeText:@"w793013053@gmail.com"];
5.
6.  XCUIElement *passwordSecureTextField = app.secureTextFields[@"Password"];
7.  [passwordSecureTextField tap];
8.  [passwordSecureTextField typeText:@"123"];
9.  [app.buttons[@"Login"] tap];
10. [app.navigationBar[@"Riding Mechanic"].buttons[@"Wi Fi"] tap];
11. [app.buttons[@"Device plugged please scan now"] tap];
12. [app.buttons[@"Yes, Wifi conneted"] tap];
13.
14. XCTAssert(app.buttons[@"Start Trip"].exists);

```

Testing for starting trip module will also use UI testing in. Firstly, it will connect login and connect to OBD-II scanner's Wi-Fi. Secondly, it will use star trip function to read data from the car and show vehicle information. Finally, it will stop recording and choose to save trip information.

```

1.  XCUIApplication *app = [[XCUIApplication alloc] init];
2.  XCUIElement *emailAddressTextField = app.textFields[@"Email address"];
3.  [emailAddressTextField tap];
4.  [emailAddressTextField typeText:@"w793013053@gmail.com"];
5.
6.  XCUIElement *passwordSecureTextField = app.secureTextFields[@"Password"];
7.  [passwordSecureTextField tap];
8.  [passwordSecureTextField typeText:@"123"];
9.  [app.buttons[@"Login"] tap];
10. [app.navigationBar[@"Riding Mechanic"].buttons[@"Wi Fi"] tap];

```

```

11. [app.buttons[@"Device plugged please scan now"] tap];
12. [app.buttons[@"Yes, Wifi conneted"] tap];
13. [app.buttons[@"Start Trip"] tap];
14.
15. XCUIElementQuery *tablesQuery = app.tables;
16. [tablesQuery.staticTexts[@"Driving Distance"] tap];
17. [tablesQuery.staticTexts[@"Realtime MPG"] tap];
18. [tablesQuery.staticTexts[@"Total Fuel Consumption"] tap];
19. [tablesQuery.staticTexts[@"Fuel Cost"] tap];
20. [tablesQuery.staticTexts[@"Sharp Braking"] tap];
21. [app.navigationBars[@"Trip Information"].buttons[@"Stop"] tap];
22. [app.alerts[@"Do you want to store trip information?"].buttons[@"YES"] tap];

```

Testing for trip analysis module will also use UI testing in. Firstly, it will connect login and go to analysis screen. Then, it will show trip information based on current date. Finally, it will select different date to search trip information.

```

1. XCUIApplication *app = [[XCUIApplication alloc] init];
2. XCUIElement *emailAddressTextField = app.textFields[@"Email address"];
3. [emailAddressTextField tap];
4. [emailAddressTextField typeText:@"w793013053@gmail.com"];
5.
6. XCUIElement *passwordSecureTextField = app.secureTextFields[@"Password"];
7. [passwordSecureTextField tap];
8. [passwordSecureTextField typeText:@"123"];
9. [app.buttons[@"Login"] tap];
10.
11. XCUIElementQuery *tabBarsQuery = app.tabBars;
12. [tabBarsQuery.buttons[@"analysis"] tap];
13.
14. XCUIApplication *app2 = app;
15. [app2.buttons[@"8"] tap];
16. [app2.buttons[@"10"] swipeRight];
17. [app2.buttons[@"7"] tap];
18. [app2.buttons[@"6"] tap];
19. [app2.buttons[@"5"] tap];
20. [app2.buttons[@"4"] tap];
21. [app2.buttons[@"3"] tap];
22. [app2.buttons[@"2"] tap];
23. [app2.buttons[@"1"] tap];
24. [tabBarsQuery.buttons[@"More"] tap];
25. [app2.tables.staticTexts[@"Account"] tap];
26. [app2.tables.buttons[@"Log Out"] tap];
27. [app.alerts[@"Log Out Succeed!"].buttons[@"Ok"] tap];

```

Testing for more module will also use UI testing. Firstly, it will connect login and go to more screen. Secondly, it will go to speed alert screen to change speed limit. Thirdly, it will go to tire driving screen to change tired driving limit.

Fourthly, it will go to engine coolant temperature screen to change coolant temperature limit. Fifthly, it will go to vehicle screen to change fuel price. Sixthly, it will go to adapter screen and about screen to view detailed information. Finally, it will use function of changing password and function of logout.

