DEVELOPMENT OF A TWO-FACTOR AUTHENTICATION FOR VEHICLE PARKING SPACE CONTROL BASED ON AUTOMATIC NUMBER PLATE RECOGNITION AND RADIO FREQUENCY IDENTIFICATION

BY

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirement for the award of the degree in Masters of Computer Science

Master of Science in Computer Science

December 2019

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I, the undersigned, declare that this dissertation has not previously been submitted in candidature for any degree. The dissertation is the result of my own work and investigations, except where otherwise stated. Other sources are acknowledged by given explicit references. A complete list of references is appended.

Some sections of this work has been published in the International Journal of Advanced Computer Science and Applications (IJACSA), under the title: **Development of a two factor authentication for vehicle parking space control based on Automatic Number Plate Recognition and Radio Frequency Identification.**

Volume 10 Issue 1, 2019.
Digital Object Identifier (DOI) : 10.14569/IJACSA.2019.0100174

Signature: ……………………………………………………………….

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Approval

This dissertation by **Friday Chisowa Chazanga** is approved as fulfilling the requirements for the award of the degree of Master of Science in Computer Science at the University of Zambia.
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Acknowledgement

I am greatly thankful to Dr. Jackson Phiri who provided unreserved parental guidance throughout the research period. His supervision and guidance is second to none. He remains a great inspiration and a mentor. Acknowledgement is also given to Mr Sebastian Namukolo and Dr. Simon Tembo for their encouragements.

I also wish to acknowledge the contributions made by my dear colleagues Kasanda Kabwita, Liyanda Situmbeko and Tandiwe Tembo through their undergraduate projects.

Last but not the least, I am indebted to my dear wife and my children for the support, encouragements and understanding during the period of study.

May the grace of the Almighty God be upon the aforesaid through Christ Jesus our Lord and Saviour.

Dedication

I dedicate this dissertation affectionately to the Almighty God for health life and all success. My wife Monica Mulenga Chazanga, my children; Mainess, Emmanuel, Ruth, Friday and Luyando, my biological parents and my parents in law who have always been on my side. I will always cherish their unconditional love, support and endurance.

I also heartily dedicate this dissertation to my church family and friends for their prayers and good will throughout the study.

Abbreviations and Acronyms

ANPR	Automatic Number Plate Recognition
RFID	Radio Frequency Identification
UNZA	University of Zambia
IR	Infra-Red
ADC	Analogue Digital Converter
OOB	Object Oriented Design
RGB	Red, Green and Blue
AVR	Automatic Voltage Regulation
USB	Universal Serial Bus
LED	Light Emitting Diode
PWM	Pulse Width Modulation
GND	Ground
TX	Transmit
RX	Receive
DC	Direct Current
AC	Alternating Current
LCD	Liquid Crystal Display
CCD	Charge Coupled Display
CMOS	Complementary Metal-Oxide Semiconductor
USI	Universal Serial Interface
MOSFET	Metal Oxide Semiconductor Field Effect Transistors

Abstract

The University of Zambia is experiencing increasing challenge of car parking space and vehicle access controls to and within campus premises. Vehicles have been stolen without being detected. There has not been any effective means of recording and tracking vehicle activities in and out of campus. This is because the current vehicle access controls at the University of Zambia (UNZA) is manual. This study proposes an automated vehicle access control system that will regulate vehicle access to designated car parking areas, prevent car thefts as well as track vehicle activities in the campus. The study was guided by two (2) objectives. A baseline survey was conducted to assess the performance of the current manual vehicle access control system. The results of the survey reviewed that members of staff found difficulties in finding parking spaces due to intrusion. The survey results also showed acts and threats of car thefts within campus premises. As a result of these shortfalls, most respondents recommended for an electronic system that would keep records of vehicle and driver activities and prevent car thefts. Scholar databases were examined to find related literature. Technologies such as Automatic Number plate Recognition (ANPR) and Radio Frequency Identification system (RFID) were found to have been widely used in the automobile industry. A two factor authentication for vehicle access control based on Automatic Number Plate Recognition (ANPR) and Radio Frequency Identification system (RFID) for the University of Zambia (UNZA) was developed. The outcome of the system provided five configurable states each being suited for a particular access point. The system used 'ORed' and 'ANDed', logic settings to achieve the different authentication states. A functional prototype was developed using Arduino to ascertain the feasibility of the system. From the results of the study, it has been recommended that the University of Zambia implements the system in order to effectively monitor and control vehicles, prevent vehicle thefts and bring about effective and efficient use of parking space.

Keywords: RFID, ANPR, Vehicle access control, Multifactor authentication

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CHAPTER ONE
INTRODUCTION TO THE RESEARCH

1.1 Introduction

With the rise of a number of vehicles that enter campus premises, vehicle access controls and management becomes a challenge. Currently, the University of Zambia is using manual system to authenticate vehicles that enter and leave the campus. Car thefts are on the increase, Parking spaces are becoming scarce, monitoring and tracking of vehicles is becoming difficulty. Attempts to authenticate every vehicle and driver at various access points by the security personnel leads to congestion and inefficient time management.

This study proposed a model that electronically provided authentication to vehicle access into and out of car parks and campus premises. The system also provided monitoring and tracking of vehicle movements through number plate captures and driver identification. The implementation was done by using a boom gate barrier system prototype for vehicle access in and out of premises at particular access points. The model offered five configuration access states that would be tailored to suit access authentication requirement at different access points. The study was necessitated by the outcome of a survey that was carried out that highly recommended for a secure electronic vehicle access control system that would keep records of both vehicle and driver activities.

A proposed model addressed the limitations and challenges reviewed in the survey by providing a two factor authentication with five configurable authentication states. Traditional manually operated gates have been inefficient and are rapidly being replaced by the superior electronic control systems with a variety of features [1]. If strict adherence of all admittance conditions and record keeping is done on manually operated gates, inefficient time management, congestion and human error would be eminent. Elimination of vehicle thefts as well as tracking stolen vehicles become difficulty. This design of an electronic vehicle access control system was based on needs assessment and is an answer to the challenges faced.

1.2 Background Information

The University of Zambia (UNZA) has in the recent years experienced unprecedented increasing challenge of car parking space control and vehicle access controls to campus premises. In a survey that was conducted to ascertain the need for an electronic system, three categories of personnel were interviewed, thus; Members of staff, Visitors/students and Security personnel. Most respondents highly recommended for a secure electronic system that would keep records of both vehicle and driver activities. Survey findings reviewed that access to parking space by members of staff in a number of Schools has been a challenge due to students' and visitors' access to them. On the other hand, car thefts are also a threat to most staff. Some entrances to the University require user authentication. Security personnel have failed to authenticate each vehicle due to vehicle frequency and human limitations. Some drivers are non-cooperative to them too. This failure has led to unauthorized vehicles using the premises as a drive way, that has led to accidents and death. This paper proposes a solution to vehicle access controls by developing a two factor authentication based on Automatic Number plate Recognition (ANPR) and Radio Frequency Identification system (RFID).

ANPR is a tool that has the capability to detect and recognize the vehicle's number plate and provide the information regarding it with reference to the data base [2] [3]. On the other hand, (RFID) is an ADC technology that uses radio-frequency waves to transfer data between a reader and a tag to identify, categorize, and track objects among others. It is fast, reliable and does not require sight of line or contact to communicate [4]. The Automatic Number Plate Recognition (ANPR) system was invented in the mid-1970s in the United Kingdom at Police Scientific Development Branch. The usage of number plate recognition grew over the years. In 2003, the Netherlands improved their number recognition system by presenting a new font. Currently Automatic Number Plate Recognition systems (ANPR) have become reliable in a number of applications. One of the key application is that of law enforcement of traffic rules or for crime detection by the police.

The history of RFID technologies originates from radar theories discovered by the associated forces during World War II. The technology has been on wide commercial use since early 1980's in a number of applications[5]. Some of the uses include highway and bridge tolls, livestock tracking, transportation freight tracking and motorcycle manufacturing. Due to the technology's versatility, the device has undergone rigorous exploration by several organization [6].

In this study, we are proposing a robust two-factor authentication access control mechanism for vehicles in and out of a restricted premise or car park, using Automatic Number Plate Recognition (ANPR) and Radio Frequency Identification (RFID).

This research develops a two-factor authentication system modal based on ANPR and RFID technologies. A boom gate barrier system prototype will be built for vehicle access in and out of the car park and restricted premises. As much as this research outcome can fundamentally be applied to many institutions where security of vehicle movements is strictly adhered to, we will confine our analysis and application to the University of Zambia.

1.3 Statement of the Problem

The University of Zambia is facing a challenge in the management of vehicle access controls. The current manual vehicle access control is ineffective and inefficient causing congestion and time wastage. Records of car thefts within campus are on the rise with no trace on the suspects. Vehicle activities records are inaccessible. Unauthorised vehicles gain access into and through campus premises.

Studies have been done using technologies such as Number Plate Recognition and Radio Frequency Identification for vehicle access Controls elsewhere but no such study has been done here in Zambia towards such local concerns.

1.4 Aim

To develop a two factor authentication for Vehicle Access Control to restrict and control the use of parking space using a barrier (boom gate) based on ANPR and RFID technologies.

1.5 Objectives

(1) To develop a two factor authentication system modal for vehicle access control based on RFID and AI technologies such as machine learning and Optic Character Recognition (OCR) for ANPR.

(2) To implement a two factor authentication barrier system prototype for vehicle access in and out of the car park based on the modal in 1.

1.6 Research Questions

(1) How can we develop a two factor authentication model based on OCR, RFID and AI technologies for ANPR?

(2) To what extent can we implement a two factor authentication barrier system prototype for vehicle access in and out of the car park?

