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An Automatic Number Plate Recognition System for Car Park Management

Mutua Simon Mandi

**Submitted in partial fulfillment of the requirements for the Degree of Master of Science in
Mobile Telecommunications and Innovation at Strathmore University**



Nairobi, Kenya

June, 2016

Declaration

I declare that this work has not been previously submitted and approved by Strathmore University or any other University. To the best of my knowledge and belief, the dissertation contains no material previously published or written by another person except where due reference is made in the dissertation itself.

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Abstract

With an increased number of motor vehicles on the Kenyan roads, there is need for a vehicle identification mechanism that is effective as well as timely. Automatic Number Plate Recognition (ANPR) is an internationally recognized methodology that is used in vehicle identification. ANPR systems allow for real time recognition of a vehicle's number plate. Vehicle parking is an important component within any transportation system, whereby vehicles must be parked at every destination. Most vehicles are parked most of the time during the day. There has been a problem with the car park entry registration process for visitor/staff/student entering the Strathmore University. The problem involves a security guard having to confirm membership details by checking for membership sticker on the windscreen of the vehicle or by checking the driver's identification card. The security guard has then to record by writing onto an occurrence book the vehicle details include vehicle number plate, color, model, entry/exit timings as well as the ticket number assigned to the vehicle. This process of writing is tedious and time consuming and is also prone to inaccurate recordings, furthermore the backup and sharing of this vehicle information is difficult because the data is hard copy. This dissertation has its basis on the adoption of software solution operating on a mobile device that has ANPR capabilities to aid in vehicle identification and vehicle registration. The software application that was developed adopted an object oriented analysis and design methodology, the software developed implements Optical Character Recognition (OCR) using the mobile device camera to detect and capture the vehicle number plate. This resulted in the elimination of the pen and paper that were required in the registration process and introduced a faster electronic means of vehicle identification and vehicle registration as well as an easier means of vehicle data storage and vehicle data sharing.

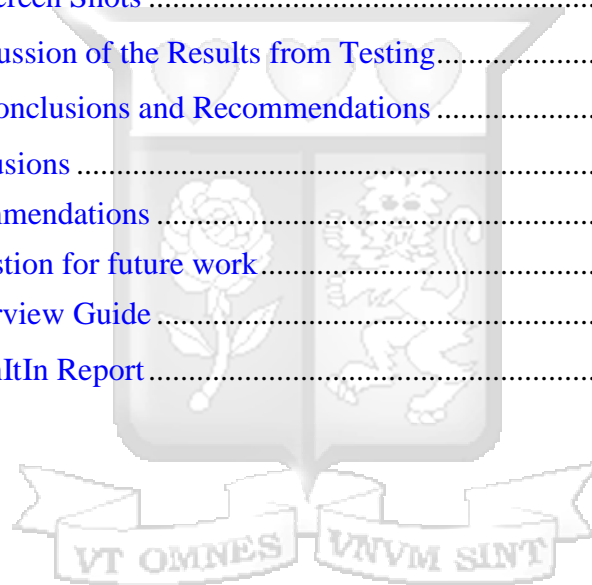
Keywords: ANPR (Automatic Number Plate Recognition), Car, Hard Copy, Vehicle, Parking, Number Plate, Optical Character Recognition,

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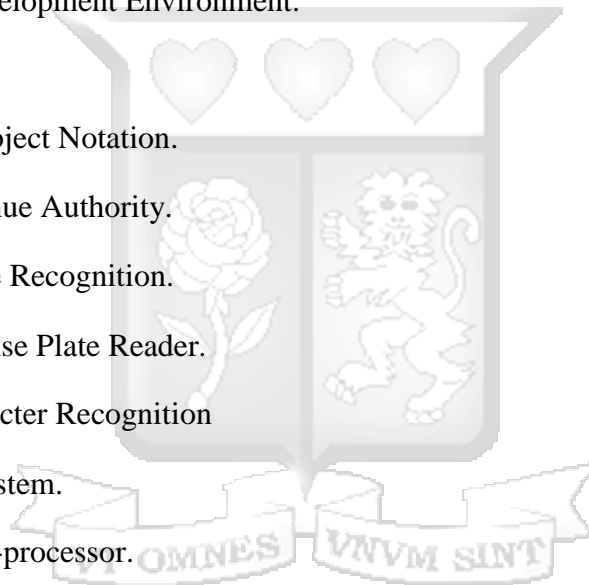
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Abbreviations/ Acronyms

- ALPR** – Automatic License Plate Reader.
- ANPR** – Automatic Number Plate Recognition System.
- ASCII** – American Standard Code for Information Interchange.
- AVI** – Automatic Vehicle Identification.
- CPR** – Car Plate Recognition.
- HTML** – Hyper Text Markup Language.
- IDE** – Integrated Development Environment.
- IR** – Infrared.
- JSON** – JavaScript Object Notation.
- KRA** – Kenya Revenue Authority.
- LPR** – License Plate Recognition.
- MLPR** – Mobile License Plate Reader.
- OCR** – Optical Character Recognition
- OS** – Operating System.
- PHP** – Hypertext Pre-processor.
- UML** – Unified Modeling Language.
- WLAN** – Wireless Local Area Network.



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Acknowledgments

I thank God for His endless favor my parents and family for their support, encouragement and belief in me.

I am thankful to Safaricom Organization for their scholarship program in partnership with Strathmore University and for awarding me the scholarship to undertake this course.

I thank my colleagues and lectures with whom I interacted with during this course.

Last but not least I thank my supervisor for the assistance he has given me in carrying out my research.



Chapter One: Introduction

1.1 Background

Parking is an important component within any transportation system, whereby vehicles must be parked at every destination. Most vehicles are parked most of the time during the day. Parking convenience is the ease of accessing a safe and preferable parking position, hence affecting the ease of reaching destinations (Litman, 2013; Subramani, 2012).

Automatic number plate recognition (ANPR) is a mass surveillance method that was first developed in 1976 at the Police Scientific Development Branch in the United Kingdom with aim of combating crime. ANPR is a process where vehicles are identified or recognized using their number plate or license plate. ANPR uses image processing techniques in order to extract the vehicle number plate from digital images (Cornwall, 2009).

Roberts and Casanova (2012) stated that ANPR systems generally comprises of a camera; processor and application capable of performing sophisticated optical character recognition (OCR) to transform the image of the plate into alphanumeric characters; application software to compare the transformed license plate characters to databases of license plates of interest to law enforcement; and a user interface to display the images captured, the results of the OCR transformation, and an alert capability to notify operators when a plate matching an agency's wanted list is observed.

ANPR is sometimes known by various other terms such as automatic license plate recognition (ALPR), automatic license plate reader (ALPR), automatic vehicle identification (AVI), car plate recognition (CPR), license plate recognition (LPR), or mobile license plate reader (MLPR) (Automatic number plate recognition, 2015).

A license plate recognition system generally works in four main parts namely image acquisition, license plate recognition/detection, character segmentation, and lastly character recognition (Lotufo, Morgan & Johnson, 2013).

First is the image acquisition stage the image of the vehicle is captured using a photographic camera. The constraint is that the image of the vehicle should be captured in such a way that the

selected input image contains rear or front view of the vehicle with the number plate (Reshma, 2012).

The next stage that follows is the license plate recognition phase that does several functions such as resizing of the image to a feasible aspect ratio. The colored image is then converted into a grey scale image (Reshma, 2012).

Then character segmentation takes place whereby this process can be defined as a technique, which partitions images of lines or words into individual characters. It is an operation that seeks to decompose an image of a sequence of character into sub images of individual symbols (Kumar & Singh, 2011).

Character recognition is the last stage in an ANPR system. Character recognition can be described as the process of detecting and recognizing characters from input image and converting it into alphanumeric characters or other equivalent machine editable form (Shah & Jethava, 2013).

Successful implementations of ANPR systems have resulted in faster and easier vehicle identification, this has also resulted in faster and easier search and retrieval of vehicle information mostly done the law enforcers in identifying vehicles that are uninsured, stolen, or driven by someone without a license or prohibited from driving. It is also used by law enforcement to control access to restricted areas, to patrol international borders, and, in some parts of the world, as a counter-terrorist measure (ACPO, 2013).

1.2 Problem Statement

With the rising number of vehicles, it is getting difficult to effectively manage vehicles. The vital question here is how to find a particular vehicle? The obvious response to this question is by using the vehicle's number plate (Gaikwad, Samhita & Borole, 2014). Similarly there is a need to identify all vehicles entering and exiting Strathmore University currently, the ongoing vehicle entry registration process for visitor/staff/student entering the Institution involves a security guard having to confirm membership details by checking for membership sticker on the windscreen of the vehicle or by checking the driver's identification card. The security guard has then to record by writing onto an occurrence book the vehicle details such as vehicle number plate, color, model, entry/exit timings as well as the ticket number assigned to the vehicle. This process of writing is

tedious and time consuming and is also prone to inaccurate recordings, furthermore the backup and sharing of this vehicle information is difficult because the data is hard copy.

The proposed solution to the challenges in the vehicle entry registration process is an automatic number plate recognition system that can operate on a handheld device that allows the easy member identification as well a convenient means of data collection and data storage.

1.3 Research Objectives

- i. To investigate the automatic number plate recognition methodologies.
- ii. To design for vehicle entry registration process using mobile phone technology.
- iii. To develop an automatic number plate recognition system for car park management.
- iv. To test the functionality of the automatic number plate recognition system.

1.4 Research Questions

- i. What are the requirements needed in implementing an automatic number plate recognition system?
- ii. How can the design a new vehicle entry registration process, using mobile phone technology?
- iii. How can a mobile application be developed that automatically recognizes and captures a vehicle's number plate?
- iv. How can the functionality of the ANPR system be tested?

1.5 Scope

License plate recognition system consists of four major processes namely: Image acquisition, Number plate localization Character segmentation and recognition. This study only focused on these four areas in relation to image processing techniques that are required in the number plate recognition process for the automation of the vehicle entry registration process.

1.6 Significance of the Study

ANPR is an internationally recognized tool that is used in vehicle identification. ANPR systems allow for real time recognition of a vehicle's number plate thus saving the time spent in vehicle identification in certain instances.

When it comes to the application of ANPR, there is an ever-growing range of scenarios where this technology is having a positive impact for example:

i. Law Enforcement:

Automatic Number Plate Recognition (ANPR) technology is used within the Metropolitan Police Service (MPS) to help disrupt criminality at a local, national and regional level, including tackling traveling criminals, organized crime groups and terrorists. ANPR provides lines of evidence in the investigation of crime and is used by forces throughout England, Wales, Scotland and Northern Ireland (ACPO, 2013).

ii. Car Park Access Control:

Automatic Number Plate Recognition (ANPR) technology is used in car park access control. Whereby ANPR is used to identify the license plate has been registered to a particular vehicle for the reserved car park space and also in locations where restricted access is enforced to pre-registered authorized vehicles (Advanced Parking Solutions, n.d.).

iii. Weighbridges:

An Automatic Number Plate Recognition system can alleviate the traffic-flow problems caused by the queuing and merging of traffic at toll booths. The ANPR system identifies cars that have valid permits, as well as those vehicles that need to pay the required congestion charge or toll fee. (Essa Technology, n.d.).

There is an emerging need for ANPR technology as there is need for real time vehicle identification. ANPR technologies allow for automatic vehicle number plate recognition thus making the vehicle identification process more effective, efficient and time saving.

Chapter Two: Literature Review

2.1 Introduction

According to the Kenya National Bureau of Statistics the total number of vehicles on Kenyan roads has been steadily growing as the number of vehicle owner's in Kenya increase. The number of newly registered vehicles in the year 2013 stood at 222,178 up from 173,044 the previous year. With this increase of vehicles on Kenyan roads there needs to be a mechanism that allows for easier and faster management of vehicle information in various fields such as access control and traffic law enforcement, toll gate access, parking area access, speed trap and traffic light trespassing just to mention a few.

2.2 Automatic Number Plate Recognition

Automatic number plate recognition (ANPR) is a surveillance method that was first developed in 1976 at the Police Scientific Development Branch in the United Kingdom with aim of combating crime (Cornwall, 2009). Automatic Number Plate Recognition is a process where vehicles are identified or recognized using their number plate or license plate. ANPR uses image processing techniques in order to extract the vehicle number plate from digital images.

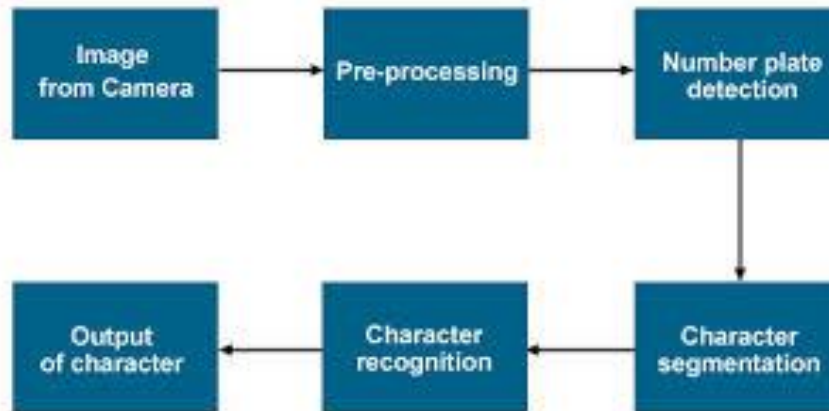
ANPR systems normally comprises of two components: A camera that used in capturing of vehicle number plate images, and software that extracts the number plates from the captured images by using a character recognition tool that allows for pixels to be translated into numerical readable characters (Friedrich, Jehlicka & Schlaich ,2008).

ANPR system is an image processing technique that identifies vehicles by their number plates. It consists of acquisition of an image, detection the numbers' location in the image and extraction characters to interpret the pixels into numerically readable characters (Mutholib,Gunawan,Chebil Kartiwi , 2013). ALPR systems consist of a camera; a processor and software application capable of performing optical character recognition (OCR) that transforms the image of the number plate into alphanumeric characters; an application software that compares the transformed number plate characters from a database of number plates of interest to law enforcers; a graphical user interface to display the results of the OCR process, and an alert functionality to notify users when a number plate is matched. (Roberts & Casanova, 2012).

A license plate recognition system generally works in four main parts namely image acquisition, license plate recognition/detection, characters segmentation, and lastly character recognition (Lotufo, Morgan & Johnson, 2013).

Figure 2.1 shows typical ANPR process that result in text from an input image.

Figure 2.1 Typical ANPR Process



Typical ANPR Process (Camera-sdk, n.d.).

2.3 Image Acquisition

The first step is the image acquisition stage the image of the vehicle is captured using a photographic camera. The constraint is that the image of the vehicle should be captured in such a way that the selected input image contains rear or front view of the vehicle with the number plate (Reshma, 2012).

The image is usually captured in a RGB (Red, Green and Blue) color model. The captured image is affected by many factors like: optical system, distortion, system noise, lack of exposure or excessive relative motion of camera or vehicle thus resulting in a degradation of a captured vehicle image hence adversely affecting the results of the overall image processing. As a correction mechanism an image pre-processing stage is introduced to take care of any errors that may have occurred during the image acquisition stage. Image pre-processing mainly involves converting the RGB image into gray color, noise removal, and border enhancement for brightness. Image pre – processing is usually done through image filtering (Dhiraj, Pramod & Borole, 2014).