```

1. XCUIApplication *app = [[XCUIApplication alloc] init];
2. XCUIElement *emailAddressTextField = app.textFields[@"Email address"];
3. [emailAddressTextField tap];
4. [emailAddressTextField typeText:@"w793013053@gmail.com"];
5.
6. XCUIElement *passwordSecureTextField = app.secureTextFields[@"Password"];
7. [passwordSecureTextField tap];
8. [passwordSecureTextField typeText:@"123"];
9. [app.buttons[@"Login"] tap];
10. [app.tabBars.buttons[@"More"] tap];
11.
12. XCUIElementQuery *tablesQuery2 = app.tables;
13. XCUIElementQuery *tablesQuery = tablesQuery2;
14. [tablesQuery.staticTexts[@"Alert"] tap];
15. [tablesQuery.switches[@"Alert"] tap];
16. [tablesQuery.switches[@"Alert"] tap];
17. [tablesQuery.staticTexts[@"Speed Alert"] tap];
18. [tablesQuery.switches[@"Speed Alert"] tap];
19. [tablesQuery.switches[@"Speed Alert"] tap];
20.
21. XCUIElement *textField = [[tablesQuery2.cells containingType:XCUIElementTypeStaticText identifier:@"Speed Limit"] childrenMatchingType:XCUIElementTypeTextField].element;
22. [textField tap];
23. [textField typeText:@"80"];
24. [app.navigationBars[@"Speed Alert"].buttons[@"Alert"] tap];
25.
26. XCUIElement *tiredDrivingAlertStaticText = tablesQuery.staticTexts[@"Tired Driving Alert"];
27. [tiredDrivingAlertStaticText tap];
28. [tablesQuery.switches[@"Tired Driving Alert"] tap];
29. [tablesQuery.switches[@"Tired Driving Alert"] tap];
30.
31. XCUIElement *textField2 = [[tablesQuery2.cells containingType:XCUIElementTypeStaticText identifier:@"Tired Driving Hour Limit"] childrenMatchingType:XCUIElementTypeTextField].element;
32. [textField2 tap];
33. [textField2 typeText:@"4"];
34.
35. XCUIElement *alertButton = app.navigationBars[@"Tired Driving Alert"].buttons[@"Alert"];
36. [alertButton tap];
37. [tiredDrivingAlertStaticText tap];
38. [alertButton tap];
39. [tablesQuery.staticTexts[@"Water Temperature Alert"] tap];
40. [tablesQuery.switches[@"Water Temperature Alert"] tap];
41. [tablesQuery.switches[@"Water Temperature Alert"] tap];
42.

```

```

43. XCUIElement *textField3 = [[tablesQuery2.cells containingType:XCUIElementTypeStaticText identifier:@"Water Temperature Limit"] childrenMatchingType:XCUIElementTypeTextField].element;
44. [textField3 tap];
45. [textField3 typeText:@"220"];
46. [app.navigationBars[@"Water Temperature Alert"].buttons[@"Alert"] tap];
47. [app.navigationBars[@"Alert"].buttons[@"More"] tap];
48.
49. XCUIElement *vehicleStaticText = tablesQuery.staticTexts[@"Vehicle"];
50. [vehicleStaticText tap];
51.
52. XCUIElement *textField4 = [tablesQuery2.cells childrenMatchingType:XCUIElementTypeTextField].element;
53. [textField4 tap];
54. [textField4 typeText:@"2.35"];
55.
56. XCUIElement *moreButton = app.navigationBars[@"Vehicle"].buttons[@"More"];
57. [moreButton tap];
58. [vehicleStaticText tap];
59. [moreButton tap];
60. [tablesQuery.staticTexts[@"Adapter"] tap];
61. [app.navigationBars[@"Connectivity"].buttons[@"More"] tap];
62. [tablesQuery.staticTexts[@"Unit"] tap];
63. [app.navigationBars[@"Unit"].buttons[@"More"] tap];
64. [tablesQuery.staticTexts[@"About"] tap];
65. [app.navigationBars[@"About"].buttons[@"More"] tap];
66. [tablesQuery.staticTexts[@"Account"] tap];
67. [tablesQuery.staticTexts[@"Reset Password"] tap];
68.
69. XCUIElement *currentPasswordSecureTextField = app.secureTextFields[@"Current password"];
70. [currentPasswordSecureTextField tap];
71. [currentPasswordSecureTextField typeText:@"123"];
72.
73. XCUIElement *newPasswordSecureTextField = app.secureTextFields[@"New password"];
74. [newPasswordSecureTextField tap];
75. [newPasswordSecureTextField tap];
76. [newPasswordSecureTextField typeText:@"111"];
77.
78. XCUIElement *confirmNewPasswordSecureTextField = app.secureTextFields[@"Confirm new password"];
79. [confirmNewPasswordSecureTextField tap];
80. [confirmNewPasswordSecureTextField tap];
81. [confirmNewPasswordSecureTextField typeText:@"111"];
82. [app.buttons[@"Submit"] tap];
83. [app.alerts[@"Password change succeed"].buttons[@"OK"] tap];
84. [tablesQuery.buttons[@"Log Out"] tap];
85. [app.alerts[@"Log Out Succeed!"].buttons[@"Ok"] tap];

```

Testing for health scan module will also use UI testing. Firstly, it will connect login and go to health scan screen. The system will show diagnostic information when the screen is loaded. Finally, it will use re-diagnosis function to get newest diagnostic information from the vehicle.