1.7 Significance of the Study

With the rise of incidences of espionage, theft of property and motor vehicles as well as scramble for parking spaces in many institutions, it has become absolutely necessary to build a robust secured access system to premises that are highly restricted. Additionally, in companies that have a pool of vehicles and drivers like the University of Zambia transport yard, it is usually a challenge to determine which driver has gone with which vehicle and log in and out times. The mostly used manual log in and log out is so ineffective especially on data retrieval and analysis on vehicle usage and activities. By use of this multiple authentication system with a well-built organised database, information retrieval and analysis will become effective, as log in and log out times of both the driver and the vehicle will be saved. Driving out with a non-designated vehicle is impossible thereby reducing vehicle theft.

1.8 Scope

As much as this research outcome can be fundamentally applied to many institutions, such as military premises, central banks, data centres, power stations, maximum security prisons or any other restricted premises, we will confine our analysis and application to higher learning institutions – The University of Zambia, Great East Road Campus.

1.9 Outline of the Dissertation

This dissertation is organised in five main chapters. The first chapter gives the overview of the research. It gives a brief outline of the work done in the dissertation. It includes the following sub titles; background information, statement of the problem, aim, objectives, research questions, significance of the study and the scope.

The second chapter looks at the background theories and related works. In this chapter, a comprehensive literature review on the two main technologies, ANPR and RFID were thoroughly scrutinised as regard to their background, operations and applications. Additionally a review was done for the technology's accessories . Lastly, related works were reviewed.
In the third chapter we looked at the methods used to conduct the baseline survey and the system implementation. Chapter four (4) presented the research findings of the baseline survey and the system implementation. The final chapter, chapter five (5) discussed the results and concluded the research.

1.10 Summary

This chapter cantered at understanding and scrutinising the main challenges faced at UNZA hypothetically. This was addressed by looking at the statement of the problem, aim, objectives, the significance of the study and the scope. The chapter was closed by looking at the outline of the dissertation.

CHAPTER TWO:
LITERATURE REVIEW

2.1 Introduction

This Chapter presents a review of the literature of various players in the study and implementation of Automatic Number Plate Recognition (ANPR) and Radio Frequency Identification Technologies (RFID). Scholar's databases were examined to find related literature. The examination reviewed that studies have been done on Multifactor Authentication security systems in many areas of Artificial Intelligence, Machine Learning and Neural Networks. Many researchers have also proposed different algorithms covering a wider range of vehicle access control systems using technologies such as RFID and ANPR. Infra-Red sensors have been used in the detection of objects and actuation of the system cameras to photograph an image. In this research, a review has been done on Multifactor Authentication, RFID and ANPR technologies, and IR sensors among other techniques and technologies.

2.2 Multifactor Authentication

A multifactor authentication has been deemed a more secure security implementation in many areas of security concerns. Phiri et al [7][8] described a multifactor authentication system as a system that creates a more secure authentication to minimise cybercrime. The system was employed through a fuser block of an artificial neural network and adaptive neural-fuzzy inference system.

2.3 Automatic Number Plate Recognition

2.3.1 Definition

The Automatic Number Plate Recognition (ANPR) system of vehicle number plate consists of two main modules. First is a digital camera of high speed and resolution to capture images of the number plates, infrared "IR" to detect an incoming vehicle and actuate the camera; a processor and application that is able to manipulate Optical Character Recognition (OCR) into numerical characters. The characters are compared with the databases and desired logical output is given[9]. Simin et al [10] and Sonavene et al [11] defined Automatic Number Plate Recognition (ANPR) as a system where car number plate is recognized and identified automatically. Initially, the camera is actuated by an infrared lighting to allow it take a photo.

The camera senses and takes a picture of the vehicle. The vehicle captured image will be sent to pre-processing stage where Grey Image Conversion takes place. The second stage involves Removal of undesirable Lines. Vertical Edge Detection Algorithm are implemented to eradicate undesirable lines and scan the license plate. The Desired Details of the image around the plate area are highlighted and extracted at the third stage[12]. Since ANPR is an image processing technology which uses number plate to identify the vehicle, there is no need for any additional hardware to be installed on vehicles. Figure 2.1 demonstrates the logic of number plate extraction from the capturing of the image to the extraction of the number plate characters.

2.4. System Design

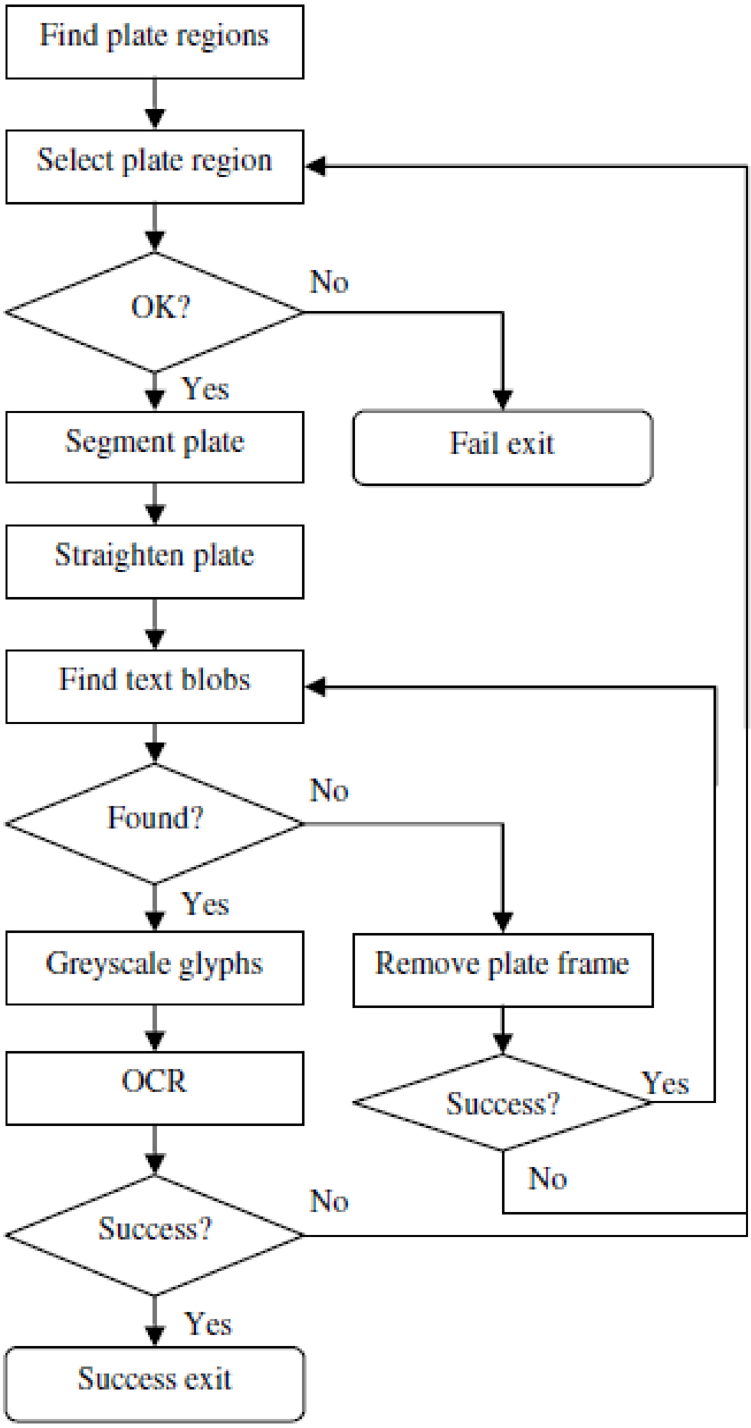


Figure 2- 1 System Design[13]

2.4.1 Image Processing

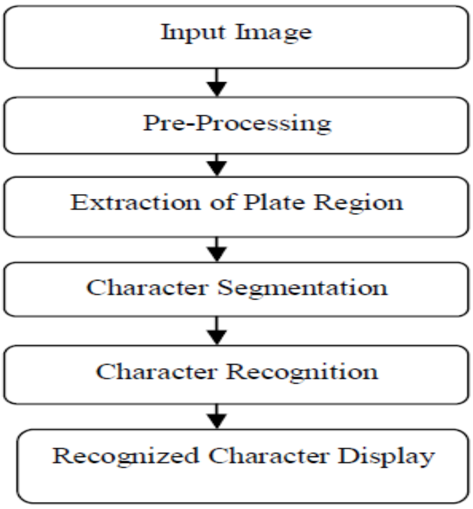


Figure 2- 2 Image processing flow chart[14]

Typical ANPR system consists of four steps, these are Image Acquisition, License Plate extraction, character segmentation, and character recognition as shown in Figure 2.2.

2.4.1.1 Image Acquisition

The first step in automatic number plate recognition image processing process is the Acquisition of an image. The camera powered by IR sensors will be actuated to take pictures of the incoming vehicle[9]. A high resolution digital camera is used, to get an image. The images caught are in RGB (Red, Green and Blue) format so it can be further processed for the Number Plate Extraction. [13].

2.4.1.2 Image Enhancement

Image enhancement is a pre-processing stage that comes after the image has been captured. This step is a very significant step to improve plate image quality for superior segmentation and recognition. It includes adjustment of the image intensity levels, removal of noise and image thresholding[14]. The processes involves classifying connected components and removal of noise. The action is taken in a sequential manner[14]. The classification of components picks suitable data from a large collection. Generally, in this method, transformation is used to manipulate raw data to produce a single input and normalization is used to manage the data in a more suitable way for ease of access [14].

2.4.1.2 Image Processing

Image processing consists of two phases which include; Banalization and Noise Removal:

1) Binarization: At this stage the Image captured in RGB format is converted to gray-scale level. A gray-scale image has a display range of 256, while a binary image has a display range of 2. After the conversion into gray-scale the sobel operator a 3*3 masks the whole image to yield the detected edge[15].
2) Noise Removal: The image captured by camera is affected by noise which is born from the system itself, relative motion of camera or vehicles etc. This noise is eliminated through the filtration process. The result is the improved quality of the image [16].