The image acquisition stage heavily depends on the camera. There are a number of other factors concerning the setup of a camera that should be taken into consideration such as the field of view,

if this is too great the number plates may appear too small to be recognized by the ANPR device; however, if it is too narrow the complete number plates may not be captured. It should be ensured that the vehicles are visible within the field of view for long enough for the ANPR device to capture and successfully read the vehicle registration number (Reshma, 2012).

Proper camera setup is essential for accurate deployment of the ANPR system the properties of the camera form an important part in the image acquisition process. There are a number of factors that need to be taken into account when choosing the type of camera, such as: Iris-size, shutter speed, range of view, angle, position of camera height, type and size of lens (Gurney,Head Lyons & Ramalingam n.d.).

A blurry image is a factor that greatly affects the accuracy of the ANPR system, whereby from the start images with proper sharpness and contrast need to be acquired if the system is going to correctly recognize the characters in the number plate. In order to ensure proper images are acquired we need to ensure that specific camera factors are combined in the right way. These factors include: Optics, image sensor, camera and lighting (Gurney,Head Lyons & Ramalingam n.d.).

Some other factors affecting the number plate readability include number plate skew and rotation with respect to the camera. There are considerable variations in how successful ANPR systems are at reading number plates when the plates themselves are not straight on to the camera. Problems may be caused either by the vehicle turning with respect to the camera or the steep angle of the camera with respect to the road when installed. Depending on the system being used there will be a limit on the degree to which the camera can be angled. Some ANPR devices may allow skew settings to be configured.

The positioning of a permanent camera is a factor affecting the performance of ANPR systems, whereby camera positioning needs to be carefully surveyed. In particular careful positioning in order to avoid low light levels, glare from headlights, intense sun reflection and the uneven illumination at night time use can be a problem for cameras. These problems can be reduced by using infrared illumination and appropriate camera positioning (Lyons, 2014).

Light is another factor affecting the accuracy of ANPR systems, whereby the amount of light reaching the camera is a critical factor in the success of ANPR applications. The source and quantity of light will need to be appropriate for the type of camera in use; typical light sources that

are used include visible light from daylight, street lighting or infrared light from dedicated illuminators. It is essential that any artificial illumination used should cover the whole field of view within which number plates might be captured. Weather and climatic conditions may affect the ANPR performance conditions such as rain, snow, hail and sandstorms may obscure the camera view as a counter mechanism the cameras may have physical shield on them (Gurney, Head & Lyons, n.d.).

2.4 Number Plate Detection

The next stage that follows is the license plate recognition/number plate recognition phase that does several functions such as resizing of the image to a feasible aspect ratio. As well as converting the colored image into a grey scale image (Reshma, 2012).

Number plate detection searches an input image in order to identify specific features that contain the number plate. The number plate can be found anywhere within an image, it is impractical to check all the pixels of the image in order to locate the number plate. Therefore we only focus on those pixels that have the number plate. Number plate detection methods can be categorized into three categories: color-based, edge-based, and texture-based (Kawde, 2014).

2.4.1 Edge Based Detection

These algorithms operate on the principal that the number plate is located in an area of the image with high contrasts usually composed of black and white or black and yellow. The characters on the plate are organized in one row, or a few rows resulting in frequent changes in the horizontal intensity. This provides the reason for detecting the horizontal changes in pixel intensity, since the rows that contain the number plate are expected to exhibit many sharp variations (Enyedi, Lajos & Fazekas, 2006).

The major disadvantage with edge based methods is that they alone can hardly be applied to complex images. This is because the edge based approach is too sensitive to unwanted edges, which may also show a high edge magnitude or variance (Hongliang & Changping, 2004).

2.4.2 Texture Based Detection

Texture based approach is the process of detecting and locating those regions that contain texts from a given image. However text variations related to size, style, orientation, and alignment, as

well as low contrast and complex backgrounds make the problem of automatic text detection extremely challenging. (Kim, Jung & Hyung, 2003).

Texture-based algorithms mainly use image transformation to analyze the texture information. The most common image transformation techniques include Gabor filters, Hough transform and wavelet transform. These techniques directly analyze texture information without limitation of the number plate direction and size.

Texture-based methods are known to perform well even with noisy, degraded, textured, or complex texts and backgrounds, however they are usually time consuming as texture classification is inherently computationally dense (Kim, Jung & Hyung, 2003).

2.4.3 Color level processing

Color-based approaches are based on the principal that different countries have different colors on their number plates. Color level processing obtains the number plate by locating the specific colors on the number plate (Kawde, 2014).

Color-based information of license plates also plays an important role in license plates detection, where the unique color or color combination between the license plates and vehicle bodies are considered as the key feature to locate the license plates. This technique uses color features for license plate detection. However, this method is sensitive to the license plate color and brightness and needs much processing time (Kim, Jung & Hyung, 2003).

2.5 Character Segmentation

Character segmentation can be defined as a technique, which partitions images of lines or words into individual characters. It is an operation that seeks to decompose an image of a sequence of character into sub images of individual symbols (Kumar & Singh 2011). Character segmentation is an operation that seeks to decompose an image of a sequence of characters into sub-images of individual symbols (Casey & Lecolinet, n.d.).

Character segmentation is the process through which the text component within an image is isolated from the background. In order for proper text recognition to take place the line of text is first segmented, then from the segmented line the words are segmented and then from that the characters are segmented (Saha, Basu, Nasipuri & Dipak, 2010).

Character separation also known as segmentation can work in two modes:

- i. Fixed (constrained) spacing mode: In this mode character size is known in advance and therefore segmentation can be very robust.
- ii. Variable (arbitrary) spacing mode: In this mode no priori information can be assumed. (Thakkar, Kandarp, Juhi & Tailor, 2012).

There are three pure segmentation strategies and these include:

- i. The classical approach, in which segments are identified based on character-like properties. This process of cutting up the image into meaningful components is given a special name, dissection.
- ii. Recognition-based segmentation, in which the system searches the image for components that match classes in its alphabet.
- iii. Holistic methods, in which the system seeks to, recognize words as a whole, thus avoiding the need to segment into characters (Casey & Lecolinet, n.d.).

Dissection is an operation to decompose the image into sequence of sub images using general features. It is an intelligent process in that an analysis of the image is carried out, however classification into symbols is not involved at this point. The criterion for good segmentation using the dissection approach is the agreement of character properties in the segmented sub image and the expected symbol. The character properties include height, width, separation from neighboring components and disposition along the baseline (Thakkar, Kandarp, Juhi & Tailor, 2012).

Dissection directly into characters uses two main techniques: White space and Pitch.

- i. White space is the simplest and earliest dissection approach relies on the vertical whitespace between successive characters.
- ii. In the Pitch technique the number of characters per unit of horizontal distance is defined as pitch and it can be used for estimating segmentation points. For the sake of convenience the segmentation approach used a fixed pitch (Thakkar, Kandarp, Juhi & Tailor, 2012).

Recognition based segmentation also segment words into individual units. Recognition based segmentation in effect bypass the requirement to discretely segment the word. Recognition based segmentation systems generally work as follows: First, the windowing is performed on the image

to generate segmentation hypothesis. After this, the best hypothesis (guess) as determined by the classifier is chosen during verification step. Recognition based segmentation can be implemented using these techniques:

- i. **Recursive Segmentation:** This approach uses the windowing techniques that classify the character, based on a prototype character. The system exhaustively searches all possible cut points in the image until all characters are matched against a prototype library within a given threshold.
- iii. **Shortest Path Segmentation:** This method combines dynamic programming and neural net recognition for finding the best segmentation from the many obtained for the given word (Thakkar, Kandarp, Juhi, & Tailor, 2012).

A holistic process recognizes an entire word as a unit. A major drawback of this class of methods is that their use is usually restricted to a predefined lexicon, as they do not deal directly with letters but only with words, recognition is necessarily constrained to a specific lexicon of words. This point is especially critical when training on word samples is required a training stage is thus mandatory to expand or modify the lexicon of possible words. This property makes this kind of method more suitable for applications where the lexicon is statically defined and not likely to change (Casey & Lecolinet, n.d.).

2.6 Character Recognition

Character recognition is process of detecting and recognizing characters from input image and converting it into meaningful text in ASCII (American Standard Code for Information Interchange) or other equivalent machine editable form (Shah & Jethava, 2013). Character recognition is the process to classify the input character according to the predefined character class (Dedgaonkar, Chandavale & Sapkal, 2012).

Template matching, or matrix matching, is one of the most common classification methods. In template matching, individual image pixels are used as features. Classification is performed by comparing an input character image with a set of templates from each character class (Shah & Sharma, 1998).

A very basic description of a functional ANPR process is:

Step1: The camera takes a picture of the vehicle containing the number plate (Image acquisition).

Step2: The camera isolates the plate, adjusts the brightness and contrast and segments it into characters (Number plate detection and Character segmentation).

Step3: The pattern of each character is analyzed to convert the picture into text (Character recognition).

2.7 Applications of OCR

There are widespread appearances of commercial OCR products over the last few years meeting different user requirements. There are two main application areas of OCR these include: process automation and data entry:

- i. Process automation: This area is not concerned with reading what was printed but rather to control a specific process. For instance automatic address reading for sorting mail thus the aim is to direct each mail (letter) into the appropriate bin automatically by just reading off the mail address (Eikvil, 1993).
- ii. Data entry: This process deals with entering of large amounts of text. This process typically involves the use of camera or scanners to obtain digital images of the original documents, then the OCR software extracts the text from the images, thus returning the text that is contained in the images (Eikvil, 1993).

2.7.1 OCR on Mobile Devices

Existing mobile applications that implement the use of OCR include:

Nokia Multi-scanner: is a freeware application designed for cell phones with Symbian OS. The application supports picture taking and consequently sending it through MMS, Bluetooth or via infrared. It is possible to transfer the image into a text and save it and at the same time the selection of certain area can be made by dragging. Another possibility is to send the image for business card recognition. This option automatically recognizes contact details on the business card and fills in the details for adding a new contact. The OCR engine supports post-processing on the basis of

language. However this solution do not support real virtual keyboard or clipboard copy and paste features furthermore the application runs only on Symbian Operating System (DailyMobile, 2008).

Cam-Card - Business Card Reader: Cam-Card is an application specialized on reading business cards. It is targeted at cell phones which run on OS Android, iOS (OS of iPhone cell phones), or Windows Mobile and BlackBerry phones. Furthermore, the Cam-Card is an extensively automated business card reader with detection of a rotation and a language. The whole recording takes just couple of presses. The main disadvantage is the narrow specialization on business cards and its price (iMore, 2012).

2.7.2 Other OCR Implementations

There are many other areas in which OCR applications exist, an example includes within the legal industry; there have been a significant movement to digitize paper documents. In order to save space and eliminate the need to sift through boxes of paper files, documents are being scanned and entered into computer databases. OCR further simplifies the process by making documents text-searchable, so that they are easier to locate and work with once in the database. Legal professionals now have fast, easy access to a huge library of documents in electronic format, which they can find simply by typing in a few keywords (OCR applications, n.d.).

Aid for blind: Software applications that assist the blind to understand printed documents. The OCR software is integrated with speech synthesis capability that allows for words to be read out after they have been recognized.

Signature identification and verification: These applications are specifically useful in the banking environment. These systems establish the identity of the writer without attempting to read the handwriting. The signature is considered as a pattern and is matched with signatures stored in a reference database (OCR applications, n.d.).

2.7.3 Applications of ANPR

One of the most common applications for ANPR technology is identifying and recovering stolen vehicles. The ANPR system is set to read number plates of the vehicles as the police car is on patrol. The vehicle number plates are automatically read, and compared to an on-board vehicle stolen database, hence whenever a match is found an alarm is raised (Competitive Survey and White Paper of Automated License Plate Recognition Vendors, n.d.).

ANPR systems can also be used in acquiring and storing license plate information of vehicles. This information can be used in crime investigation whereby each number plate that was read can be placed at a specific time and place. This information might be helpful in criminal investigation whereby a placing a suspect (witness) at a particular location at a fixed time (Automatic Number Plate Recognition Systems Solutions, n.d.).

2.8 Elements of ANPR Systems

Automatic Number Plate Recognition Systems normally consist of hardware and software units.

2.8.1 Hardware Components of ANPR systems include:

- i. Camera(s) – Digital cameras are used in the image acquisition stage. They are primarily used in obtaining images or video footage of vehicles.
- ii. Infra-Red – Light source at night maybe provided by Infra-red in order to provide illumination for the camera.
- iii. Frame Grabber – This is a hardware interface between the digital camera and the computer. The Frame Grabber is tasked with getting the digital image from the camera storing it temporarily and then submits it to the computer for processing.
- iv. Computer – This is the central processing unit in ANPR systems. The computer has the ALPR application installed in it (Competitive Survey and White Paper of Automated License Plate Recognition Vendors, n.d.).

2.8.2 Software Components of ANPR systems include:

- i. ALPR Software – This software has the OCR capabilities which results in the extraction of the number plate from the digital image.
- ii. Database – This provides storage for the data (number plates that have been read by the ANPR).
- iii. Back End Software - The back end software is located on a server and provides many functions such as:
 - a. Data collection from cameras.
 - b. Data mining of previously collected data for investigations and pattern analysis.
 - c. Allowing for sharing of data with other agencies (Competitive Survey and White Paper of Automated License Plate Recognition Vendors, n.d.).

2.9 ANPR Implementations

RPX-LIVE is an advanced, interactive vehicle monitoring application that controls the RoadPixel ANPR engine. It can log all traffic movements; perform real-time database checks and alerts as well as instant transmission of vehicle data to the RoadPixel Cloud-based Back Office (RPX-BOF). The intuitive user interface may be used in a desktop environment to monitor or control any site entrance, car park or traffic flow. The same GUI can be also be used with a Touch Screen or Tablet PC in a Police or Enforcement vehicle to check passing traffic against multiple hotlists (Road Pixel, n.d.).

The ROADSTER-M1 PC is a fully E-Marked powerful Rugged Mobile Computer / In-Vehicle PC that can support a wide variety of applications for Police and Mobile Enforcement use. The processor unit is normally mounted in the boot of a vehicle and has a range of high-brightness rugged touch screens and backlit keyboards to fit all vehicle types. The unit can also be supplied with a perforated metal cage to protect the computer unit and its connectors from damage from other objects in the vehicle boot. In addition to its ANPR capability, the ROADSTER-M1 can record and encrypt video from an on-board windscreen mounted analogue camera using a dedicated MPEG channel. The ROADSTER-M1 is designed especially for use in a moving vehicle coping well with varying voltages and temperatures (Rugged Mobile Computer, n.d.).