```

1. XCUIApplication *app = [[XCUIApplication alloc] init];
2. XCUIElement *emailAddressTextField = app.textFields[@"Email address"];
3. [emailAddressTextField tap];
4. [emailAddressTextField typeText:@"w793013053@gmail.com"];
5.
6. XCUIElement *passwordSecureTextField = app.secureTextFields[@"Password"];
7. [passwordSecureTextField tap];
8. [passwordSecureTextField typeText:@"123"];
9. [app.buttons[@"Login"] tap];
10. [app.tabBars.buttons[@"scan"] tap];
11. [app.buttons[@"Rediagnosis"] tap];

```

6.2.3 Code coverage

UI testing from Xcode also provides users with testing code coverage. Figure 20 has shown the testing code coverage from Xcode. As it indicated in the figure, some classes are not covered. The reason that they have little testing code coverage is some classes are external classes or from third-party library which has lots of functions. But only one or two functions will be used for this application among those functions.






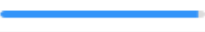

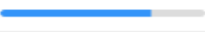

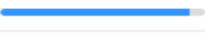

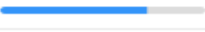

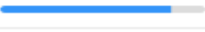



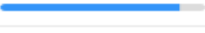

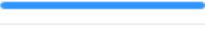

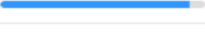

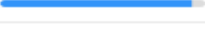

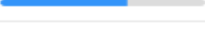

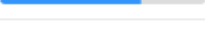

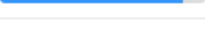

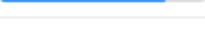





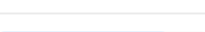

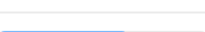

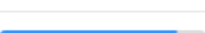

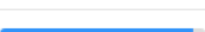

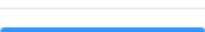

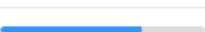

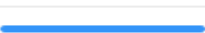

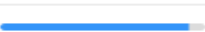

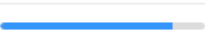

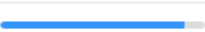

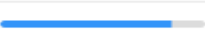
















Name	Coverage
▼  RidingMechanic.app	
▶  WaterTemperatureAlertTableViewCell.m	
▶  LoginViewController.m	
▶  ResetPasswordViewController.m	
▶  RestAPI.m	
▶  SetInitialStatus.m	
▶  CarModelViewController.m	
▶  AboutViewController.m	
▶  ConnectivityTableViewCell.m	
▶  AlertTableViewCell.m	
▶  AccountTableViewCell.m	
▶  ForgetPasswordViewController.m	
▶  Reachability.m	
▶  UnitTableViewCell.m	
▶  AlertTableViewController.m	
▶  SpeedAlertTableViewCell.m	
▶  AppDelegate.m	
▶  ASDayPicker.m	
▶  AnalysisViewController.m	
▶  TiredDrivingAlertTableViewCell.m	
▶  HealthScanViewController.m	
▶  SendCommand.m	
▶  SettingsTableViewCell.m	
▶  ShowTripInfoTableViewCell.m	
▶  ConnectionViewController.m	
▶  main.m	
▶  RegisterViewController.m	
▶  VehicleTableViewCell.m	
▶  Session.m	
▶  MenuViewController.m	
▶  RecvMessageAnalysis.m	
▶  HcdProcessView.m	
▶  Base64Transcoder.m	
▶  HSK_CFUtilities.m	
▶  NSData+Base64Additions.m	
▶  NSStream+SKPSMTPExtensions.m	
▶  SKPSMTPMessage.m	

Figure 20. Code coverage

6.3 Integration testing