2.4.1.3 Character Segmentation

The main function of Character Segmentation is to separate each character from the number plate of the vehicle. Once separated, each individual character has to be differentiated from each other. The combined characters of the number plate of vehicle saves as a unique identity [15]. For each character to be extracted , the location of the number plate and its dimensions have to be determined. Horizontal and vertical projections are determined by the individual columns and individual rows of the extracted number plate. Each character is separated by a line, and the black letter is cropped with a white background. After cropping the image then it can be resizes to specific size [15].

2.4.1.4 Character Recognition

Character recognition employs Optical Character Recognition (OCR) to compare each discrete character alongside the other. Optical Character Recognition (OCR) is the electronic conversion of handwritten, typewritten or printed text from still or motion images to machine-encoded text. Common uses include scanning of books for electronic retrieval or scanning to edit documents electronically. The first patent of OCR was in German by Gustav Tauscher in the 1920s [17].

Template matching is one of the procedures used for OCR. It can only discriminate the character that shows a resemblance with the standard template created for each character in the database [15].

There are two methods used for Optical Character Recognition (OCR). These are template-matching method and neural network method [18]. According to Patel et al [18], the use of artificial neural network (ANN) in Optical Character Recognition applications generally simplifies code and increases system's performance, extensibility and effectiveness. It is therefore able to recognise more character sets than initially defined. The reading and recognition of single characters on the number plate is the final and one of most important steps in vehicle license plate detection and recognition [18].

2.4.1.5 Neural Networks

Neural Network is just a web of inter connected neurons which are millions and millions in number. With the help of this interconnected neurons, all the parallel processing is done in human body and the human body is the best example of Parallel Processing [19] . A neural network provides a very exciting alternative for complex problem solving and other application which can play important role in today's computer science field so researchers from different discipline are designing the artificial neural networks to solve the problems of pattern recognition, prediction, optimization, associative memory and control [20].

2.2.2 Application

Automatic number plate recognition (ANPR) technology has been widely used in many systems such as traffic monitoring system, toll tax collection, Crime detection system, Stolen vehicle detection, parking system, Border crossings, Traffic control, among others [11].

2.2.2.1 Traffic Monitoring

Gaikwad et al [21] developed an algorithm to improve on the accuracy and quality of the images obtained on the captured images for the Automatic Number Plate Recognition System that is used by city traffic department to monitor the traffic as well as to track the stolen vehicles. Wen et al [22] built an intelligent transportation system algorithm for number plate recognition system whose novel was shadow removal technique and character recognition algorithms. His major contributions was on the new binary shadow removal method, based on the enhanced Bernsen algorithm combined with the Gaussian filter.

In his efforts to ensure order and adherence to regulations on attendance to Amkkah in the Pilgrimage seasons, Mohandes [3] developed an intelligent system for tracking of vehicles for traffic offences committed. Admittance of vehicles to Amkkah in the Pilgrimage seasons is restrictive to specific vehicles on particular days. In this system RFID was used for tracking offenders whereas ANPR was used for admittance to the premises. Deepavali and Lomte [23] developed an ant robbery system that granted permission for registered vehicle passage. Rajavanshi developed a method for the vehicle number plate recognition from the image using a special form of optical character recognition (OCR) to control vehicles in restricted car parks was discussed. It used the optical character recognition to read number plates through CCTV systems, which enables vehicle registration numbers to be stored, analysed and retrieved, as required [24]. Gaikwad [21] made a comprehensive review on an efficient automatic vehicle identification system by using the vehicle number plate for various applications including automatic toll tax collection, parking system, Border crossings, Traffic control, stolen cars.

2.2.2.2 Toll Collection

Roshni et al [25] did a review of systems that use number plates for Toll collections. System takes images of a vehicle and extracts the number plate that is matched with database containing owner's bank details. The authors points out that Toll deductions also happens through e- wallet assigned to the corresponding number plate of the vehicle that belongs to the owners' account. Subramanian [26] described a new method of classification of number plate for collection of Toll with application to Automated Toll System. The system identifies the position of the number plate on the vehicle using template matching and extract number from the plate and process it for collection of toll. The developed system identifies the extracted number plate in the database and associates it with user's personal information and bank account for deductions. Shevale [27] described a Smart Vehicle Screening System, which automated recognition of a number plate of a vehicle through captured images once installed in the vehicle. Image fusion, neural networks and threshold techniques were used. [28] Devised an android application that helped to recharge and deduct money. The paper focused on Electronic Toll Collection System that used automatic number plate recognition technology. The system compared extracted number plates database records in order to get information about the vehicle and the owner. Singh et al [29] examined an automatic toll paying system that efficiently processed toll vehicle payment using automatic number plate recognition. The system had high speed cameras that captured images, processed them and retrieved database information for automatic billing. Rodrigues [30] described the development of a consistent and accurate automatic number plate recognition system. This was done in view of the system's potential application in traffic monitoring systems and highway toll collection. The paper described the system as having attracted significant attention as part of an Intelligent Transport System recently. Saranya et al [31] implemented K-Means Clustering Algorithm for automatic number plate recognition system number plate extraction. The algorithm ensured maximum stability on the vital region for number plate segmentation. Template matching method for number plate recognition & also payment in toll plaza was used. Shirodkar [32] proposed a technique where collection of tolls could be done electronically using image processing technique where a vehicle number plate was to be detected, processed and the toll amount was deducted from the vehicle owner's account. The proposal also took an account of eradication of corruption after the implementation. Bhore et al [33] proposed a system for automated toll deduction that takes place through e-wallet allocated to the owner of a particular number plate of the vehicle. The daily toll collection information could be collected and sent to the governing authority for verification. Memon et al [34] designed and developed a prototype model that efficiently captured and processed Vehicle Number plates for automatic toll tax collection. The system used Template matching technique for character recognition. Once captured, the number plate is compared to the database in order to gather vehicle and owners' information for corresponding toll tax charge. The system could then open road barrier for the vehicle and generate toll tax receipt. Records of transaction are recorded and stored in the database for future reference.

2.3 Radio Frequency Identification (RFID)

2.3.1 Definition

Radio Frequency Identification (RFID) technology is a technology that uses radio waves to identify people or objects from a distance. RFID is the combined term with RF and ID where RF means a wireless communication technology and ID means identification of information of the tag. It combines two main components, that is, a tag and a reader. The two components are used for proof of identity purposes [35]. A cypher is stored in the tag which is attached to an object. With this attached tag, objects are uniquely identifiable. The code embedded in the tag is transmitted to the reader wirelessly. RFID is therefore a wireless networking technology that transmits object identification information stored in the memory of a computer. RFID gets the information by the use of radio frequency waves. RFID technology operates with 50 kHz to 2.5 GHz frequency ranges [36]. RFID uses different means of identifying object, though the most common one is the use of stored serial numbers that classifies a person or object. The RFID tag and reader have their circuitry attached to the antenna which propagates analogue carrier waves to the reader. The antenna also enables the receiving of the propagated waves that carries microchip stored information The propagated radio waves are in analogue form. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to the computer that can make use of it [37].

2.3.2 Background

The history of RFID technologies originates from radar theories developed in the 1930s. The technology was deployed in the military aviation on a large scale during the second world war. The British used it to detect whether planes belonged to "friend or foe". Due to cost factors, the use of RFID was restricted to Defence and armed forces industries [38]. Mario W. Cardullo is known to have received the first U.S. patent for an active RFID tag with rewritable memory in 1973. The U.S. government was also working on RFID systems. Around the same time after the discovery, scientists came up with the concept of placing a transponder in the automobile and readers at the gates to provide secure access systems. The reader antenna at the gates would activate the RFID tag in the automobile, which would reply an identification (ID) and release other information stored in it. The usage was commercialized in the 1980s when the first automated toll payment systems was developed [39]. The systems became widely used on roads, bridges and tunnels around the world. However, the technology usage grew to wide civilian commercial use in the early 1980's in a number of applications [5]. Building from the concepts developed by Stockman [40] of 1948 that Radio, light and sound waves can be used for Point-to-point communication where a carrier is able to generate power at the receiver which reflects back to the source. The basic notion for reflected power communication was debated from the point of view of conventional radar transmission, and the law of propagation. It was agreed that the reflected-power communication technique produced improved security, and easy ways of proof of identity and navigation.

2.3.2 The Structure of RFID system

RFID has a combination of a reader, a tag (transponder) and a data processing system. Data processing unit is the systems backend that stores information such as scanned product descriptions. The data processing system is either a personal computer or microcontroller [41]. It uses electromagnetic coupling to recognise items, animals and humans as distinctive objects. The transceiver (reader) produces radio signals that activates the tag, scans the tag and communicates any data collected to a processing unit through the antenna [42]. Reading of information contained in the tag by the reader is done from a distance without making any physical contact or requiring a line- of- sight. The read information is sent to the data base for a logical decision either to permit or deny access. The backend or processing unit comprises of a database and an application interface. When information is received by the backend, it is taken to the database where it is manipulated [43].