2.9.1 ANPR on Mobile Devices

Check Plate is a handheld ANPR capture solution that uses portable lightweight devices to perform ANPR in all conditions, day and night. Once it has captured a vehicle's registration number, the number can be checked against a database to provide the user with information about the vehicle. Common uses for Check Plate include vehicle stock checks, parking services (checking stay time and issuing private car number) as well as security checks in places such as airports, train stations and government buildings. Some of the key benefits of Check Plate include, a lightweight, low cost ANPR solution, fast and accurate means of reading and recording vehicle number plates, allows for linking between the front-line staff with information from back office systems (Intelligent mobile solutions, n.d.).

Matrix Pocket is a handheld based number plate recognition software, which runs on Windows Mobile and Android OS environments. The Matrix Pocket mainly allows for checks to be made from a smart phone it allows for quick, simple and easily check the vehicle registration numbers.

Addition to their many advantages these the Matrix Pocket also ensures that vehicles will only be stopped where the systems shows that something is wrong. This reduces the unnecessary harassment of law-abiding citizens and the number of disruptions caused by traffic controls (Automatic Number Plate Recognition Systems Solutions, n.d.).

ROK LPR, a hand-held ANPR system. Developed for use in Android mobile devices, the new ROK LPR system is a fast, reliable and accurate ANPR technology. The application is available either as stand-alone technology or as an integrated part of the RHS law enforcement mobile application system. It can be used in a hand-held overt manner or can be mounted in a vehicle, and also from a fixed position with tripod and telephoto lens (ROK launches mobile phone-based ANPR system, 2013).

The TES Mobile ANPR application is installed on a phone or handheld computer and enables Civil Enforcement Officers to detect potential contraventions and process vehicle details using hand held ANPR. The TES Mobile ANPR app reads the number plate of a vehicle and checks if it is on an authorized list, (e.g. residents parking permits) if the vehicle is not on the list it is then flagged as a potential contravention that requires further attention (TES Mobile ANPR, n.d.).

2.10 Challenges

There are a number of factors that may cause the ANPR system not to function effectively some of these factors include:

Misidentification: In case the number is read partially, the remote computer might identify the number plate incorrectly or would not be able to decrypt at all. Characters and numbers may be detected wrongly and interchanged identity may occur; characters may be read as numbers and vice versa. Problems in recognition under bad weather conditions: Natural Calamities like heavy rainfall or snowfall may hinder the performance of the detection system. Non-standardized number plates (Moharil, Ghadge, Gokhale& Tambvekar, 2012).

There are a number of possible difficulties that the software must be able to cope with. These include:

- i. Poor image resolution, usually because the plate is too far away but sometimes resulting from the use of a low-quality camera;

- ii. Blurry images, particularly motion blur;
- iii. Poor lighting and low contrast due to over exposure, reflection or shadows;
- iv. An object obscuring (part of) the plate, quite often a tow bar, or dirt on the plate;

While some of these problems can be corrected within the software, it is primarily left to the hardware side of the system to work out solutions to these difficulties. Proper camera position could help overcome some of these challenges.

2.11 Conclusion

It is a requirement by law in most countries that every vehicle must have a vehicle registration number. A vehicle registration is a metal or plastic plate attached to a motor vehicle for official identification process. The vehicle registration plates are placed at the back or at the front of the vehicle.

An automatic number plate recognition (ANPR) system provides for means that allow for vehicle number plates to be captured and stored automatically without much need of human intervention.

Thus an automatic number plate recognition system works in four main stages namely:

- i. Image acquisition: - capturing of the vehicle image that contains the number plate.
- ii. Image detection: - identification of where the number plate exists within the image.
- iii. Character segmentation: - dividing of the number plate image into individual characters.
- iv. Character recognition: - detecting and recognizing characters from input image and converting it into meaningful text.

However there are several challenges faced by ANPR systems such as non-standard number plates or deliberate countermeasures on some vehicles prevent the optical character recognition (OCR) software from accurately reading those plates. It is recommended to scan the front license plate because of reason such as ease of location of the number plate as compared to most rear number plates that usually tend to be dirty and characters might be blocked by various items such as spare wheel, bumper, and boot door handle.

Camera setup in desktop ANPR systems can be quite challenging due to issues such as where to position the camera, how to mount the camera, the preferred type of camera to use. Most of these challenges can be eliminated in the adoption of ANPR systems on mobile phone devices.

Chapter Three: Research Methodology

3.1 Introduction

Research design is the overall plan for connecting the conceptual research problems to the pertinent (and achievable) empirical research. In other words, the research design articulates what data is required, what methods are going to be used to collect and analyze this data, and how all of this is going to answer your research question (Van Wyk, 2012).

This chapter describes the methods adopted in this research and explains why certain methods were preferred over others. It also highlights a number of issues relating to the research process, research facilitation and field-based research within a school environment.

3.2 System Development Methodology

This research adopted an Object-oriented System Development methodology. An Object-oriented software design is a design strategy where system designers think in terms of ‘things’ instead of operations or functions. The executing system is made up of interacting objects that maintain their own local state and provide operations on that state information (Rakesh & Bharat, n.d.).

Object-oriented analysis and design is more cost-effective and a faster way to develop software and systems. This technology cuts development time, overhead and enables software engineers to make reusable, reliable and easily maintainable applications. In addition, this technology offers a new and powerful model for writing software. OOP (Object-oriented programming) allows decomposition of a problem into a number of objects and then builds data and functions around these objects (Rakesh & Bharat, n.d.).

Object-oriented development methodology ensures that the system being developed is refined and transformed through analysis, design, code and test phases. Details and modifications are added in successive iterations (changes and improvements are introduced as needed) and incremental releases of software modules are delivered (Maciaszek, 2001).

Object-oriented software development life cycle is an iterative process that has five key phases. Figure 3-1 is an image detailing the key stages in this methodology. These phases include:

- i. Requirements analysis: - This phase is critical to the success of the project. Expectations need to be fleshed out in great detail and documented. This is an iterative process with much communication taking place between stakeholders, end users and the project team (Justin, 2013). The key stakeholders and users included the University's Head of Security as well as the Security Personnel manning the entry points of the University, the Researcher interacted with them so as to fully understand their day to day processes as well as to collect/gather the desired system features.
- ii. Design: - During this phase the technical design requirements were prepared. The User requirements were used to define how the application was written, the technical requirements are specified to detail for instance; database to be used, features and functionalities, security processes and hardware and system requirements (Alwan, 2016).
- iii. Code: - At this stage the design was translated into a machine-readable form. Programming tools like compilers, interpreters, debuggers are used to generate the code. Different high level programming languages like, C, C++, Java, PHP, HTML are used for coding. (Think Together, n.d.). Details of the exact tools the researcher used are in the subsequent chapter.
- iv. Test: - This stage occurs after the application has been developed; different types of testing were performed including performance and integration testing. User acceptance testing is the last part of testing and is performed by the end users to ensure the system meets their expectations. At this point, defects may be found and more work may be required in the analysis, design or coding (Alwan, 2016).
- v. Maintenance: - This phase confirms the software passed the user acceptance stage and now is operational. If required, the users are trained on, or aided with the documentation on how to operate the software and how to keep the software operational. The software will be maintained from time to time by updating the code according to the changes taking place in user end environment or technology. This phase may face challenges from hidden bugs and real-world unidentified problems (Software Development Life Cycle, n.d.).

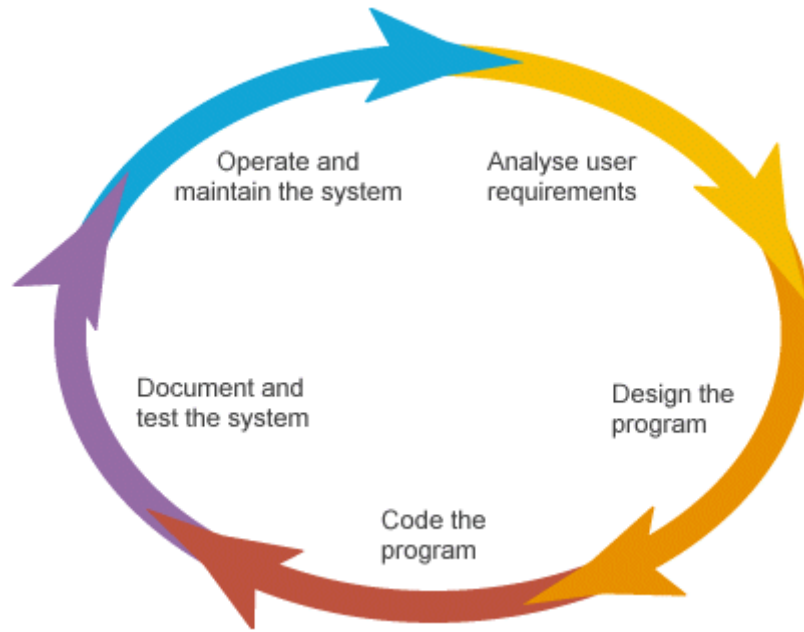


Figure 3.1 Object Oriented System Development Methodology

3.3 System Analysis

3.3.1 Research Design

This research seeks to investigate the challenges vehicle entry registration process. It also tries to establish the best way to develop a mobile base system that can be used to register vehicles' as they enter and exit the University.

The research type implemented was an action research type that aims to come up with a solution to the challenges faced by the security guards in the Institution. This research type was preferred because a mobile based solution was implemented for the challenges faced in the vehicle entry registration.

3.3.2 Location of the Study

This research was carried out within Strathmore University's main campus located in Madaraka estate in Nairobi County. This study mainly focused on the vehicle's entry registration process that occurs in the different entry points of the Institution. The location of the study was divided into three main areas namely:

- i. Entrance into Strathmore's University Administration area.
- ii. Entrance into Strathmore Business School.
- iii. Entrance into Strathmore's University parking bay.

3.3.3 Target Population and Sampling

This research implemented a purposive sampling as a sampling strategy, and the sample population consisted of the University's Head of Security and security guards manning the entrance and exit points of the Institution.

One of the main advantages of purposive sampling is essential when researchers are studying a specific characteristic, feature or function. This method ensures that the research returns relevant information and avoids wasting time taking samples that have nothing to do with the research topic.

However, some of the challenges associated with purposive sampling include: it is prone to researcher bias because the samples are taken from such a specific group. The subjectivity and bias within purposive sampling can lead to data that is not trustworthy or accurate. In order to mitigate this challenge the researcher ensured that proper validity and reliability were achieved during the sampling process.

3.3.4 Data Collection and Procedure

3.3.4.1 Research Instruments

According to Marter (2012) a research instrument is a tool primarily used to collect data during a research. The researcher used face to face interviews and observations as the main research instruments in order to collect data about the current vehicle entry registration process.

3.3.4.2 Un-structured Interviews

This research implemented the use un-structured interviews whereby this allowed the respondents to answer questions in much detail as they wanted to. It also ensured that valid information about respondent's attitudes, values and opinions were obtained. The informal atmosphere encouraged the respondents to be open and honest. The use of un-structured interviews also allowed for flexibility whereby the researcher was able to modify the interview questions with ease as the interview took place.

The following are reasons as stated by McLeod (2014) why a researcher would opt for the use of un-structured interviews:

- i. Unstructured interviews are flexible as questions can be changed depending on the respondents' answers. The interview can also deviate from the interview schedule.
- ii. Unstructured interviews provides for open questions. The respondent is allowed to talk in-depth, choosing their own words.
- iii. Unstructured interviews have increased validity because it gives the interviewer the opportunity to ask for a deeper understanding, as well as any further clarification

The interview guide that was followed during the interview has been attached in the appendix section on this dissertation.

3.3.4.3 Structured Observations

Observations are structured when an observation list is used with a fixed number of points to notice, and when this list is applied in a pre-determined number of situations, or with a pre-determined number of people. The research adopted the use of structured observations this is because the researcher had already identified what is, that was to be observed (Bentley, Boot, Gittelsohn & Stallings, 1994). In this case referring to the vehicle entry registration process as currently being done within Strathmore University.

3.4 System Design

3.4.1 Use Cases

Use cases describe how the system-to-be from a user's perspective. They answer the question: How will the system be used, once it is built? Use cases are used to show the functions to be supported (Mylopoulos, 2004).

A use case description (sometimes called the use case narrative), which is the text-based, detailed, step-by-step interactions and dialogue between the actor and the system (Kupersmith, Mulvey & McGoey, n.d.).

A use case diagram displays the relationship among actors and use cases. The two main components of a use case diagram are use cases and actors. An actor is anything that needs to exchange information with the system. An actor could be a person, or another external, system. Actors define roles that users can play while using the system (Learn System Analysis and Design, n.d.).

The main actors in the automatic number plate recognition system for car park management system include the University's Head of Security as well as the Security personnel manning the entrance/exit to the University.

3.4.2 System Sequence Diagram

System sequence diagrams are visual summaries of the individual use cases. System sequence diagrams describe the flow of messages, events, actions between objects they show concurrent processes. In addition they also show time sequences that are not easily depicted in other diagrams. A system sequence diagram should specify and show the following: External actors, Messages (methods) invoked by these actors, Return values (if any) associated with previous messages, Indication of any loops or iteration area (Fowler, n.d.).

3.4.3 Database Schema

A database schema is the skeleton structure that represents the logical view of the entire database. It defines how the data is organized and how the relations among them are associated. A database schema defines its entities and the relationship among them. It contains a descriptive detail of the database (Data schemas, n.d.).

3.5 System Implementation

Implementation is the realization of an application, or execution of a plan, idea, model, design, specification, standard, algorithm, or policy. An implementation is a realization of a technical specification or algorithm as a program, software component, or other computer system through computer programming and deployment. System Implementation uses the structure created during architectural design and the results of system analysis to construct system elements that meet the stakeholder requirements and system requirements (Grady, 1994).

3.6 System Testing

System testing is the process of performing a variety of tests on a system to explore functionality or to identify problems. System testing is usually required before and after a system is put in place. System testing is performed on the entire system in the context of a Functional Requirement Specification(s) (FRS) and/or a System Requirement Specification (SRS) (System Testing, n.d.).

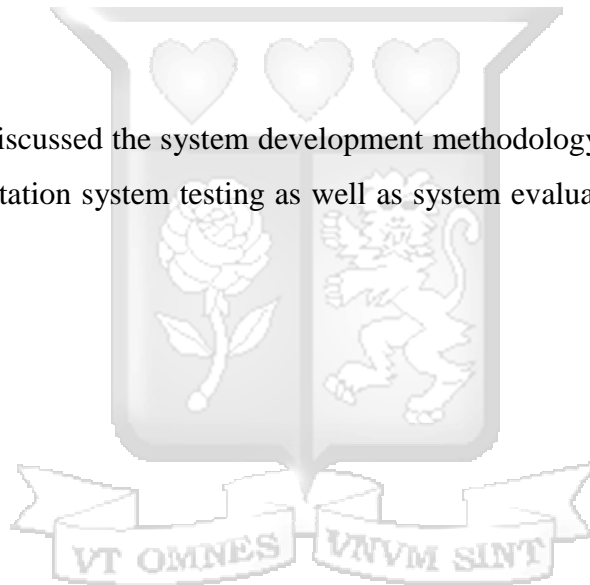
The system tests that were performed so as to ensure the software met the user requirements as well as desired system functionalities included: Performance testing, Functionality testing and User acceptance testing.