As mentioned above, this application should be used along with an OBD-II W-Fi scanner connected to the OBD-II port on the car. So, integration testing is performed while the tester is driving. As previously mentioned, this application can read real-time data from a car. Reading real-time data is the core part of this project and it will involve most modules of this application. So, integration testing will focus on data comparison between data from the application and data from the car. Table 10 uses those recorded data to compute the margin of error.

Driving distance recorded by the app (mile)	Driving distance recorded by the car (mile)	Margin of error (%)
0.00	0.0	0%
0.20	0.2	0%
0.82	0.8	2.5%
1.42	1.4	1.4%
1.67	1.7	1.7%
1.91	1.9	0.5%
2.39	2.4	0.4%
3.34	3.3	1.2%
3.78	3.8	0.5%
4.22	4.2	0.4%
5.07	5.1	0.5%
6.54	6.5	0.6%
11.56	12.0	0.3%
25.44	25.5	0.2%
28.64	28.7	0.2%
Geometric Mean		0.9%

Table 10. Data comparison and margin of error

Figure 20 shows those data in coordinate system. Green points are consisted of those two kinds of data. X value is data recorded by the app and Y value represented data recorded by the car. The orange line represented $Y=X$.

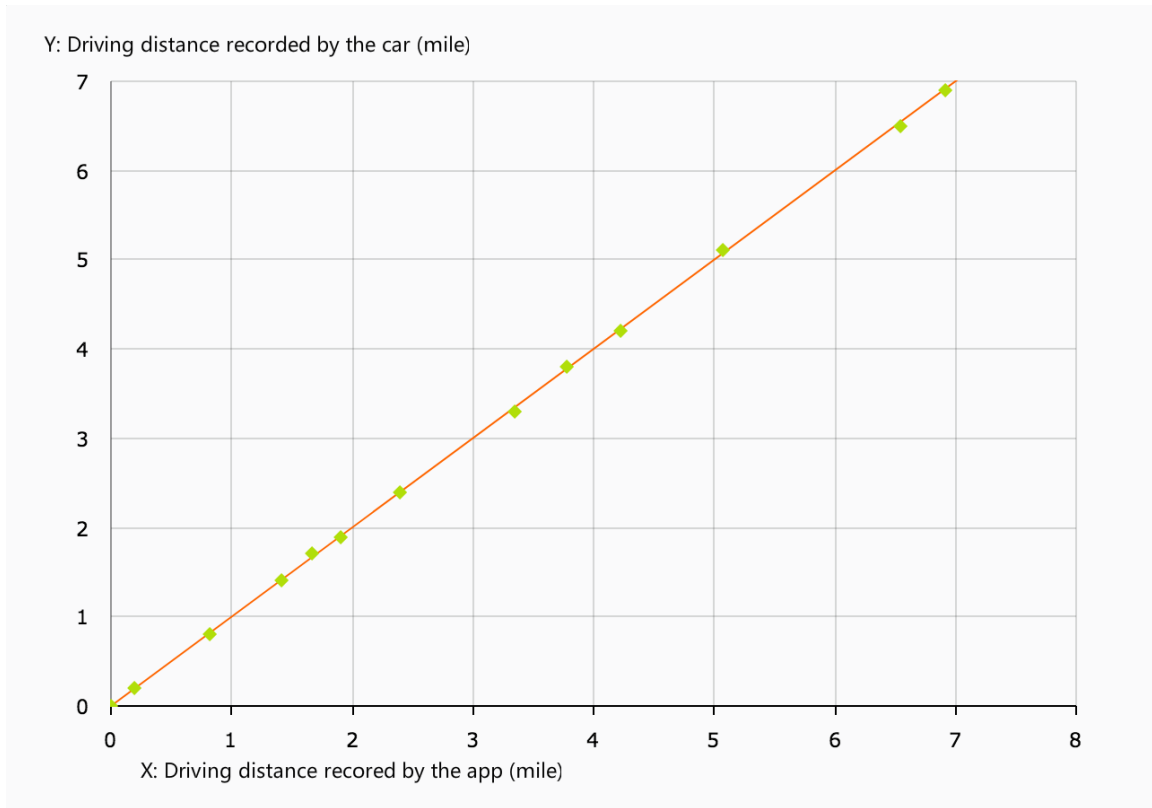


Figure 21. data comparison in coordinate system

6.4 System testing

System testing will focus on if the application satisfied users' requirements. Table 11 gives comparisons between required functions from users and functions in this application.

A user want to do (during a journey)	Application	Status
A user want to use an application to connect to a car	The app can help to build connection between the user and the car	Completed

A user want to get how long he had been driving	The app can provide the user with driving time	Completed
A user want to get specific speed	The app can provide the user with specific speed value	Completed
A user want to get specific RPM	The app can provide the user with specific RPM value	Completed
A user want to get average speed	The app can provide the user with average speed value	Completed
A user want to get fuel consumption	The app can provide the user with fuel consumption	Completed
A user want to get fuel cost	The app can provide the user with fuel cost	Completed
A user want to get engine coolant temperature	The app can provide the user with engine coolant temperature	Completed
A user want to get control module voltage	The app can provide the user with control module voltage	Completed
A user want to get sharp acceleration times	The app can provide the user with sharp acceleration times	Completed
A user want to get sharp braking times	The app can provide the user with sharp braking times	Completed
A user want to save related information of a journey	The app allows the user to register for an account to save related information of a journey	Completed
A user want to search journey information of specific date	The app allows the user to search journey information of that date	Completed
A user want to get diagnostic information of the car	The app can provide users with the car's diagnostic information	Completed