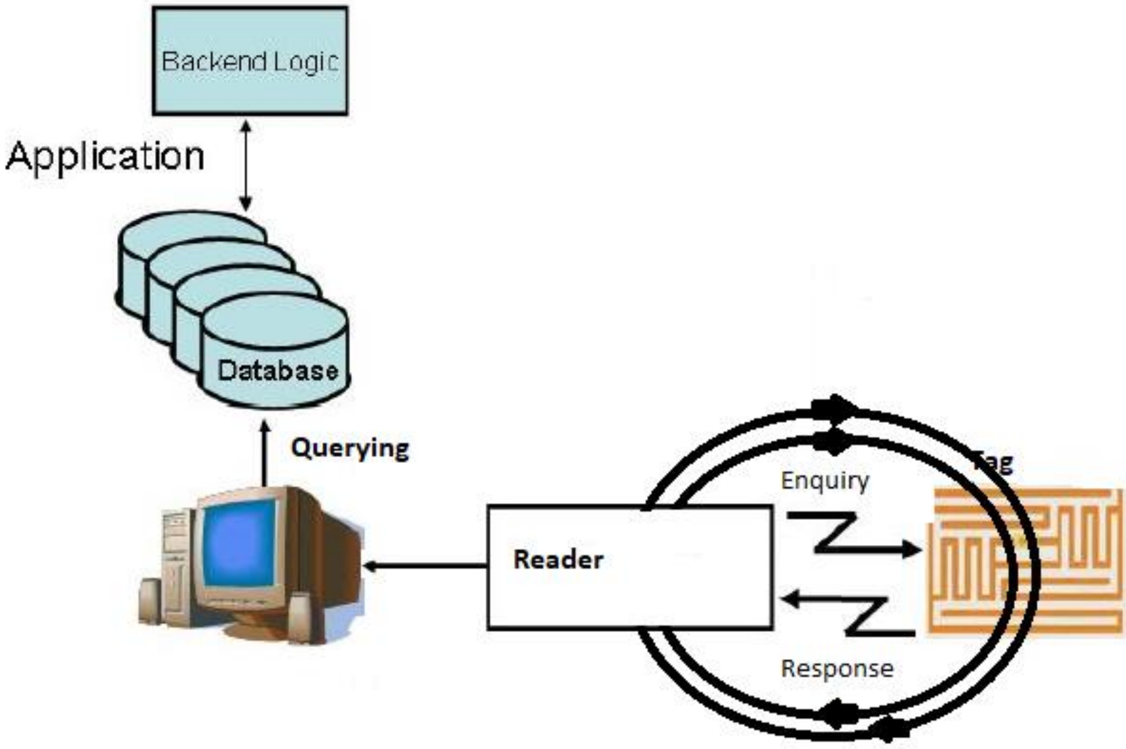


Figure 2- 3 A Simplified RFID System

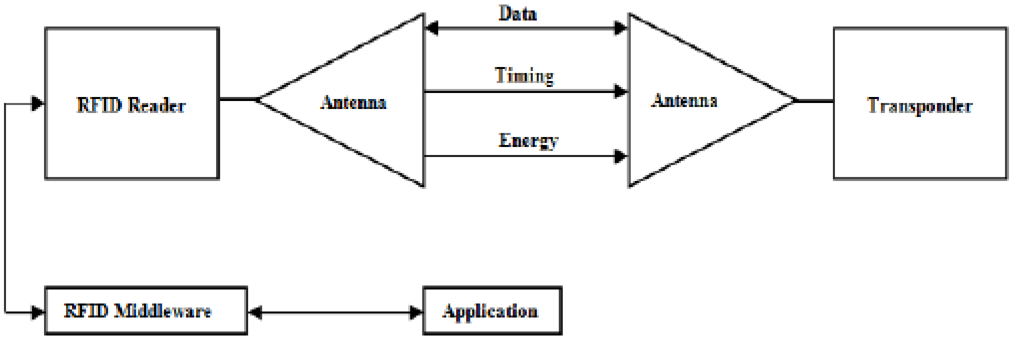


Figure 2- 4 RFID System Operation[38]

2.3.2.1 Reader

Figure 2.3 and Figure 2.4 illustrates the communication that takes place between the RFID reader and the transponder. An RFID reader produces and propagates the electromagnetic signals into space and pays attention for a response from the tag. The propagated waves are in analogue format which later upon being received are converted into digital data. The radiation and reception of radio waves from the reader are done via an antenna. The reader's propagated signals provides the tag with instructions to read or write its information on the memory [44].

2.3.2.2 Tags

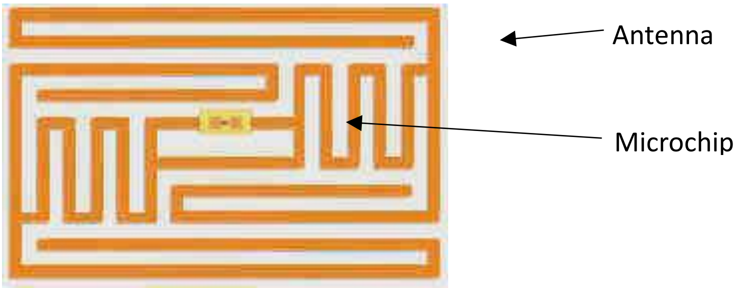


Figure 2- 5 Inside view RFID tag[43]

Figure 2.5 shows a tag with the microchip. A tag is a small device armed with a microchip carrying data and an antenna. It is also called a transponder. It has two main parts: the Integrated circuit and the antenna: the integrated circuit stores and processes information, modulates and demodulates signals, and other specific tasks. On the other hand, the antenna receives and transmits the radio frequency signals between the reader and the RFID device [45].

RFID tags are generally classified as active or passive. The active tag has an inner power source through an inner built battery and can transmit signals autonomously. Its lifespan is largely dependent on the battery life [42]. As such, active RFID tags have limited life span as compared to Passive RFID tags. Because of their inbuilt power source, active tags sends signals without being interrogated by the RFID reader. Active RFID tags have longer coverage radius due to devoted power source. They however have a short life span which is about five years. Active tags are used can be used for long range communications [37].

On the other hand, passive tags do not have an inbuilt power supply, they have no battery and need an external power source to stimulate signal transmission. It is small in size making it more portable and convenient. The RFID reader provide power to the tag through mutual induction[6]. The reader generates an electro-magnetic field which induces a current into the tag's antenna which is also responsible for communicating data to the reader. The induced power source powers the chip the chip. At the same time, the current charges the tags condenser which guarantees continuous power supply to the chip. The passive tags has a longer lifespan as compared to the active tags and smaller in size. Passive tags are used for near range communications[42].

2.3.3 RFID Operations

A Radio Frequency Identification RFID system consists of a tag, reader, and middleware software. Tags have a microchip with an antenna coiled internally. The tags are generally categorized as active or passive. Active tag use batteries or power source to power the circuitry and generate broadcasted signals. It Propagates electromagnetic waves containing information in the far field to the reader. The tag operates in the UHF and microwaves frequency bands. Because of its dependability on a power source, active tag has a short life span. Its cost is high and the size does not support usage in some applications. This makes an active RFID tag not suitable for regular usage. It however has a longer read range than the passive tags [38][45]. Passive RFID tags are independent of internal power source. They are also called 'pure passive', 'reflective' or 'beam powered'. They get their functional power from the reader through electromagnetic induction in the tag's antenna. The tag then reflects modulated radio frequency signal to the reader. On the other hand a reader is an interrogating device that has internal and often times external antennas that send and receive signals. The middleware software allows the system read/write tags and provides a means to catalogue and query tag information.[45]. Passive RFID have benefits of lengthy lifespan and its small physical size makes it appropriate for useful adhesive label. As such, passive RFID tags are used for many applications[38].

2.3.4 Application

RFID technology has had an increasing application in many industries due its versatility, miniaturization, cost-effectiveness and ease of availability. It is used in a wide range of applications such as Information Technology Asset Tracking, Race Timing, Passports, Mobile payments, Automation, Security and Access control, Supply chain management, Healthcare, Transport[36]. Review carried out by Das [46] indicates that RFID market is rapidly expanding in a number of sectors that include; automotive, transportation, logistics, healthcare and military sectors, Military Assets, consumables, conveyances, vehicles sensing Smart and Secure Trade lanes global initiative Intermodal containers, Logistics Items, assets and conveyances. In Passenger transport/automotive Vehicle, premises and computer access, vehicles, ticketing, assets Key fobs, The growing application has brought about expanded number of users and suppliers of RFID on the market. Additionally, RFID finds a wider application in Institutions such as Schools, Colleges and Universities. In this sector, it can be used for Identification and Tracking of Students in Institution campus using RFID tagged items[47].

2.3.4.1 Toll Collection

In Bhavke and Almanza developed an automatic toll collection using RFID which used IR sensors to trigger the RFID reader to take readings [48][49]. On the other hand Satyasrikanth designed and implemented a one authentication vehicular access control using RFID. The automated toll collection system using passive Radio Frequency Identification (RFID) tag emerges as a convincing solution to the manual toll collection method employed at tollgates[50]. Time and efficiency are a matter of priority of present day. In order to overcome the major issues of vehicle congestion and time consumption RFID technology is used[51]. RFID reader fixed at tollgate frame (or even a hand held reader at manual lane, in case RFID tagged vehicle enters manual toll paying lane) reads the tag attached to windshield of vehicle[52]. The object detection sensor in the reader detects the approach of the incoming vehicle's tag and toll deduction takes place through a prepaid card assigned to the concerned RFID tag that belongs to the owners' account. This makes tollgate transaction more convenient for the public use[50].

2.3.4.2 RFID in Library Management

RFID has proved to save library staff's time by automatizing their daily chores[53]. Using RFID library management tools reduces time wastage by a book reader, in waiting for his chance in a queue for borrowing or returning a book. In a library, making available to users books and reading materials are important tasks. Most of the library staff's time is spent in recording information of incoming and outgoing books. [54] Using RFID, borrowing and returning of books is entirely automated with self-check-in/out systems. A book borrower or returner identifies oneness with RFID powered card alongside the book's RFID identification details through the system's built-in RFID reader. The surveillance bit in the book's tag is deactivated by the system. When a book is returned, the check-in/out system activates the surveillance bit[55].