3.7 System Evaluation

System evaluation is the process of assessing the performance of a complete system to discover how it is likely to perform in live market conditions (Bromley, 2006). The key stakeholders who are involved in system evaluation include the key system users who included the University's Head of Security as well as the Security personnel. At this stage the user requirements were reviewed in a real world scenario to check/confirm if the system functions as desired.

3.8 Conclusion

In this chapter we have discussed the system development methodology, system analysis, system design, system implementation system testing as well as system evaluation procedures that were used by the researcher.



Chapter Four: System Design and Architecture

4.1 Introduction

Modeling is the initial step undertaken during the process of system design. Modeling provides guidance on how to develop the system.

4.2 Requirements Analysis

A requirement is any function, constraint, or property that the system must provide, meet, or satisfy in order to fulfill its purpose. The goal of analysis is to produce essential requirements (March, 2002).

The main requirements of the system were obtained at the data collection stage. The major stakeholders of the system were interviewed and observed as they performed their day to day task in order for the researcher to fully understand the current process.

4.2.1 Data Collection Results

The results that were obtained from data collection mainly included the current vehicle entry registration processes and some of its challenges. This information has been summarized in the steps that follow:

- i. Vehicle arrives at the gate with aim to gain entrance.
- ii. The security guard first checks if the driver has a valid ID (either staff or student ID).
- iii. If the ID is valid the gate is opened.
- iv. There is another security guard who hands out the ticket number while noting down on an occurrence book the vehicle details. These details include vehicle make, model and color, time of entry, as well as the ticket number issued to the vehicle.
- v. On vehicle exit the ticket issued is handed back to the security guard at the gate and the time of exit is recorded for that particular vehicle.

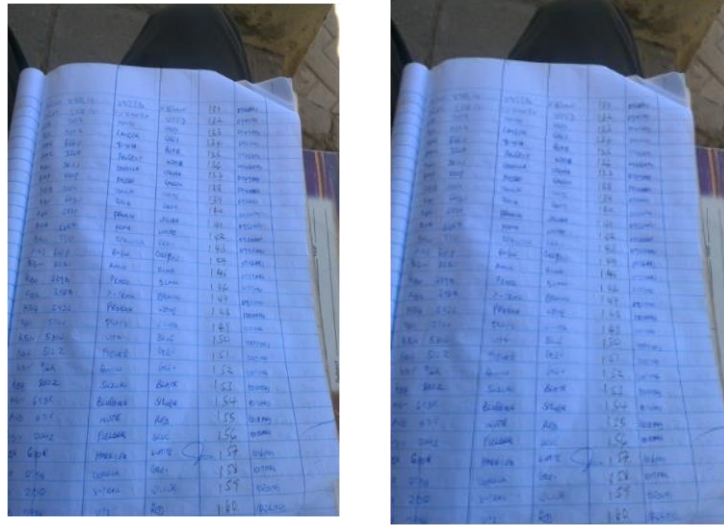
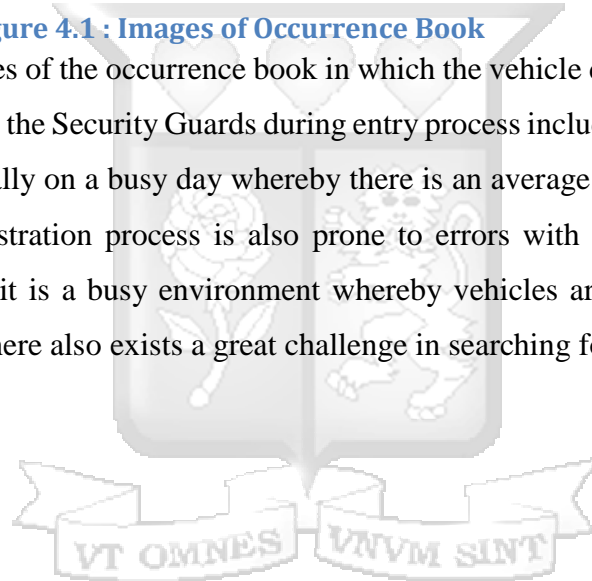


Figure 4.1 : Images of Occurrence Book

The Figure 4.1 are a copies of the occurrence book in which the vehicle details are recorded. Some of the challenges faced by the Security Guards during entry process include: the vehicle registration process is tedious especially on a busy day whereby there is an average of 200 vehicles accessing the Institution. This registration process is also prone to errors with regards to the data being recorded this is because it is a busy environment whereby vehicles are constantly entering and exiting the University. There also exists a great challenge in searching for a particular vehicle in



4.3 System Architecture

A system architecture or systems architecture is the conceptual model that defines the structure, behavior and views of a system (Jaakkola & Thalheim, 2011). The Figure 4.2 is an architectural design for the Automatic Number Plate Capture and Vehicle Registration System. This architecture can be broadly categorized into:

- a. Client Application (Front-End)
- b. Server side (Back-End)

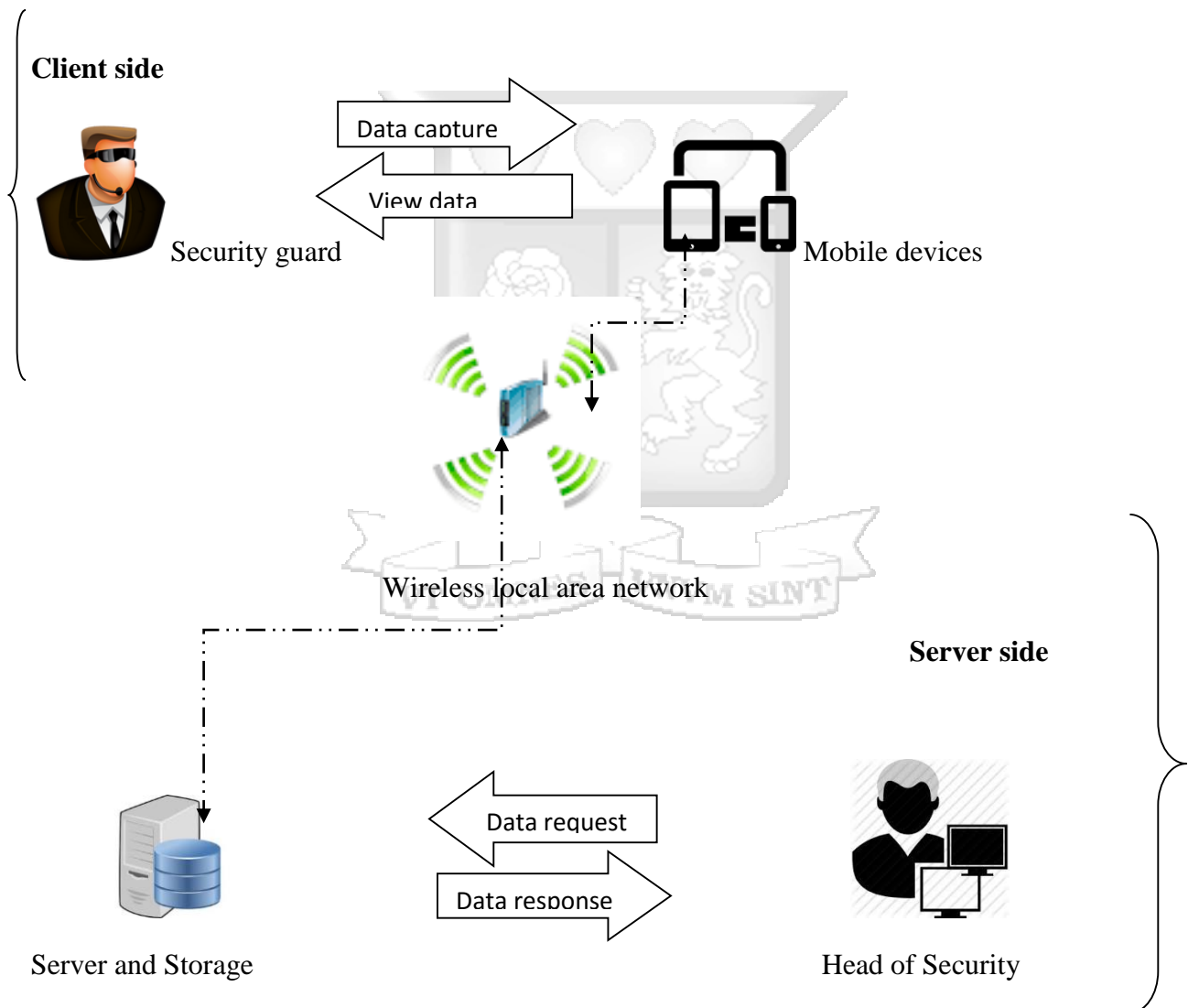


Figure 4.2: System Architecture

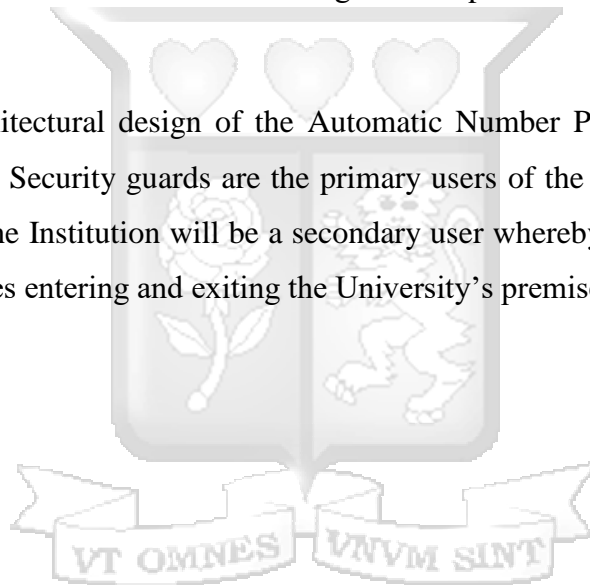
4.3.1 Client Application

This comprises the mobile application that has the Optical Character Recognition functionality required in the scanning of vehicle number plate, as well as inputting other vehicle description details. The mobile device also allows for additional services like capturing the vehicle time in by using the mobile phones' clock functionalities, as well as storage of the vehicle information. The mobile application is communicating with the server side via wireless local area network (WLAN).

4.3.2 Server Side

This consists of a server used for hosting the scripts that will be involved in the transmitting and receiving of the vehicle information. There is also a database used for storage of vehicle details as well an administrator's portal that is used in viewing of the reports of the vehicles that have been recorded.

With regards to the architectural design of the Automatic Number Plate Capture and Vehicle Registration System. The Security guards are the primary users of the mobile application, while the Head of Security at the Institution will be a secondary user whereby He will be receiving the information of the vehicles entering and exiting the University's premises from an online portal.



4.4 Use Case Diagram

A use case diagram at its simplest is a representation of a user's interaction with the system and depicting the specifications of a use case (Use Case Diagram, n.d). A use case diagram can portray the different types of users of a system and the case and will often be accompanied by other types of diagrams as well. The Figure 4.3 is a use case diagram describing the actors and the activities involved in the new vehicle registration process.

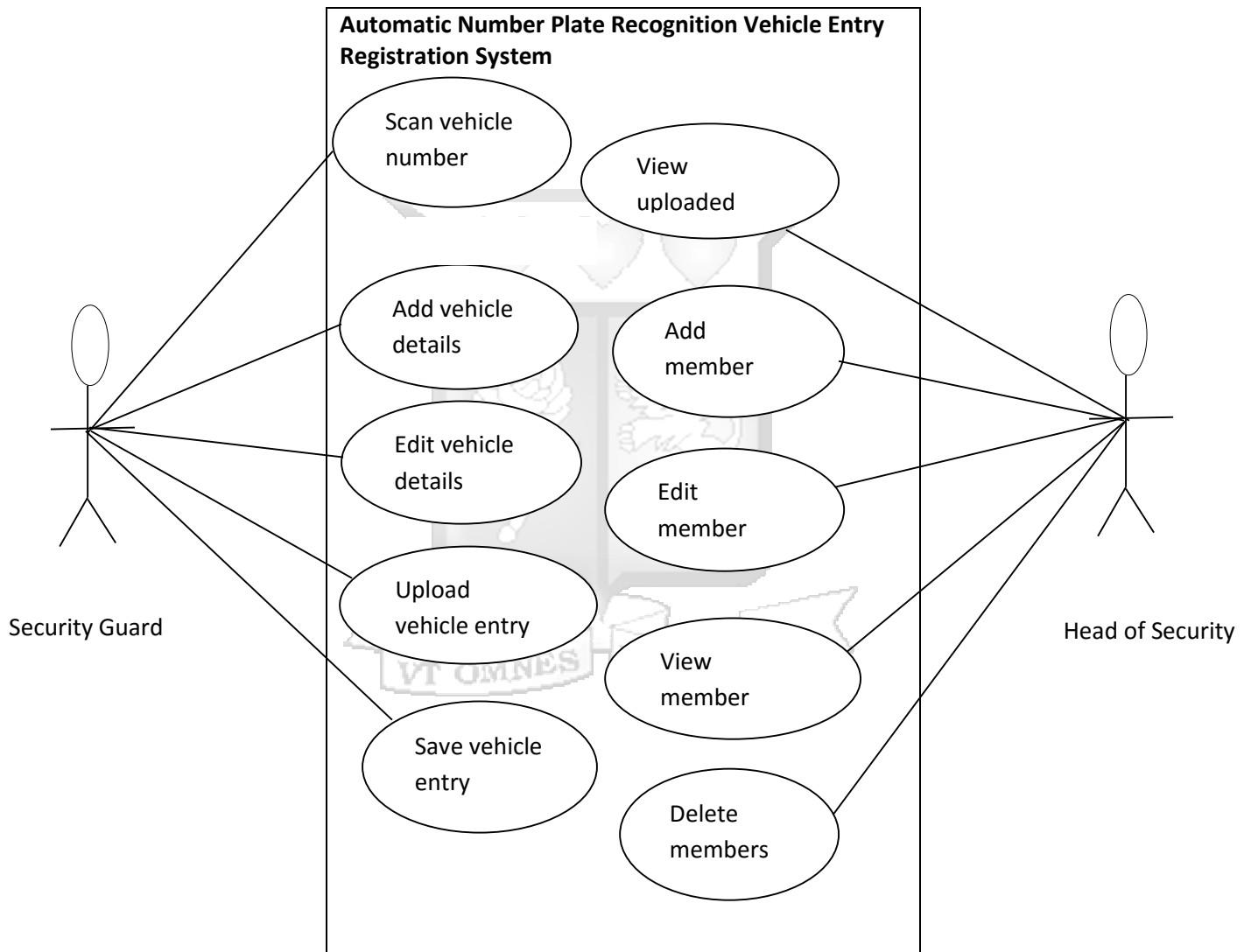


Figure 4.3: Use Case Diagram for an Automatic Vehicle Entry Registration System

4.5 Use Case Descriptions

A use case is a list of steps, typically defining interactions between a role (known in Unified Modeling Language (UML) as an actor) and a system, to achieve a goal. The actor can be a human, an external system, or time (Use Case, n.d.). The Table 4.1 gives a high level summary of the scan number plate process which is the first process within the vehicle registration system.