A user want to set an alert for over speed	The app allows the user to set up speed limit	Completed

A user want to set an alert for engine being overheated	The app allows the user to set up engine coolant temperature limit	Completed
A user want to set an alert for control module voltage being abnormal	The app allows the user to set up control module voltage limit	Completed
A user want to change measurement of unit	The app allows the user to change measurement of unit	Completed

Table 11. Achievements of requirements

7. Conclusion and Future Work

7.1 Conclusions

The overriding achievement of this thesis is use of software engineering in mobile application design. It has shown the process of analyzing user requirements, designing system architecture, constructing the whole system, implementation and testing final product which will be used by end users.

- Chapter 2 shows how to analyze users' requirements from different perspective. Functions that can be performed by users are described in detail in functional requirements. Non-functional requirements are related to system qualities.
- Chapter 3 describes both goals and constraints of system architecture design. Then it gives an overview of what the application will look like when it is completed. It also pointed out some key issues and its solutions.
- Chapter 4 presents detailed system design including database table design and use of UML diagrams to analyze user scenarios, relationship between classes and interactions between each component in the system.
- Chapter 6 shows implementation of main functions. It uses advantages of pseudocode to make logic of each process clear.
- Chapter 7 presents testing strategies and how they are used in testing. It also shows the process of testing and testing data included in each kind of testing.

Although this product has been tested for many times, there are some defects in it. User interfaces does not look very nice and does not have any appropriate message while loading data from server database. The screen does not look very fluent while logging out. Users can not select their own vehicles and find out some manufacture-defined fault codes.

7.2 Future Work

As mentioned above, there exists some weaknesses in the final product. The first thing of future work is to overcome those shortcomings. In addition, user interface can be resigned and colored to give better user experience. More data can be worked out to provide more vehicle information for users. For example, giving total idle time during a route. Because this product only provides universal diagnostic information, some manufacturer-specific codes cannot be recognized. The database can gather more information for both universal diagnostic codes and manufacturer-specific codes. It should also classify those codes. Users should have choices to select model type of their vehicles and then database can provide corresponding diagnostic codes. In a word, this application still has lots of work to do to become a real product.

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Appendices