2.3.4.3 RFID in Logistics, Transportation, and Warehousing

According to Gaukler [56] RFID offers a lot of benefits in logistics, transportation, and warehousing which is broadly classified into reduced labor and time saving and increased visibility. The former benefits class, brings to the fore basic fact that a large fraction of a product manufacturing time is wasted in waiting for documentation or the completion of labor-intensive process such as counting and totaling cases of the product. As a result, goods are interrupted by stopping points. Automated identification through RFID potentially removes many of these delays due to stopping points, allowing the product's faster movement at much lower cost and less labor.

Further, in the logistics trade, RFID is used to check the integrity of products and determine if they have been tampered with during transit [57]. RFID is also being used to check precise product factors such as temperature, pressure, and humidity and to detect the chemical and biological substances within a shipping container[58].

2.3.4.4 Inventory

The other area where RFID is being used is in improving inventory accuracy. This is where the gap between logical and physical inventory is analyzed. Logical inventory is the amount of inventory on record in the computer system. Physical inventory is what is really in stock. Ideally, the logical and physical inventory quantities are equal, but for a variety of reasons. RFID can help improve the logical inventory records due to automation of the scanning process[59].

In addition, new and more flexible inventory control policies can be devised that use the added visibility[60], for example, describe an inventory control policy that uses of knowledge about the location and timing of replenishment orders in the resupply channel to make decisions on placing additional orders from a different supplier if the existing orders are held up for some reason. It is expected that with the spread of RFID installations, many more sophisticated policies will emerge to control supply chain activities in an effort to increase efficiency[61][60].

2.3.4.5 IT Asset Tracking

Barcodes are great for Asset Tracking but inventories are still dependent on the user finding each barcode and scanning it[62]. Passive RFID tags transmit their data when the reader requests. Imagine inventorying an entire office from the doorway. Properly installed RFID tags and our RFID Asset Tracking solution can make that dream come true.[63][64]

2.3.4.6 RFID in the manufacturing Industry

RFID application can play the big role in the production assembly automation. It can improve the production efficiency and traditional work style, and reduce the reduction cost[65]. The RFID system will provide the related information such as, color, engine type, tire, basic shape etc. so that the assembly line can produce different kind of automobile[66]. The RFID reader will retrieve the information inside the tag at every ingle process stage to assure the correctness of the production[67].

2.3.4.7 Supply chain Management

Supply chain management Supply chain trials were between Marks and Spencer and some of their key suppliers[68]. The RFID tags are attached to trays of products and suppliers pass the trays through a writer situated at the end of their production lines[69]. The writer stores order, product and batch details on the tag and as the trays pass through the transport chain they are automatically read as they pass through gateways so the system is kept up to date with the location and status of goods. When the trays are emptied they return to the suppliers where they are re-used and the tags rewritten[70][71].

2.3.4.8 Healthcare

Hospitals and the medical care industry in general are adopting asset tracking technology to track equipment, to track patients including baby tracking, to track staff, and to ensure patient's receive the correct medicines and care – all in an effort to reduce expenses and save patient's lives[72]. RFID technology is key in increasing these efficiencies[73]. RFID tags put on medicines, which gives them a unique code and identity[74]. In case of illegal distribution, the fake medicines can be easily distinguished. Expired medicines can also be kept under check by using RFID tags[75].

2.3.4.9 Transport

Transportation is a major area of implementation for RFID technology[76]. For example, Yard Management, Shipping and Distribution Centers are some areas where RFID tracking technology is used[77]. Transportation companies around the world value RFID technology due to its impact on the business value and efficiency[78][79].

2.3.4.10 Student Management

RFID also works in Educational Institutions such as Schools, Colleges and universities[80]. In educational Institution it can be used for Identification and Tracking of Students in Institution campus using RFID tagged items, Library Management, Laboratory Management, Admission process, Examination centers to avoid any misconduct during Examination. RFID technology also works for student management such as Student Safety: whether each student has arrived and left the school safely[81]. Attendance check: whether each student has arrived and attended the school/college on time or late. Behavior in school, grades, attitude, etc. RFID has solutions for all these concerns .Student ID card attached with RFID tag. All the

Information related to that student like name, address, roll no, class, division, etc. will be linked to the tag[80]. As soon as a student enters/leaves the school gate, reader mounted on the gate would read the RFID tag and mark the time at which the student enters/leaves the school/colleges. If any student tries to get out of school/College without authorization, before the closing time then the RFID reader mounted on the gate would automatically sound an alarm both in the school/College system and at the gate. It could also send a simultaneous message to the security and the teacher responsible about the same. Other information like student's attendance, grades, awards etc. will also be linked with the tags for quicker retrieval and better storage. The system could also serve as a medium of interaction among the parents and the teachers[82]. Through this system the teachers would be able to intimate the parents about the holidays, behavior and other notices. While the parents will easily be able to send leave notes, grade and attendance enquiries to the teachers. RFID readers can be mounted on the ceiling of each classroom[83]. It will read the RFID tags of the students in the class and also the tag of the teacher teaching a particular subject. The reader, after reading the tags, would automatically mark the attendance, of both the teacher and the student, and upload the data on the school /Colleges server. The software would automatically calculate the attendance and would intimate the department. Schools/colleges can also issue visitor-passes to keep track of their movements in the campus and Send automatic alerts if anyone should wander into an unauthorized area or overstay a scheduled Permitted time[82].

2.3.4.11 Laboratory management

Laboratory management RFID tags can be attached to the assets of the school/colleges like computers, printers, projectors, air conditioners etc can also be tagged and tracked easily[84]. The tag would contain data like type, brand, and date of purchase, warranty period, service due dates and any other information[85]. The tags could also be attached to lab equipment's and appropriate information could be written on them. The information can be easily read and rewritten using a RFID tag reader[86]. Any unauthorized removal outside the school /college will start an alarm both in the application and also at the gate. Securing and tracking of Exam related question papers & answer books Bags containing exam papers attached with RFID tags[87] it can prevent and detect any malpractice.

2.4 Infra-Red Sensors (IR)

An infrared sensor is an electronic device that senses some features and objects around it using radiation that it emits. An IR sensor can measure the heat of an object as well as detects the motion. These types of radiations are invisible to our eyes, that can be detected by an infrared sensor. The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode which is sensitive to IR light of the same wavelength as that emitted by the IR LED. When IR light falls on the photodiode, The resistances and these output voltages, change in proportion to the magnitude of the IR light received[88]. Infra-Red sensors are extensively used as a incidence trigger, nevertheless, its response is influenced by aspects such as, displacement of the object from the IR sensor, the direction and speed of object travel and the object shape[89]. This sensor is similar to human being sight senses, it can be used to identify obstacles and it is one of the common applications in real time[88].

2.4.1 IR Sensor circuit diagram and working principle:

An Infra-Red sensor circuit is made up of the following components; the LM358 IC , an IR transmitter and receiver pair, kilo ohm range resistors, adjustable resistors. And Light Emitting Diode[88].

Its circuity diagram is as shown in Figure 2.6 below.

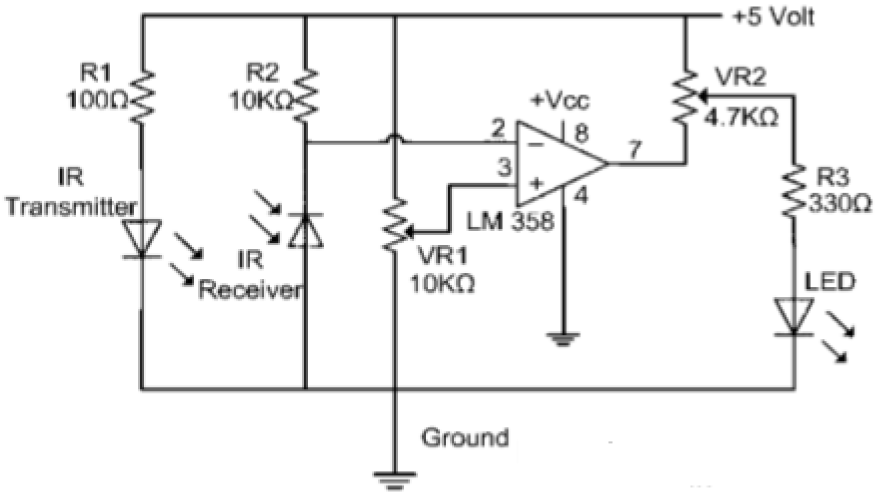


Figure 2- 6 Infra-Red (IR) Circuit Diagram[89]

Infra-Red sensors are classified into two types, photon detectors and thermal detectors based on their principle of operation. In photon detectors the radiation is absorbed within the material by interaction with electrons either bound to lattice atoms or to impurity atoms or with free electrons. The changes in the electronic energy distribution in the atom generates output electrical signals. In thermal detectors the incident radiation is absorbed to change temperature of the material object, the subsequent adjustments in some physical properties of the object generates an electrical output[90].

2.4.2 Background

Infra-Red photoconductor was first developed by Theodore W. Case in 1917. The conceptual build up developed from the discovery that substance composed of thallium and sulphur exhibited photoconductivity. Reinforced by the United States Army between 1917 and 1918, the study was improved to have the composition used as sensors in an infrared signalling device [91].

There is a large variety of IR sources, each used for different purposes[92]. All objects are composed of continually vibrating atoms, with higher energy atoms vibrating more frequently. This leads them radiate some form of infrared radiation know as thermal radiation due to generated electromagnetic waves. This is what makes Infrared radiation such a powerful resource[93]. It allows for the ability detect and gather information of an environment without the need of visible light[94].