Table 4.1: Scan Vehicle Number Plate Use Case

Title:	Scan vehicle number plate
Description:	User scans vehicle number plate using the mobile device camera.
Stakeholders and Interests 1. Security guard 2. Visitor 3. Head of Security	The security guard wants an efficient and effective way of recording vehicle number plates. The visitor wants an effective and efficient process of vehicle registration while entering the Institution. The Head of Security wants a faster and accurate means of recording the vehicle's that are accessing the institution.
Primary Actor:	Security guard.
Pre-conditions:	A vehicle arrives at the gate; with an intention to gain entrance into the Institution. The vehicle has to have a clear and visible number plate.
Success Guarantee (Post-conditions)	The vehicle number plate is accurately captured by the system.
Main Success Scenario:	<ol style="list-style-type: none"> i. A vehicle arrives at the Institution's entrance. ii. The Security guard points the mobile device camera onto the vehicle number plate. iii. The application captures an image of the number plate. iv. The system then extracts the number plate from the image. v. The system then outputs the captured number plate in text format.

Table 4.2 is a use case description of the add vehicle detail process, this process allows the Security Guard to capture additional information about the vehicle, for instance the vehicle model, vehicle color as well the ticket number assigned to it.

Table 4.2: Add Vehicle Details Use Case

Title	Add vehicle details
Description:	User records additional vehicle details.
Stakeholders and Interests: <ol style="list-style-type: none"> 1. Security guard 2. Visitor 3. Head of Security 	<p>The security guard is interested in capturing other vehicle description such as make and model, vehicle color, time in as well as ticket number issued.</p> <p>The visitor wants an efficient and effective way that allows for his/her vehicle details to be accurately recorded.</p> <p>The Head of Security wants a time efficient and an accurate way of recording vehicle details.</p>
Primary Actor:	The Security guard.
Pre-conditions:	The vehicle number plate was scanned and its number plate was successfully captured.
Success Guarantee (Post conditions)	Vehicle details have been successfully saved in relation to a particular vehicle number plate.
Main Success Scenario:	<ol style="list-style-type: none"> i. Once the number plate has been successfully captured. ii. The security guard inputs the extra vehicle descriptions. iii. The vehicle details are then saved with regards to the number plate.

Table 4.3 is a use case description of the upload vehicle details process, this process allows the Security Guard to upload the records that have been captured onto an online database that can be viewed remotely by the Head of Security.

Table 4.3: Uploading Vehicle Details Use Case

Title	Uploading of vehicle details
Description:	The system should automatically upload the vehicle details recorded to a central location.
Stakeholders and Interests: 1. Security guard 2. Head of Security	The Security guard is interested in having the information recorded for a particular vehicle stored in a safe manner. The Head of Security is interested in having real time information on the entry and exit of vehicles
Primary Actor:	The System
Pre-conditions:	Vehicle details must have been successfully captured and inputted by the Security guard. The application should have internet connection.
Success Guarantee (Post condition)	Vehicle information is successfully logged onto a central location, and this information should be accessible to the Head of Security.
Main Success Scenario	<ol style="list-style-type: none"> i. Once the vehicle details have been successfully captured. ii. The System should automatically upload the vehicle details onto a central location. iii. The Head of Security should be able to view the uploaded vehicle information.

Table 4.4 is a use case description of the display details process whereby the system displays vehicle's details that had been captured. This process occurs when the vehicle is about to exit the Institution.

Table 4.4: Display Vehicle Details Use Case

Title	Displays vehicle details
Description	Occurs when the vehicle is about to exit the Institution, the User should be able to access the details that had been saved when the vehicle entered.
Stakeholders and Interests 1. Security guard 2. Visitor 3. Head of Security	The Security guard wants an easier way of accessing the information of the data that had been stored. The visitor wants an efficient process that allows for quick exit. The Head of Security wants an efficient and secure way for vehicles to exit.
Primary Actor:	The Security Guard
Pre-condition:	The vehicle details were successfully recorded.
Success- Guarantee (Post condition)	The vehicle details are displayed and the Security Guard confirms the vehicle before exit. The vehicle Time out is also recorded.
Main success scenario	<ol style="list-style-type: none"> i. The vehicle is about to exit the Institution. ii. The vehicle details are displayed to the Security Guard for confirmation. iii. The Security Guard confirms the vehicle details. (i.e the ticket number issued.) iv. The vehicle exits the Institution. v. The vehicle time out is recorded.

4.6 System Sequence Diagram

System sequence diagrams are visual summaries of a use case. The Figure 4.4 is a System Sequence Diagram that depicts the add vehicle details use case. This use case has a pre-condition that requires the scan number plate process to have occurred successfully.

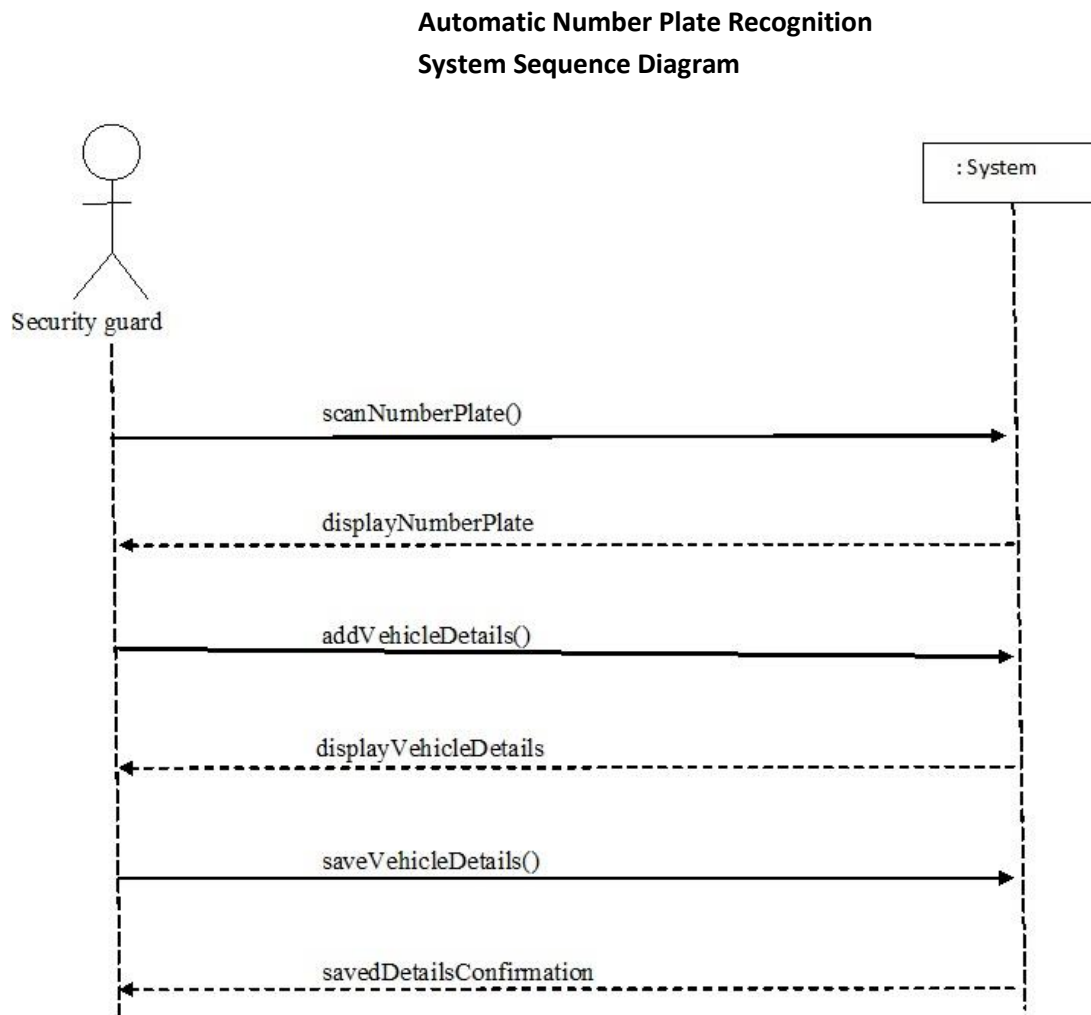


Figure 4.4: System Sequence Diagram

4.7 Context Diagram

A Context Diagram is a component of Functional Modeling that allows for a team or an individual to produce a high-level model of an existing or planned system. It defines the boundary of the system of interest and its interactions with the critical elements in its environment. A Context Diagram is a single picture that has the system of interest at the center, with no details of its interior structure or function, surrounded by those elements in its environment with which it interacts (Burge, 2011).

The Figure 4.5 is a Context Diagram for the Automatic Vehicle Entry Registration System detailing the interactions with the users of the system that include the Security Guard and the Head of Security Officer.

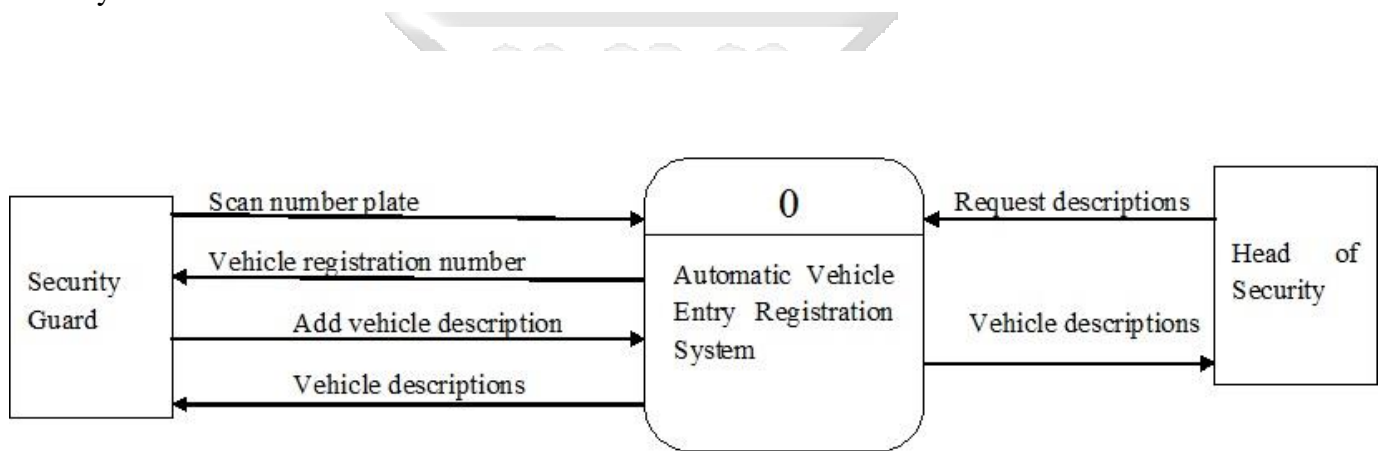


Figure 4.5: Context Diagram

4.8 Client Application Design

Figure 4.6 displays mock-up screen of the application Home Page. The first screen: Having four buttons.

- i. Entry
- ii. Logs
- iii. Members
- iv. Records

When the Members button on the home page is pressed, the application displays the Members page that allows the user to input the Member details. These details include: Vehicle Registration number, Color, Make, Member description. Figure 4.7 displays a mock-up of the Members Page.

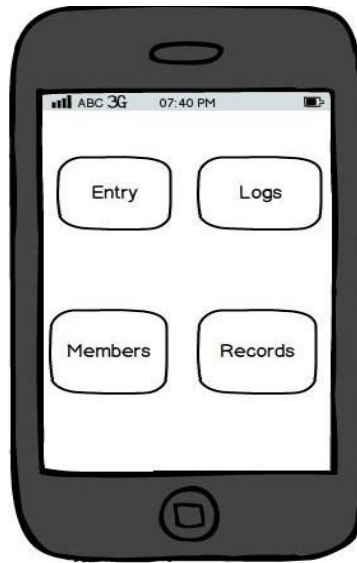


Figure 4.6: Home Page

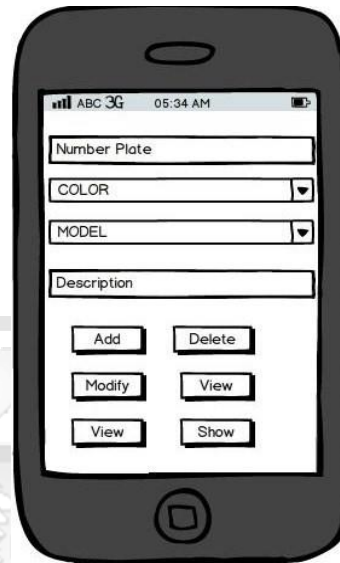


Figure 4.7: Members Page

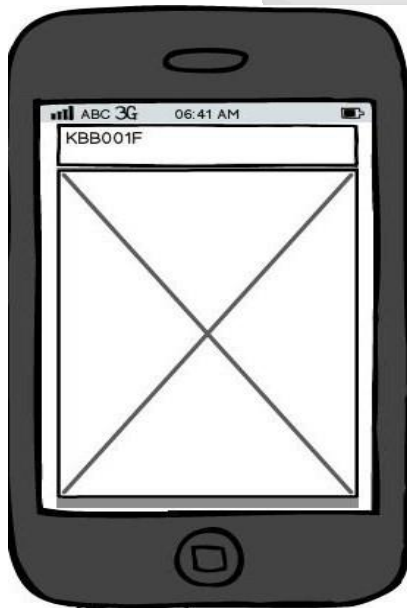


Figure 4.8: Camera view

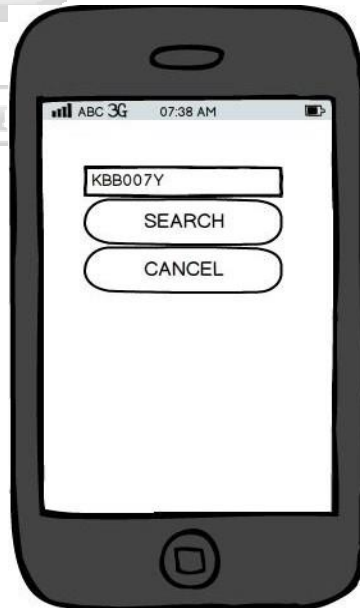


Figure 4.9: Search view

Once the user clicks on the Entry button on the home page, the mobile device camera gets activated. The mobile device camera allows for photographs of number plates to be captured. Once an image of the number plate has been captured the application should extract and display the number plate from the image. Figure 4.8 is a mock-up screen of the camera view.