2.4.4 Application

[95] ANPR can be used to store the pictures caught by the cameras and in addition the content from the tag with some configurable to store a photo of the driver. Systems ordinarily use infrared lighting to permit the camera to take the photo whenever of the day. A

2.4.4.1 Obstacle detection

In order to avoid damaging the car by hitting into an obstacle when parking, an IR circuit was constructed that would warn the driver on the proximity of the obstacle. The IR sensor would sense the object that is approximately 100m away. The information is given in terms of a tone[88]. The circuit has an in built LM555 integrated circuit that will generate the pulse which helps to produce audio output from the Frequency Modulation Circuit[88].

2.4.4.2 Shape Detection

Since IR sensors are capable in measuring data up to 0.05 cm of resolution in displacement[96]. The sensor can be used to detect the shape of an object. [96] used a stepper motor to control the movements of the object around 360 degrees. Using Matlab and CoolTerm software, analysis data was obtained to reflect the shape of the object.

2.5 Microcontroller

Microcontrollers are systems commonly presented as an integrated circuit with peripherals, memory and a processor that can be used in embedded systems. They are sometimes referred to as embedded controllers due to the fact that they are used in cell phones, automobiles and household appliances for computer system[96]. Microcontrollers are used for embedded applications, like in the automatic control of devices, office machines and even security systems. Microcontrollers executes applications, and these applications are described by 'software'. General-purpose processors are designed to fit all applications, neglecting that the application's demand for program and/or data size might run out every boundary. PIC microcontrollers originally the Peripheral Interface Controller revised to mean Programmable Intelligent Computer are widely used in sensory circuits[96][97].

2.5.1 PIC Microcontroller

Figure 2.7 shows a PIC microcontroller. The PIC Microcontroller of Microchip PIC18F452, has Operating Frequency 40MHz; input is Analog/Digital Voltage of +5V. Total power dissipation of 1.0W with Voltage Operating Range of -0.3V to +7.5V. It also has in built 10 bit ADC[97].

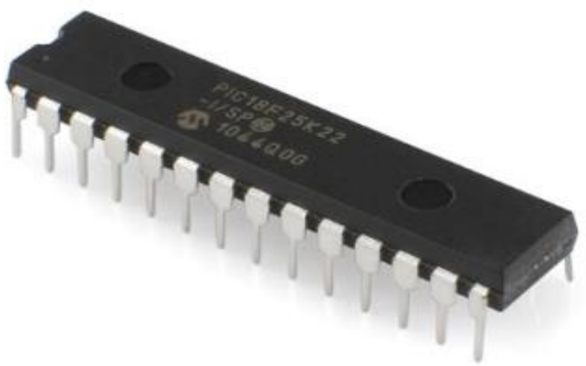


Figure 2- 7 PIC Microcontroller[97]

The PIC microcontroller initially utilized ROM and EPROM in its models but has of recent times opted to use flash memory instead, like many of its competitors like the AVR microcontroller by Atmel. The PIC uses the Harvard architecture in that its instruction and data memories are separated and can be accessed by different sets of buses.

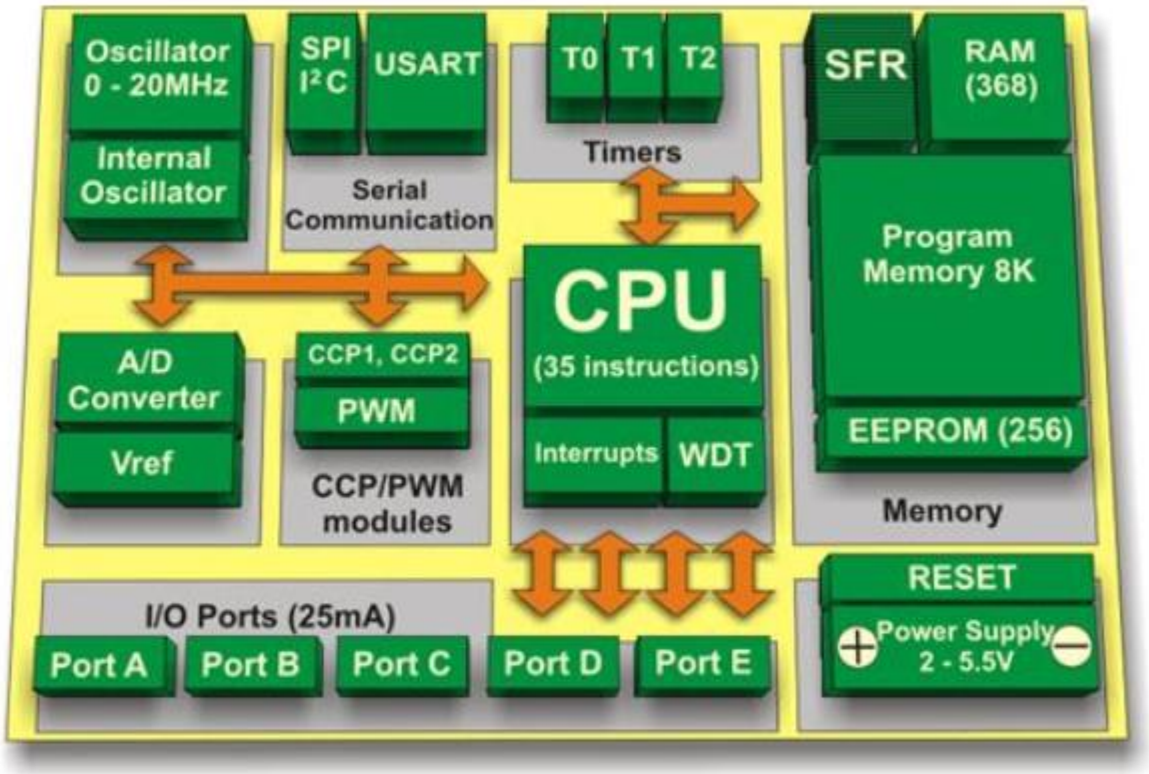


Figure 2- 8 PIC Microcontroller architecture[98]

Features[98]:

• High-performance RISC CPU

• All single cycle instructions except for program branches which are 2 cycle

• Operating speed: DC - 20 MHz clock input DC - 200 ns instruction cycle10

• Up to 8K x 14 words of Flash Program Memory,

• Up to 256 x 8 bytes of EEPROM data memory

• Pin out compatible to the PIC16C73/74/76/77

• Interrupt capability -up to 14 internal/external

• Eight level deep hardware stack

• Direct, indirect, and relative addressing modes

• Power-on Reset (POR)

• Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)

• Watchdog Timer (WDT) with its own on-chip RC Oscillator for reliable operation

• Programmable code-protection

• Power saving SLEEP mode

• Selectable oscillator options

• Low-power, high-speed CMOS EPROM/EEPROM technology

• Fully static design

• In-Circuit Serial Programming (ICSP) via two pins

• Only single 5V source needed for programming capability

• In-Circuit Debugging via two pins

• Processor read/write access to program memory

• Wide operating voltage range: 2.5V to 5.5V

• High Sink/Source Current: 25 mA

• Commercial and Industrial temperature ranges

• Merits:

• PIC‟s have been found to be reliable with a low malfunction percentage.

• PIC‟s, due to its RISC architecture, are fast operating devices.

• Interfacing and programming is easy and it is possible to connect analogue devices directly without any extra circuitry.[99]

2.6 Arduino Board

The Arduino board takes the place of the AVR microcontroller during the initial prototyping phase, taking on the responsibility of processing data and issuing out commands based on the program code[99].

Figure 2- 9 Arduino board[100]

Despite there being many types[100], general Arduino components include;

Power (USB / Barrel Jack)

The Arduino can be powered from a USB cable coming from a computer or a wall power supply that is terminated in a barrel jack. In the picture above the USB connection is labelled (1) and the barrel jack is labelled (2).

The USB connection is also a means through which one can load code onto the Arduino board. The recommended voltage for the Arduino is a voltage of 6 – 12V, with anything higher than 20V being sure enough to damage the board.

Pins (5V, 3.3V, GND, Analog, Digital, PWM, AREF)

The pins on the Arduino are the places where connection wires are terminated to construct a circuit. They usually have black plastic „headers‟ that allow one to plug a wire right into the board. The Arduino has several different kinds of pins, each of which is labelled on the board and used for different functions.

GND (3): Short for „Ground‟. There are several GND pins on the Arduino, any of which can be used to ground your circuit.

5V (4) & 3.3V (5): As you might guess, the 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the Arduino run off of 5 or 3.3 volts[100].

Analog (6): The area of pins under the „Analog In‟ label (A0 through A5 on the UNO) are Analog In pins. These pins can read the signal from an analog sensor (like a temperature sensor) and convert it into a digital value that we can read.16 Digital (7): Across from the analog pins are the digital pins (0 through 13 on the UNO).

These pins can be used for both digital input (like telling if a button is pushed) and digital output (like powering an LED). PWM (8): You may have noticed the tilde (~) next to some of the digital pins (3, 5, 6, 9, 10, and 11 on the UNO). These pins act as normal digital pins, but can also be used for something called Pulse-Width Modulation (PWM). AREF (9): Stands for Analog Reference. Most of the time one can leave this pin alone. It is sometimes used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins[100].

2.6.1 Reset Button

The Arduino has a reset button (10); Pushing it will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino. This can be very useful if your code doesn't repeat, but you want to test it multiple times[101].

2.6.2 Power LED Indicator

Just beneath and to the right of the word "UNO" on your circuit board, there‟s a tiny LED next to the word „ON‟ (11). This LED should light up whenever one plugs ones Arduino into a power source[101].

2.6.3 TX /RX LEDs

TX is short for transmit, RX is short for receive. These markings appear quite a bit in electronics to indicate the pins responsible for serial communication. In our case, there are two places on the Arduino UNO where TX and RX appear – once by digital pins 0 and 1, and a second time next to the TX and RX indicator LEDs (12). These LEDs will give some visual indications whenever the Arduino is receiving or transmitting data. Main IC Integrated Circuit (13). This is the central processing area of the Arduino and is slightly different from board type to board type, but is usually from the ATMega line of AVR IC‟s from the ATMEL company. This can be important, as you may need to know the IC type, along with your board type, before loading up a new program from the Arduino software. This information can usually be found in writing on the top side of the IC[101].

2.6.4 Voltage Regulator

The voltage regulator controls the amount of voltage that is let into the Arduino board[101].

2.7 Stepper Motor

A stepper motor is a brushless DC motor that rotates in fixed intervals called steps. It does this by interpreting electrical impulses into direct motion[102].

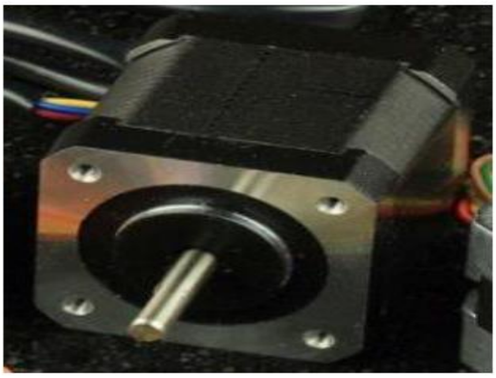


Figure 2- 10 Stepper Motor[102]

They have multiple coils that are organized in groups called "phases" and by energizing each phase in sequence, the motor will rotate one step at a time as can be shown in Figure 2.11 [103].

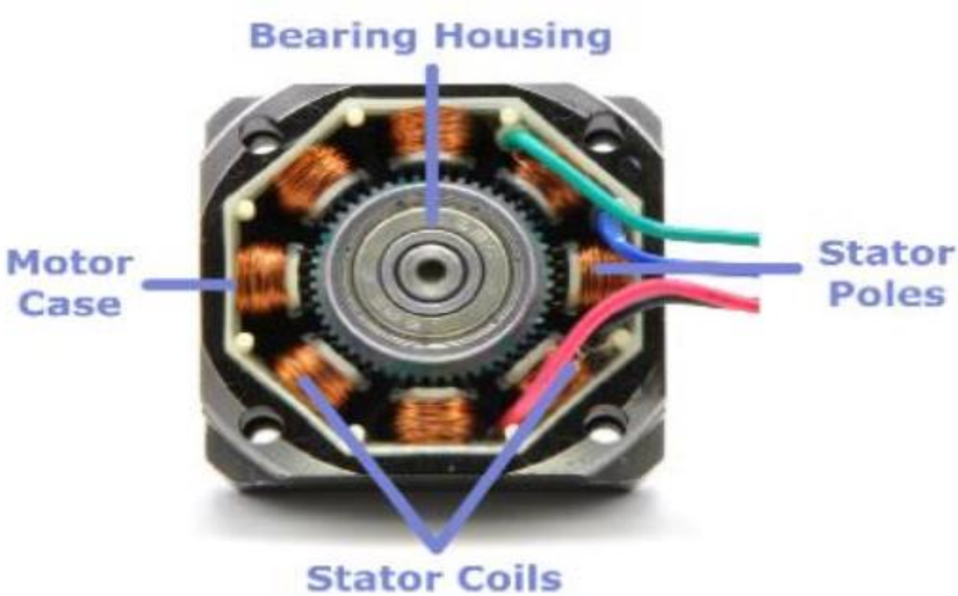
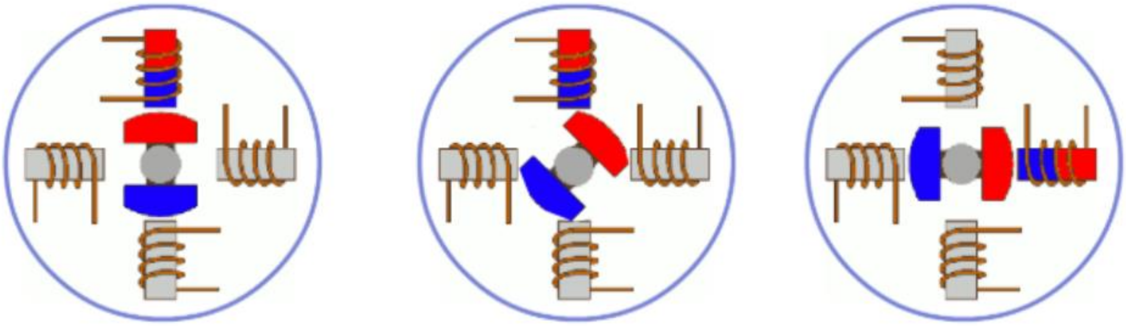


Figure 2- 11 Inside the Stepper Motor[103]

Each of those rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle.



To make the motor shaft turn, first, one electromagnet is given power, which magnetically attracts the gear's teeth.

When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet.

So when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one, and from there the process is repeated.

Figure 2- 12 Principle of Operation of a Stepper Motor[105]

Merits[104]:

1. They are useful in projects that require specific positioning since they move in precise steps. They have found use in systems such as X,Y Plotters, disk drives 3D printers and CNC machines.

2. They are useful for speed control as precise increments of movement also allow for ample rotational speed control for processes dealing in automation and robotics.

3. Stepper motors have high torque levels at low speeds unlike most DC motors, so they are a good choice for applications requiring low speed with high precision.

L293D H-Bridge motor driver

The L293D H-Bridge motor driver chip is an IC used to direct the flow of current in specific directions using its H-bridge configuration[105].

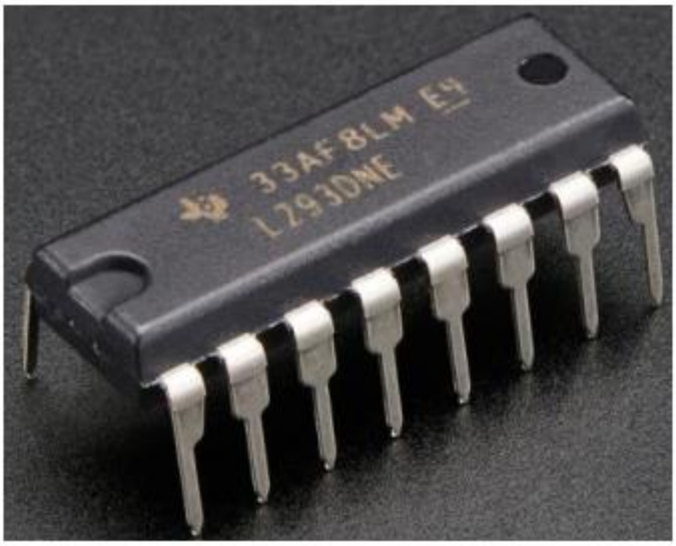


Figure 2- 13 H-Bridge Motor Drive[105]

Each chip contains two full H-bridges (four half H-bridges). That means that one can drive four solenoids, two DC motors bi-directionally, or one stepper motor. It comes with an in-built kick-back diode that prevents inductive kick from damaging the connected system and it holds PWM inputs that allow for motor control[105].

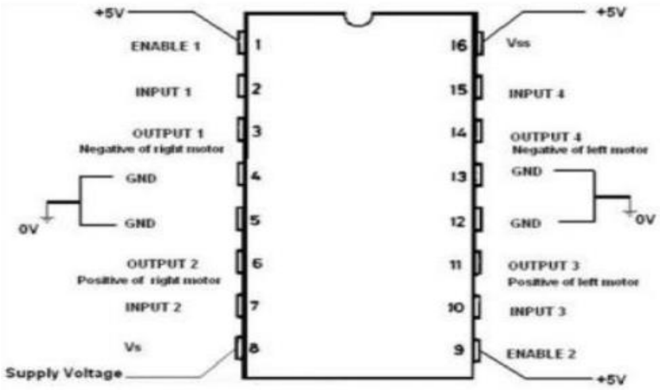


Figure 2- 14 H-Bridge Motor Drive pin layout[108][109]

Channel 1 PIN 1 - enables channel 1 for steering first load. PIN 2, 7 - logical level input (can be from MCU any I/O port pin) PIN 3, 6 - Power output[106]

Channel 2 PIN 9 - enables channel 2 for steering first load PIN 10, 15 - logical level input (can be from MCU any I/O port pin) PIN 11, 14 - Power output 2[106] Power supply PIN 8 - Power supply for logic part of the bridge. From 4.5V to 7V. PIN 16- Power supply for controlled load. From 4.5 to 36V and up to 600mA PIN 4, 5, 12, 13-Ground (-) and heat sink connection[106].

2.8 Liquid Crystal Display (LCD)

LCD's are a screen technology that supersedes the traditional Cathode-Ray tube technology, utilising pixels, millions of tiny blocks that separately produce red, green and blue light, that are switched on and off rapidly to create the smooth moving figures we commonly see on our screens[107]. In the traditional LCD televisions and project screens, the switching is done using liquid crystals to rotate polarised light - Figure 2.15.

Figure 2- 15 LCD[111]

Like any other display, the LCD display units have been used to relay information from a system to those outside it. This makes it a versatile interfacing medium between systems and operators and can be programmed accordingly to give out a wide range of information[108].

2.9 Camera

A camera is a device used to capture images and take videos. It records visual images and represents them as film, photographs or video signals and has evolved from being fully analogy to being digital [109]. Figure 2.16 shows an infra-red powered camera able to record visual images.

Figure 2- 16 Digital Camera[109]

Once the capture order on the camera is given, either through code or manually, an aperture opens at the front of the camera and light enters through the lens. Thus, there is a piece of electronic equipment that captures the incoming light rays and turns them into electrical signals. This light detector is one of two types, either a charge-coupled device (CCD) or a CMOS image sensor[109].

Light being reflected off the capture target is focused into the camera lens. This incoming image hits the image sensor chip, which breaks it up into millions of pixels. The sensor measures the color and brightness of each pixel and stores it as a number[109].