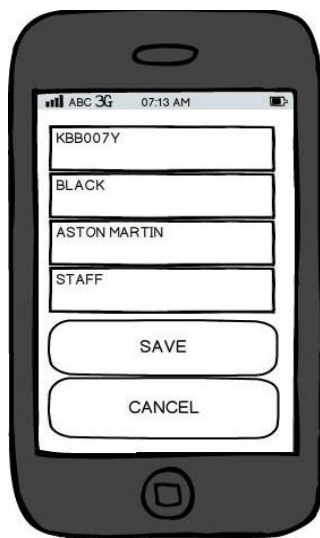


Figure 4.10: Member Details

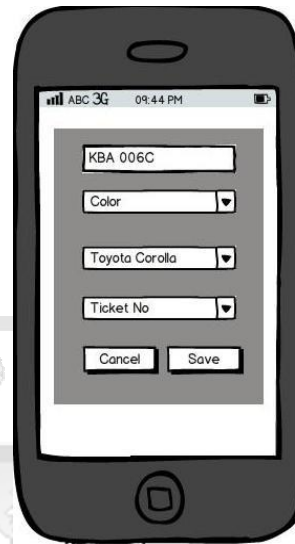


Figure 4.11: Capture Details

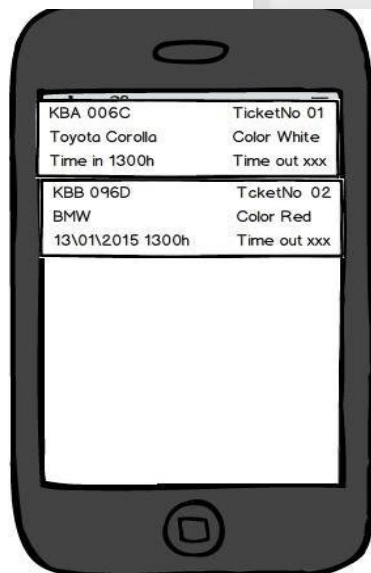


Figure 4.12: Saved Details

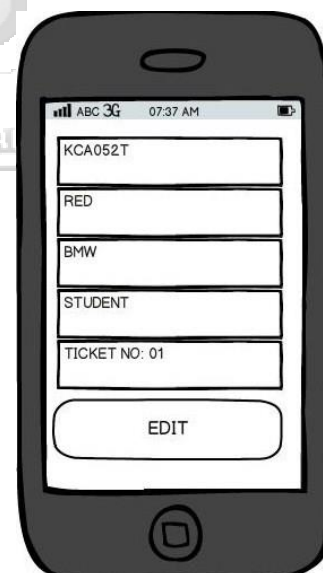


Figure 4.13: Edit Details

Once the vehicle number plate is displayed, the user may search if the number plate captured appears on the members list or not. Figure 4.9 is a mock-up screen depicting the vehicle search functionality. If the vehicle is present on the members list, then the member details are fetched and displayed. Figure 4.10 displays a screen in which a member details have been found. If the vehicle is not present in the members list then capture details screen appears. The user can select the vehicle make and color from a predefined list, as well as input the ticket number issued to the vehicle at this screen. Figure 4.11 is a mock-up of the capture details screen.

Once the user clicks on the save button either on the member details page or on the capture details page. The vehicle details are saved onto a log file. Figure 4.12 is a mock-up of the saved details screen. In case there was any inaccuracy the user can edit any of the saved details except from the time in and time out of the vehicle. Figure 4.13 is a mock-up of the edit details page.

The application has the ability to store vehicle entry records of each day so as not to mix the current records with previous records. The figure 4.14 is a mock-up of the daily lists screen having stored data on different days



Figure 4.14: Daily list

4.9 Server Side Application

The Head of Security will have an administrator's portal, where he can login to view the vehicle details that have been uploaded by the Security Guards who are manning the gates. Figure 4.15 is an example of how the login page will look like.

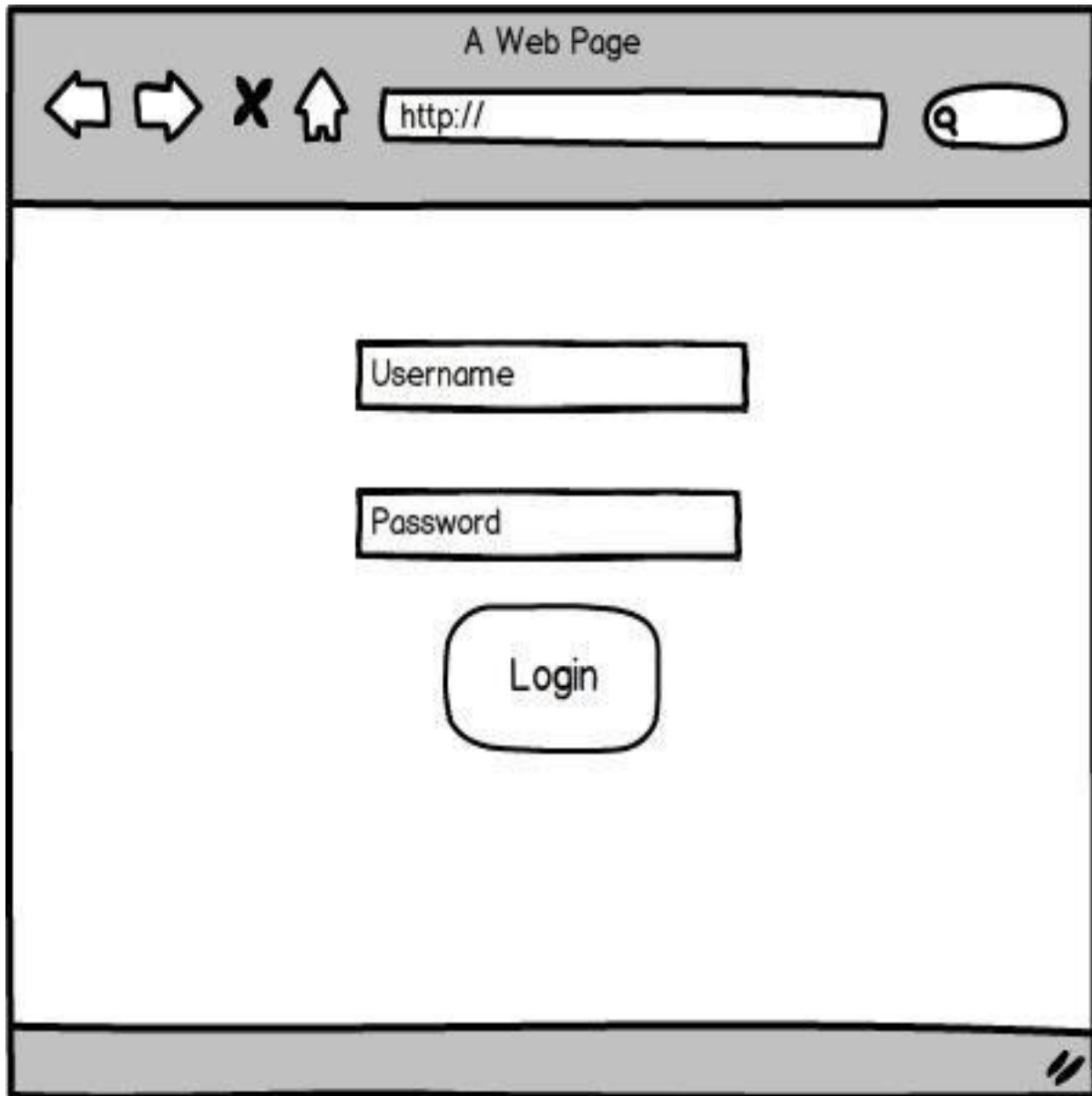


Figure 4.15 Login Portal

Once the Head of Security has successfully logged in, he will be able to view the vehicle details that have been uploaded. Figure 4.16 is an example of how the vehicle details will be presented.

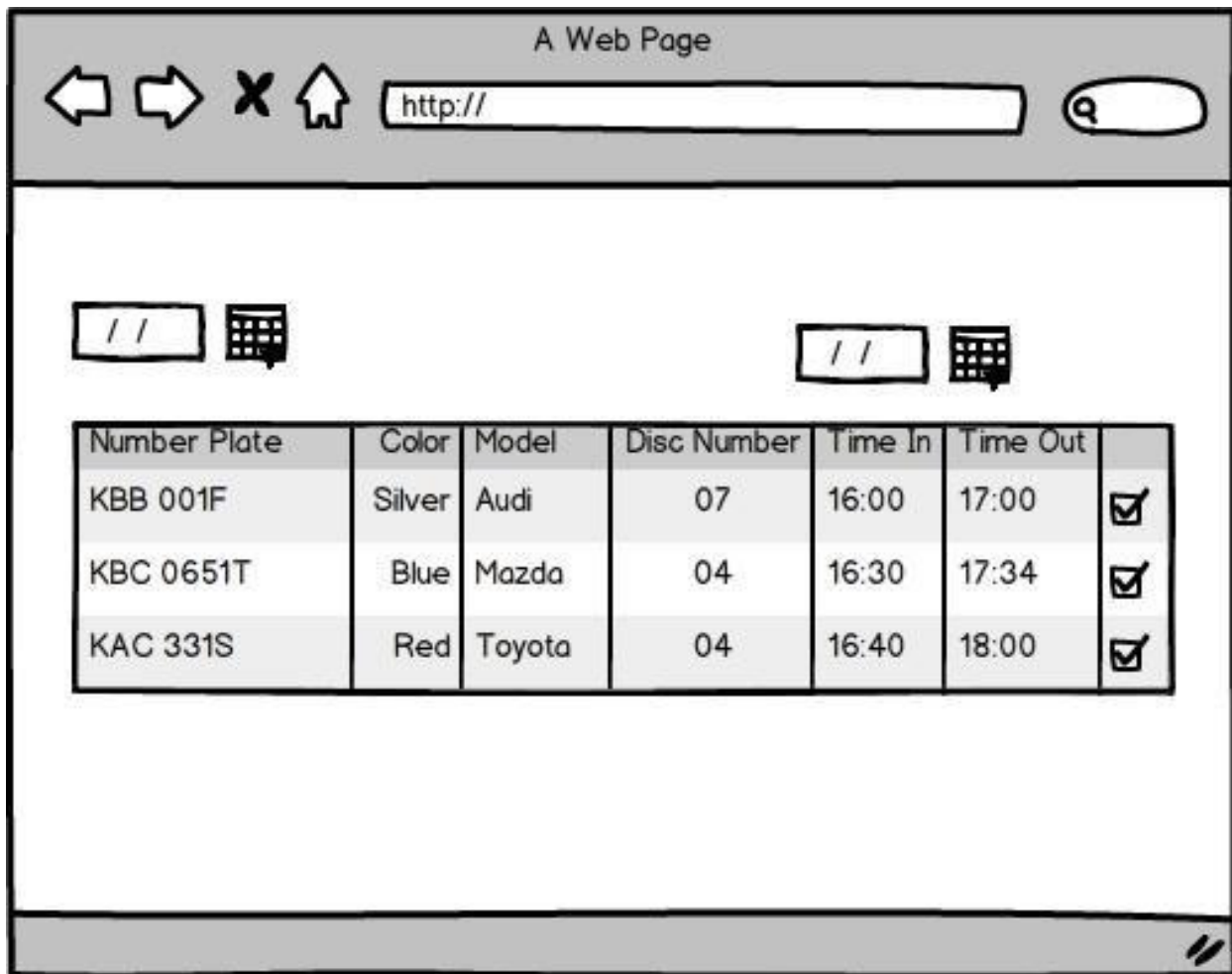


Figure 4.16 Vehicle Details Portal

4.10 Data Storage

The vehicle data that is recorded at the entrance gate of the Institution consist of:

- i. Vehicle number plate
- ii. Entry and exit time of the vehicle
- iii. Ticket number issued to vehicle
- iv. Vehicle model
- v. Vehicle color

This data will reside on the mobile device as well as on an online database. On the mobile device the vehicle data captured will be written onto a text file and saved on the external storage device.

The data saved on the mobile device will be in a JSON array format. The following is an example of how the data will be represented.

```
{“vehicleInfoArray”:[“numberPlate”:”KBB056T”,”timeIn”:”10:00 03-05-2015”,
“timeout”:”17:00 03-05-2015”,”ticketNo”:”05”,”model”:”BMW”,”color”:”White”]}
```

The Figure 4.17 is an entity relationship diagram illustrating the interactions between the various entities

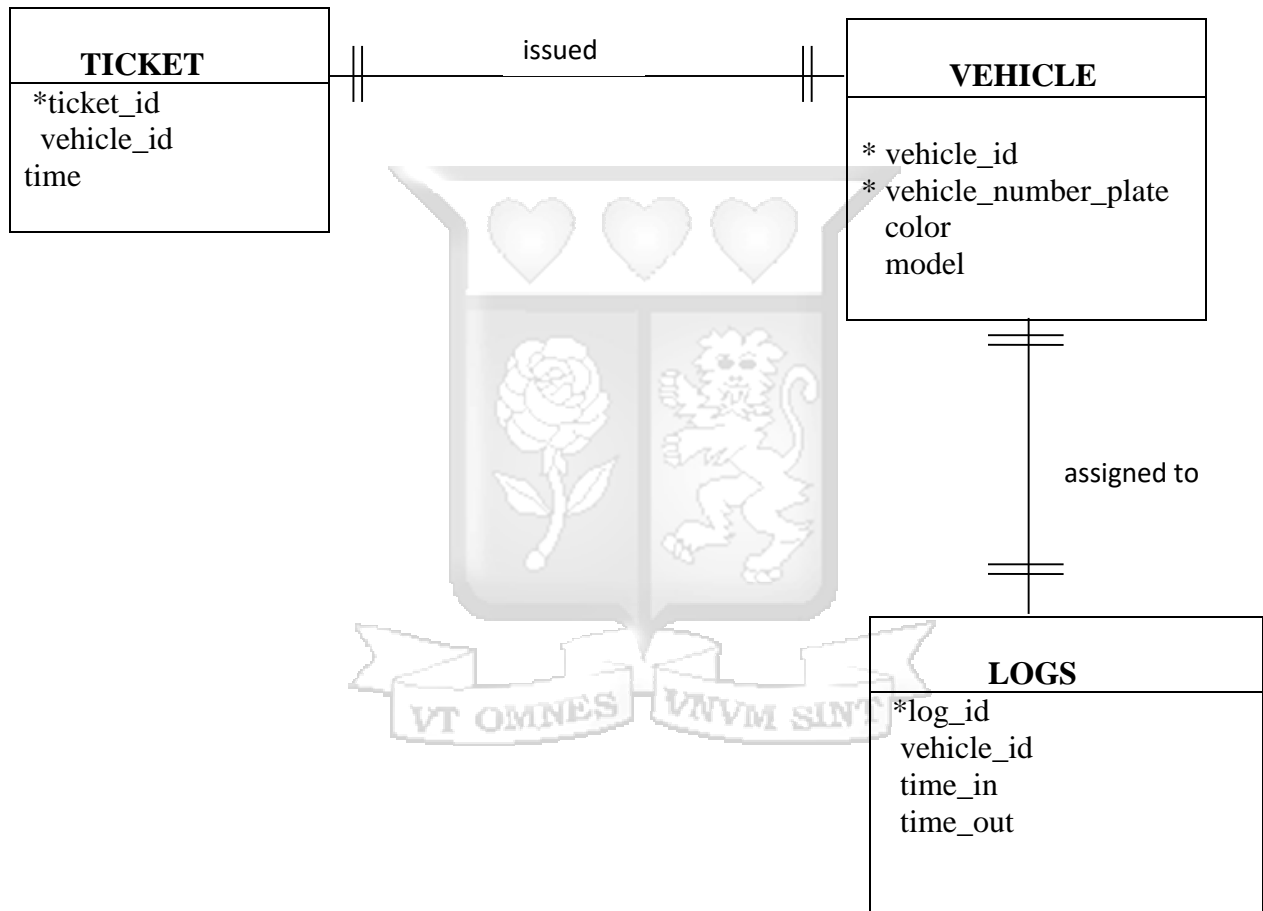


Figure 4.17 Entity Relationship Diagram

Chapter Five: System Implementation and Testing

5.1 Introduction

This chapter we discuss the development and the testing of the system. While using an Object-Oriented System Development methodology the researcher was able to test functional units of the mobile application as development was going on.

5.2 System Development Tools

With regards to the system architecture discussed in the previous chapter, this system can be split into two main categories namely the client side and the server side. The tools required in the development of the client side application include, Android SDK (Software Development Toolkit) version 4.0.3, Abby FineRead OCR library, Eclipse IDE (Integrated Development Environment).

As for the server side the main development tools include the use of MySQL database for the storage of vehicle data, HTML (Hyper Text Markup Language) for creation of web-pages, PHP (Hypertext Pre-processor) used in the writing of scripts that are used to interact between the web-pages and the database.

5.3 System Testing

The System Testing methods that the researcher has adopted due to the Object Oriented Development Methodology are described next:

5.3.1 Functionality Testing

Functionality testing is performed to verify that a software application performs and functions correctly according to design specifications. During functionality testing we check the core application functions, text input, menu functions and installation. Functionality testing verifies that an application is still fully functional after deployment (What is functionality testing in software, n.d).

5.3.2 Performance Testing

Performance testing is helpful in developing higher quality software in less time while reducing development costs. The goal is to test performance early and often in the development effort, and

to test functionality and performance in the same time. This is because the longer you wait to conduct performance tests; the more expensive it will become to incorporate changes (Performance testing in the Agile Process, n.d).

5.3.3 User Acceptance Testing (Exploratory)

User Acceptance Testing is a formal testing with respect to user needs, requirements, and business processes conducted to determine whether or not a system satisfies the acceptance criteria and to enable the user, customers or other authorized entity to determine whether or not to accept the system. In User Acceptance Test we already know what kind of feature is being tested by the user and the user's expectation (Vroomans, 2014).

5.4 Application Testing

The first release of the application was tested by the actual users of the system, the users primarily comprised of the Security Guards at the different entry points of the University. Testing was performed in order to get the users feedback on how the actual system was working in the real world.

The first test that was carried out was a functional test that was testing the most complex and challenging part of this system which included the use of Optical Character Recognition processes (OCR) in order to detect and display the number plate in a plain text format. This process is also referred to as scanning of the vehicle number plate. This process crucial in this system and it forms the basis of the entire system. The results of the unit test are recorded in Table 5.1.

Table 5.1: Scan Vehicle Number Plate Test Case results

Test Case Name: Scan Vehicle Number Plate		Test Case Number 1	
Brief Description: Application should be able to capture and display vehicle number plate			
Pre-condition: The mobile application is installed on the user's mobile device.			
Step	Action	Expected results	Pass/Fail
1.	User clicks on the entry button on the home page	The mobile device camera should open.	Pass
2.	User clicks on the record icon	The record icon button color changes to yellow to indicate camera is recording	Pass
3	User points the camera on a number plate	The application should output the number plate in string format	Pass
Post condition: The vehicle number plate is displayed.			

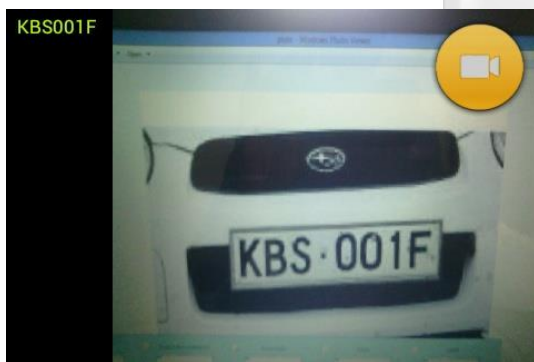


Figure 5.1: Vehicle Scan

The Figure 5.1 is screen shot of the application while performing the OCR process in order to capture the number plate from the image. The number plate that has been captured is displayed on the left side of the screen.

The second type of test performed on the system was performance testing, which was testing on the accuracy of the system in the OCR implementation in the number plate scanning process. The results of the performance test were recorded in the Table 5.2.

Table 5.2: Accurate Number Plate Display Test Case results

Test Case Name: Accurate number plate display		Test Case Number 2	
Brief Description: Application should be able to display an accurate vehicle number plate			
Pre-condition: The number plate should be clearly visible, there should be proper lighting and camera positioning.			
Step	Action	Expected results	Pass/Fail
1.	User clicks on the entry button on the home page	The mobile device camera should open.	Pass
2.	User clicks on the record icon	The record icon button color changes to yellow to indicate camera is recording	Pass
3	User points the camera on a number plate	The application should output the correct number plate in string format	Pass
Post condition: The vehicle number plate is correctly displayed.			



Figure 5.2: Vehicle Scan

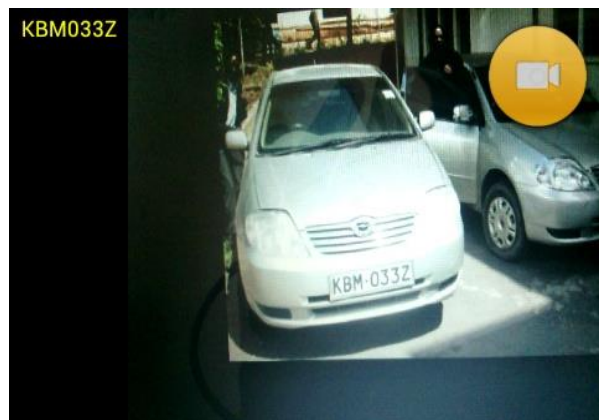


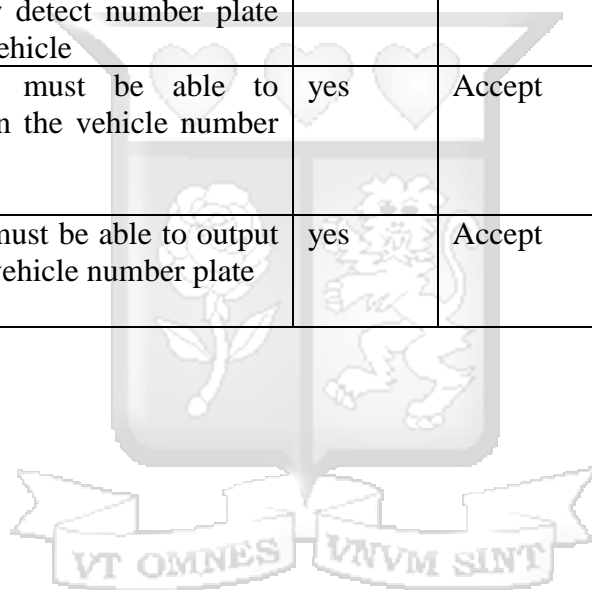
Figure 5.3: Vehicle Scan

The Figure 5.2 and Figure 5.3 are screen shots of the application while performing the vehicle scanning process in order to capture the number plate from the image. The number plates were accurately captured and displayed on the left side of the screen.

The third test conducted was the User Acceptance Test (UAT). UAT involves testing of the software by the user/client to determine whether it can be accepted or not. The results of the test are recorded in the Table 5.3

Table 5.3: Accurate Number Plate Display Test Case results

Number	Acceptance Requirement	Critical: Yes/No	Test Results: Accept/Reject	Comments
1.	The system must be able to automatically detect number plate position on vehicle	yes	Accept	Number plate detection must occur before vehicle scanning can take place
2.	The system must be able to correctly scan the vehicle number plate	yes	Accept	Scanning of the vehicle number plate allows for the vehicle number plate to be captured.
3.	The system must be able to output the scanned vehicle number plate	yes	Accept	After successful scanning the number plate should be displayed in plain text.



5.5 Application Screen Shots

The application that was developed by the researcher had the following representations. The figure 5.4 is the application home page having four buttons i.e. Entry, Logs, Members, Records. When the user clicks on the Members button, the members' page is displayed as shown with figure 5.5. On the members page the user has the options to add, delete, view, or modify any of the member details. Some of the member details include: vehicle number plate, make of the vehicle, color of the vehicle as well as the name of the member.

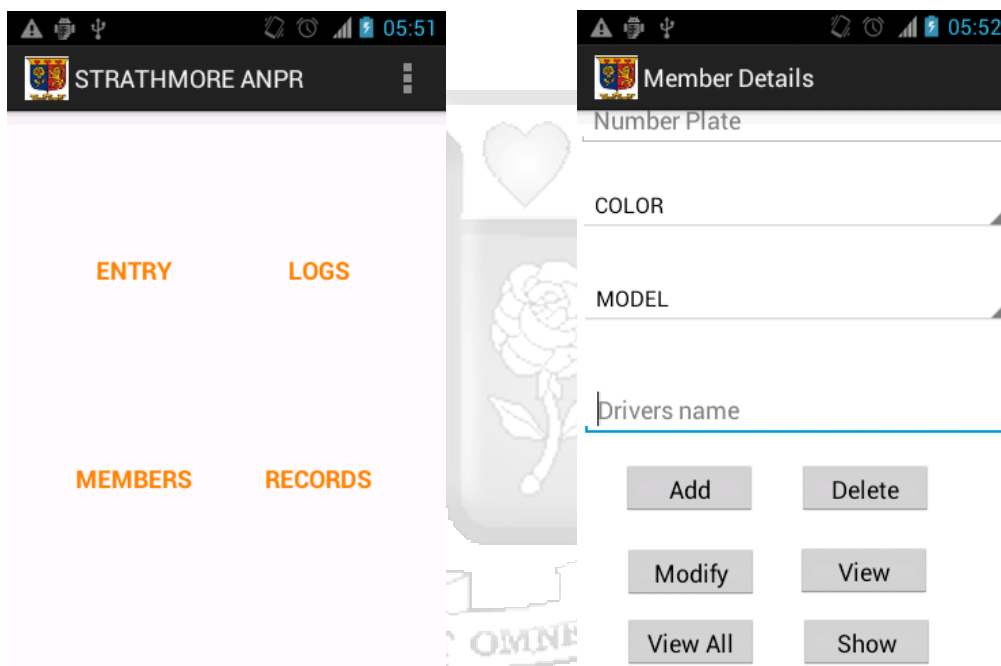


Figure 5.4 Application Home Page

Figure 5.5 Members Page

Once the user clicks on the Entry button on the home page the application opens the device camera. The figures 5.2 and 5.3 are screen shot examples of the vehicle scan page that allows for the vehicle number plate to be automatically captured. Once the number plate has been captured it is displayed to the user on the left side of the screen. Once the user clicks on the number plate a dialog box appears with two buttons search and cancels as show in figure 5.6. When the user clicks on search, the captured number plate is queried against the members' list if the number plate exists in the members' list then the stored vehicle details are displayed as shown in figure 5.7.

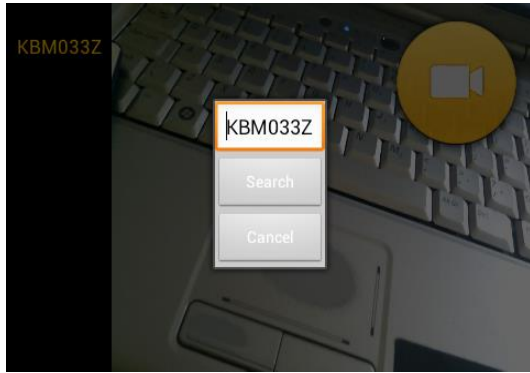


Figure 5.6: Search Dialog



Figure 5.7: Details Dialog

Figure 5.8 is a sample screen shot if the number plate captured does not exist in the members' list then application displays a different dialog box, allowing the security guard to capture the additional details such as vehicle type, color as well as ticket number assigned to the vehicle.

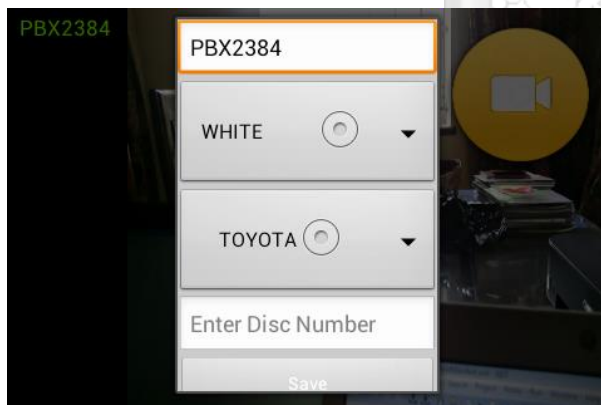


Figure 5.8: Details Dialog

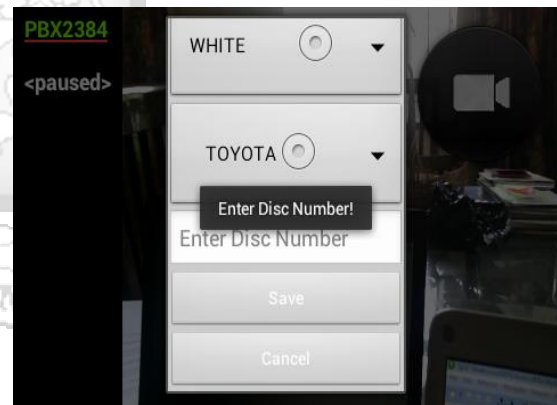


Figure 5.9: Details Dialog

It is a requirement that all vehicles entering the University have to be issued with a parking disc (ticket) these discs have number associated to each one. Hence when the user is saving the vehicle details and no disc number has been inputted. The application gives a notification of the required field as shown in figure 5.9.

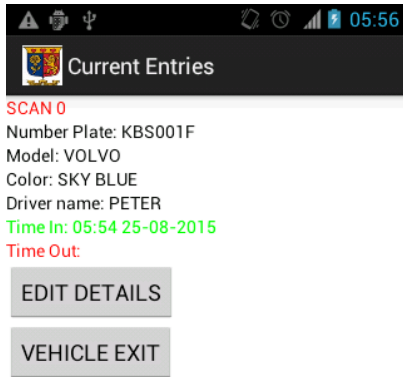


Figure 5.10 Current Entries

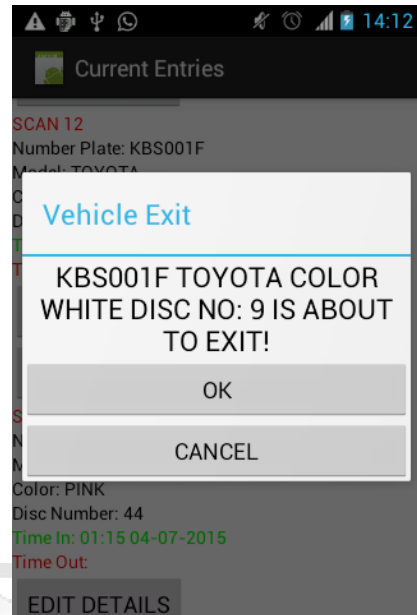


Figure 5.11 Vehicle Exit

Figure 5.10 is a screen shot of the current entries page, this page displays all the vehicles that have been recorded on that particular day. The vehicle details that have been recorded include the vehicle number plate, make of the car, driver description as well as time of entry of the vehicle. When the vehicle is about to exit, the user gets a pop-up dialog prompting him or her to confirm that the vehicle is about to exit as shown in figure 5.11.

Figure 5.12 is a screen shot of an administrators login portal, whereby the Head of Security logs in order to view the vehicle details that have been uploaded by the Security Guards.

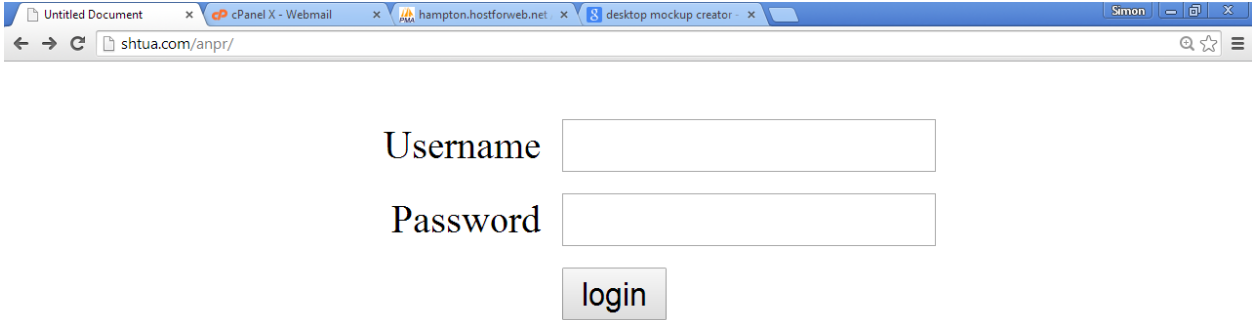


Figure 5.12 Administrators Login



Figure 5.13 is a screen shot of the vehicle details that are viewed by the Head of Security from a web portal.

Simple Admin | cPanel X - Webmail | hampton.hostforweb.net | desktop mockup creator - x | Simon

shtua.com/anpr/home.php

Welcome Kennedy

From: mm/dd/yyyy To: mm/dd/yyyy Search

PLATE FILTER Plate search

Browsing History

	DISC NO	NUMBER PLATE	COLOR	MODEL	TIME IN
<input type="checkbox"/>	32	KBJ936A	GREEN	MITSUBISHI	08:54 15-04-2015
<input type="checkbox"/>	24	KCB983E	BLACK	TOYOTA	08:54 15-04-2015
<input type="checkbox"/>	23	KBS404M	SILVER	AUDI	08:54 15-04-2015
<input type="checkbox"/>	69	KBY447U	WHITE	TOYOTA	08:54 15-04-2015
<input type="checkbox"/>	15	KBL281N	SILVER	TOYOTA	08:54 15-04-2015
<input type="checkbox"/>	51	KBH843S	WHITE	TOYOTA	08:42 15-04-2015
<input type="checkbox"/>	30	KBI717T	RED	SUBARU	08:42 15-04-2015
<input type="checkbox"/>	48	KCA790T	WHITE	TOYOTA	08:40 15-04-2015
<input type="checkbox"/>	44	KAT492W	GREEN	SUBARU	08:13 15-04-2015
<input type="checkbox"/>	62	KAR922R	SILVER	TOYOTA	08:13 15-04-2015
<input type="checkbox"/>	08	KAW430J	WHITE	TOYOTA	08:02 15-04-2015
<input type="checkbox"/>	63	KAY014M	BLUE	NISSAN	08:02 15-04-2015
<input type="checkbox"/>	67	KCA048S	BLUE	MITSUBISHI	07:44 15-04-2015

9:42 AM

Figure 5.13 Vehicle Details

VT OMNES UNUM SINT

Figure 5.14 is a screen shot of the vehicle chart records that display the total number of vehicles that entered the University in the last seven days.

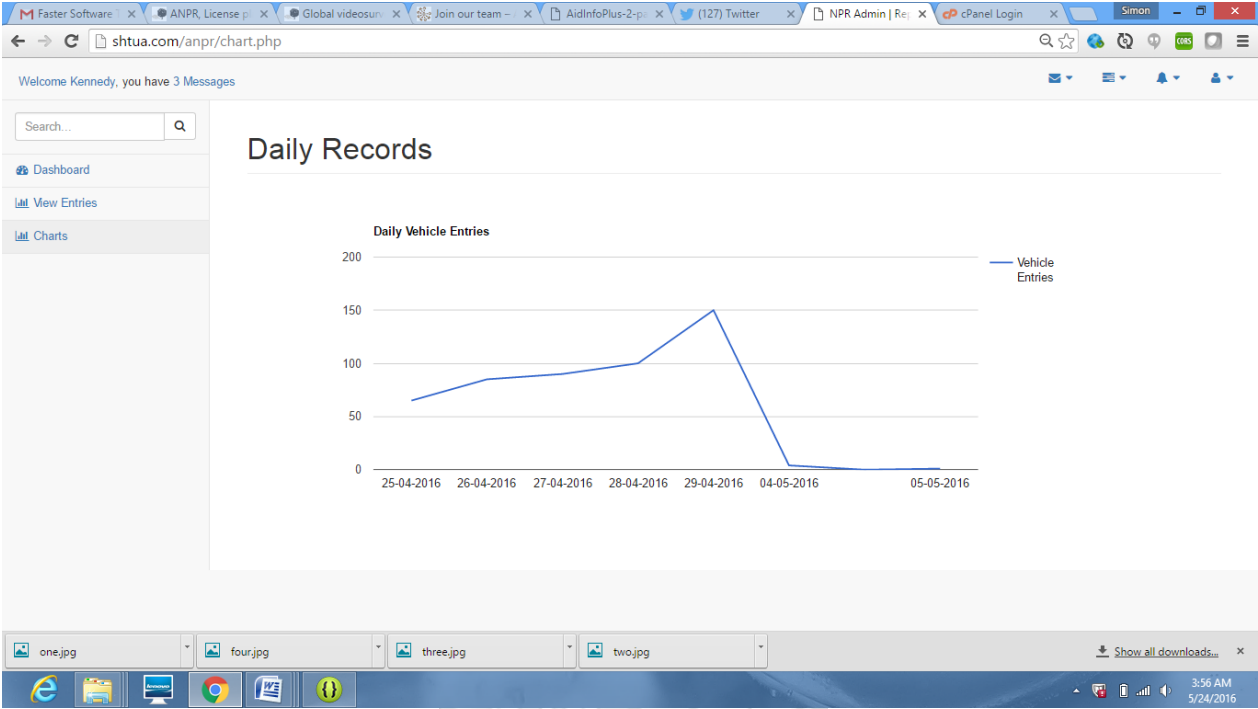
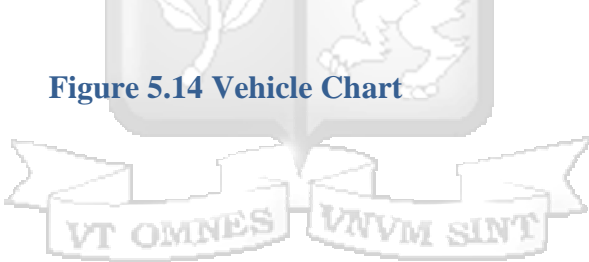


Figure 5.14 Vehicle Chart



Chapter Six: Discussion of the Results from Testing

With regards to the research objectives the researcher was able to investigate the current vehicle entry registration system within Strathmore University and the researcher found that it took approximately 30 seconds for three security guards working together in order for them to register a vehicle as it is entering the Institution. Each security guard is tasked with the specific role; the first security guard is tasked with asking for identification from the driver to prove if he or she is a student, staff or visitor. The second guard is tasked with opening the gate and handing out the ticket to the driver, while the third guard is tasked with writing down the vehicle details which includes; vehicle number plate, vehicle make, model and color, the ticket number issued as well as time of entry.

All this information is handwritten onto an occurrence book. The process of writing down all this vehicle information is quite tedious, monotonous and prone to errors. Especially on a busy day whereby there are more than 300 vehicles visiting the Institution's premises.

Due to the challenges of the current system the researcher was able to propose a new model for the registration of vehicles as they entered the Institution. This new model involved the use of Optical Character Recognition in order to automatically capture, scan and display a vehicle's number plate in a timely and user friendly manner.

The first version of the mobile application was released and it was subjected to both performance and functional tests. During testing, the application was able to correctly meet the users' expectations in that the application was able to detect, scan and display the vehicle number plate. These results proved that the researcher was able to investigate the challenges involved in implementing an automatic number plate recognition system as well as to develop mobile application that automatically recognizes and captures a vehicle's number plate. In comparison to other existing automatic number plate recognition systems, there are several hardware and software elements that are required for a successful implementation (Automated License Plate Recognition Vendors, n.d.). Whereas this research was able to prove it is possible to successfully implement an ANPR system using software that has OCR capabilities operating on a mobile device.

A user acceptance test was carried out on the first version of the application. This test was performed in order to check whether the application was able to meet the user's expectation in a

real world with regards to the vehicle entry registration process. The user acceptance test was successful due to the reason that the mobile application is able to successfully detect, scan and display the vehicle number plate in an average time of six seconds. The Table 6.1 is a comparison between the times taken to write down the vehicle details versus the time taken to scan and inputting the vehicle details.

Table 6.1 Time taken to record vehicle details

Vehicle No.	Time taken to write down vehicle details (T-₁)	Time taken to scan number plate and add vehicle details (T-₂)
1.	30 sec	7 sec
2.	25 sec	7 sec
3.	35 sec	5 sec
4.	40 sec	6 sec
5.	20 sec	5 sec
6.	25 sec	5 sec
7.	35 sec	8 sec
8.	45 sec	8 sec
9.	40 sec	7 sec
10.	40 sec	6 sec
11.	30 sec	5 sec
12.	25 sec	6 sec
13.	35 sec	5 sec
14.	30 sec	5 sec
15.	30 sec	6 sec

$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n}$$

Where: \bar{x} = average time taken
 x_i = time taken
n = number of cars

The researcher was also able to test the efficiency and effectiveness of system versus the current vehicle entry registration process. The results of the efficiency and effectiveness were affected by several factors such as number plate positioning, whereby the number plate could not be correctly read if there was an item such as a bumper in front of it.

Another factor affecting the efficiency and effectiveness was the amount of light. The application was tested during the day when there was plenty of light from the sun and the results were accurate capturing of the number plate. However, the application was also tested in the late evening where the amount of light was low and the application could not detect the number plate.

Distance between the mobile device and the number plate is another factor affecting the efficiency and effectiveness of the system. During testing it was found out that the maximum distance that is allowed in order for the system to accurately capture the number plate is five meters if the distance is greater than five meters then the application cannot detect the number plate.

The above mentioned factors that may cause system in-accuracy may be mitigated with the following strategies;

- i. Vehicle scanning of the rear number plate in case the front number plate has an item hindering it or vice versa.
- ii. Artificial light from a torch or a light bulb may be used.
Note: The light should be able to cover the entire number plate.
- iii. Use of optical zoom lenses to allow for scanning of vehicles that are far off.

Chapter Seven: Conclusions and Recommendations

This dissertation was action oriented. It sought to implement a solution to the challenges faced by the Security personnel in terms of vehicle identification and vehicle registration for all the vehicles that enter and exit the University premises. The result was the implementation of software application operating on a mobile device that allows for easy identification and registration of vehicles.

7.1 Conclusions

The researcher has been able to successfully implement the use of Optical Character Recognition (OCR) on a mobile application that allows for the automatic detection, recognition and display of vehicle number plates. The OCR process forms the basis of the entire system that was proposed by the researcher as a means of tackling the challenges faced by the security guards during the vehicle entry registration process.

The completion of the proposed system resulted in the following benefits:

- i. Elimination of the hard copy occurrence book and the need to have to physically write onto the book, because all the vehicle details records will be digitized.
- ii. Hastening of the vehicle entry registration process, thus shortening the time spent in recording vehicle details as they enter the University.
- iii. Accurate recording of vehicle information.
- iv. Provides a means of easy information sharing and information backup.
- v. Real time information sharing of the vehicles entering and exiting the Institution to the Head of Security.
- vi. Easier analysis of the vehicle information captured.

7.2 Recommendations

An Automatic Number Plate Recognition System is primarily a tool for vehicle identification. With proper implementation an ANPR system can be useful in:

- i. Identification of vehicles that have been reported as stolen.
- ii. Identification of vehicles that are wanted for having committed traffic offenses.
- iii. Identification of vehicles that have fake registration certificates.

7.3 Suggestion for future work

ANPR technologies can be implemented in several scenarios whereby there is a need to monitor all vehicles that are accessing or exiting from a particular vicinity. For example ANPR technology can greatly enhance border patrol and border surveillance whereby all the vehicles entering or exiting the country can be quickly checked to see if there are any known offences that relates to that particular vehicle before the vehicle is granted entry or exit into the country.



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Appendix A: Interview Guide

1. Build Rapport:
Provide introductions and ask rapport-building questions to put the candidate at ease.
2. Establish motive:
Explain to the candidate the reasons for wanting to conduct the interview.
3. Begin interview:

General Background

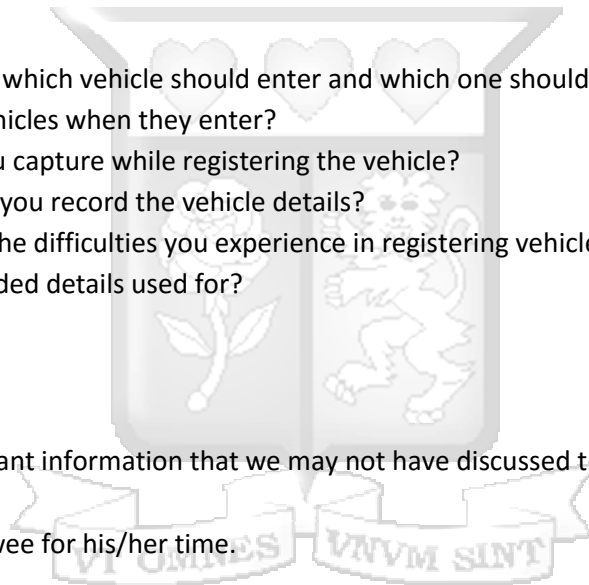
1. Name.
2. Number of years working as a Security Personnel.
3. Other work stations they have been posted in.
4. How often do they rotate in their work stations?

Specific Information.

1. How do you decide which vehicle should enter and which one should not?
2. How do register vehicles when they enter?
3. What details do you capture while registering the vehicle?
4. How and where do you record the vehicle details?
5. What are some of the difficulties you experience in registering vehicles?
6. What are the recorded details used for?

Interview conclusion

1. Is there any significant information that we may not have discussed that you would like to include?
2. Thank the Interviewee for his/her time.



Appendix B: TurnItIn Report