2.10 Related Works

Table 2-1 Analysis of Contributions from related works and gaps noted

#	Topic	Year	Author	Contributions	Gaps
1	An Intelligent System for Vehicle Access Control using RFID and ALPR Technologies.	2016	M. Mohandes et al	Developed and implemented the ANPR and RFID technologies to control vehicle access into restricted premises using RFID and used number plate to track offenders.[3]	The two technologies where not integrated to provide a two factor authentication access control system for versatility.
2	Image Processing Based Automatic Toll	2016	M. P. Singh, M. Soni, S.	examined an automatic toll paying system that efficiently processed toll	The system captures and processes the numbers plate and

	Booth in Indian Conditions		Rajpoot, and S. Pareyani	vehicle payment using automatic number plate recognition. The system had high speed cameras that captured images, processed them and retrieved database information for automatic billing.[29]	once toll fee link payment is established, access was granted.
3	Design and implementation of a vehicular access control using RFID	2016	D. L. Almanza-ojeda and M. A. Ibarra-manzano	Developed and implemented a vehicle access control system to authenticate vehicle entry into a restricted premises using RFID tags for identification and RFID reader to read the card content. Boom gate was used as a barrier. [49]	Provided a static vehicle access control system that could not be tailored to suit a two factor authentication needs. Tracking of a vehicle in case of theft by a card holder is not possible with this system.
4	Automatic Monitoring and control of Vehicle Entry / Exit In Forest Area with Raspberry-pi , python and open cv	2016	Alone, Ms Priyanka N Umale, V M Dolas, A N	Proposed an automated monitoring and control of vehicle entry-exit in restricted area using raspberry pi system. The design captured the vehicle image along with its number plate automatically processes it and verified the details with the database. Details are authenticated by Raspberry Pi to authorise to enter the vehicle in the forest area.[111]	The proposed system authenticated the vehicles and not the driver as well. This gives room for the vehicle to be granted access even when its being driven by an unauthorised personnel. The system therefore needs to be enhanced with driver identity.
5	Solar Photovoltaic Automobile Recognition System for Smart-Green Access Control RFID and LoRa LPWAN Technologies	2017	O. Victor, O. Adebayo, et al	Developed vehicle admittance system using Solar Powered RFID with a boom gate barrier. The system offered no threat to eco environment and survived on the solar renewable energy[112].	Provided a static vehicle access control system that could not be tailored to suit a two factor authentication needs. Tracking of a vehicle in case of theft by a card holder is not possible with this system.

2.11 Summary

In this chapter, a comprehensive review of related works to the use of RFID and ANPR technologies in various sectors was done. Literature review that has been carried show that RFID market is rapidly expanding in the automotive, transportation, logistics, healthcare and military sectors, Military Assets, consumables, conveyances, vehicles sensing Smart and Secure Trade lanes global initiative Intermodal containers, Other Logistics Items, assets, conveyances. RFID has also found a wider application in vehicle secure access controls, security and safety controls. ANPR is another technology that is on the increase in the automobile industry as reviewed in this chapter. It has been used in vehicle monitoring, access control and tracking. Other literature associated with the two technologies were also reviewed.

CHAPTER THREE:
METHODOLOGY

3.1 Introduction

This chapter presents Materials and Methods that were used to conduct this study. First of all, we start by looking at the methodology that was employed to collect the data through baseline survey. It will discuss details of the data analysis procedures that were used in the research. This is followed by the methodology used in development of the model and implementing the prototype.

3.2 Baseline Study

A baseline survey was conducted at the University of Zambia Great East Road Main Campus in order to establish the challenges faced by the University on the management of vehicle access on exit and entry points. The access points include, Great East Road Main Entrance, the Kamloops entrance, Lufwanyama entrance and Car parking areas. The car parks that were under consideration were the members of staff car park in the School of Education, the administration block car park servicing top management staff and the car park servicing School of Natural Sciences and School of Engineering. The final secured premise that was taken into account was the transport yard where all university vehicles are parked. A mixed method research methodology was used comprising of key informants, qualitative and quantitative approach. According to [117] a mixed Methods research Methodology comprised qualitative and quantitative methods and provides a better understanding.

3.2.1 Study Setting

This study was conducted at the university of Zambia Great East Road Campus. The study area was purposely chosen as the research hypothesis targeted the location. The University of Zambia Great East Road campus is located along the Great East Road, about 10km from Lusaka town Centre. It is the biggest high learning Institution in the country with a student population of about thirty thousand and a total of two thousand five hundred (2,500) members of staff. Eight hundred and seventy nine (879) are academic members of staff and one thousand six hundred and twenty one (1,621) are administrative members of staff. The number of staff having and using their own vehicles is increasing by each year. The premises has three main entrances into the campus namely; Great East Road Main Entrance, the Kamloops entrance and the Lufwanyama entrance. It has six (6) main designated car parking areas that include Veterinary, Agriculture, Engineering/Natural Sciences, Administration, Education and Mines, clinic, and the transport Yard all named after the area being served. Four (4) are secured with boom gates manually operated by guards whereas all the three (3) main entrances are manned by the guards with manually operated boom gates.

3.2.2 Sampling

The sample for the study population was purposively sampled. The researcher's focus in this study had a specific characteristic of the population's interest. Hence a homogeneous purposive sampling technique was used. This technique enabled the researcher answer particular questions of interest. A sample of one hundred (100) respondents were selected divided into three categories namely; Members of staff, Security Personnel and Visitor/students. Out of 100 questionnaires twenty five (25) were administered to the Security Personnel, twenty five (25) to the Visitors/Students and fifty (50) to the members of Staff using personal vehicles. Out of the twenty five (25) guards, three (3) were key informants that included the University of Zambia chief security. A purposive choice of some key informants among the security respondents was to get key information on vehicle security concerns and challenges of the current system.

3.2.3 Inclusion Criteria

The study population included the members of staff from the School of Education, School of Humanities, School of Natural Sciences and School of Engineering who uses private vehicles to come for work and uses the university premises to park their vehicles. It also included the security personnel manning the three main entrance/exit gates, the School of education staff car park, Confucius car park, Administration car park, School of Natural Science/Engineering staff car park, transport yard, UNZA security office, among others. The other category randomly sampled were visitors/students.

3.2.4 Data Collection

Data was collected for a period of one (1) week in the mid of June 2018. The self-administered questionnaires were distributed to the targeted sample within the location. Some of the respondents were requested sufficient time for responding to the questionnaires, while some found it necessary to complete them without much time wastage. Some respondent's especially among the security personnel, the questionnaires had to be turned into oral interviews due to failure by the respondents to write. The researcher completed the collection of all completed administered questionnaires towards the third week of June. Unstructured interviews with key informants was done during the same period of time.

3.2.5 Data Processing

Collected questionnaires were organized and data entered into the computer based software which is the Statistical Package for Social Sciences (SSPS) for analysis. Qualitative data was grouped into themes of questions and analyzed in SSPS software package as well.

3.2.6 Ethical Consideration

All the respondents were requested not to review their identity by writing their names or put any identification mark. An assurance was also given that none of the responses would be attributed to their personalities and that the questionnaire was intended for academic purposes. That is , confidentiality and non-persecution may be attributed to the responses.

3.2.7 Limitation of the Baseline Survey

The researcher may not have obtained accurate data from security personnel beyond one year as the company has only been in service at the University of Zambia for nine (9) months. Shuffling of security personnel may have also reduced their grip to have a deeper understanding on the operations of some places. The study also faced apathy from some of the respondents who were not interested in responding to the questionnaire citing busy schedule. Some questions were not answered by the respondents and some questionnaires were collected without being answered.

3.2.8 Presentation of the Findings

Data arising from the findings was analyzed and summarized in form of graphs, charts, and percentages. Qualitative data obtained from the survey were analyzed and from themes created.

3.3 System Automation

The analysis of the results of the baseline survey were used to come up with a conceptual model of an electronic automated vehicle access control system in entry and exit points. The findings reviewed that different entry and exit points had heterogeneous authentication requirements. In order to meet the heterogeneity of the different access points, the model has been designed to offer five configurable levels. The proposed model is expected to offer an effective and efficient means of providing access to the premises to the authorized individuals. It is expected to reduce congestion, keep records of driver/vehicle activities in a data base which can be queried with easy at any time from a centralized database.

The data obtained was used to come up with the system requirement and model design of the system in the study. In addition the data reviewed the current system's inefficiency in a number of dimensions.

The analyzed data was used to come up with system requirements and system model design. The current manual system was reviewed and seen not to meet the required access control needs of the authorities.

3.3.1 Current Vehicle Access Control Processes

The currently existing vehicle access control system as was described from the survey and through site visits that was conducted is fully explained in this section. The survey reviewed that different vehicle access points have access rules. The vehicle access points under consideration include the three(3) main entrance and exit points to the campus premises and out of the campus premises. The three are the Great East Main Entrance, Lufyanyama entrance and Kamloops entrance. The other access points are car parking area entrance and exit points. These include the carpark used by members of staff from the School of education. The carpark used by the administration staff and the carpark used by the School of Humanities, Natural Sciences and School of Engineering. Additionally, the entrance and exit to the transport yard.

3.3.1.1 The admittance process of the current System

The current vehicle access controls into the university campus and through to the car parking areas is manually done. Members of staff of the university are issued with identity cards for general use. Those with vehicles are also issued with vehicle stickers that are displayed on the vehicle windscreens. Upon reaching the entrance or exit point, the security personnel requests to see the University of Zambia car sticker OR the Member of staff identity card. Upon producing either of the two, the vehicle is allowed to gain access. Guards use a book to make records of entrances and exits into and out of the premises.

Challenges such as entering user data, vehicle details such as the number plate, slow process associated with manual processes have been eminent with the current system.

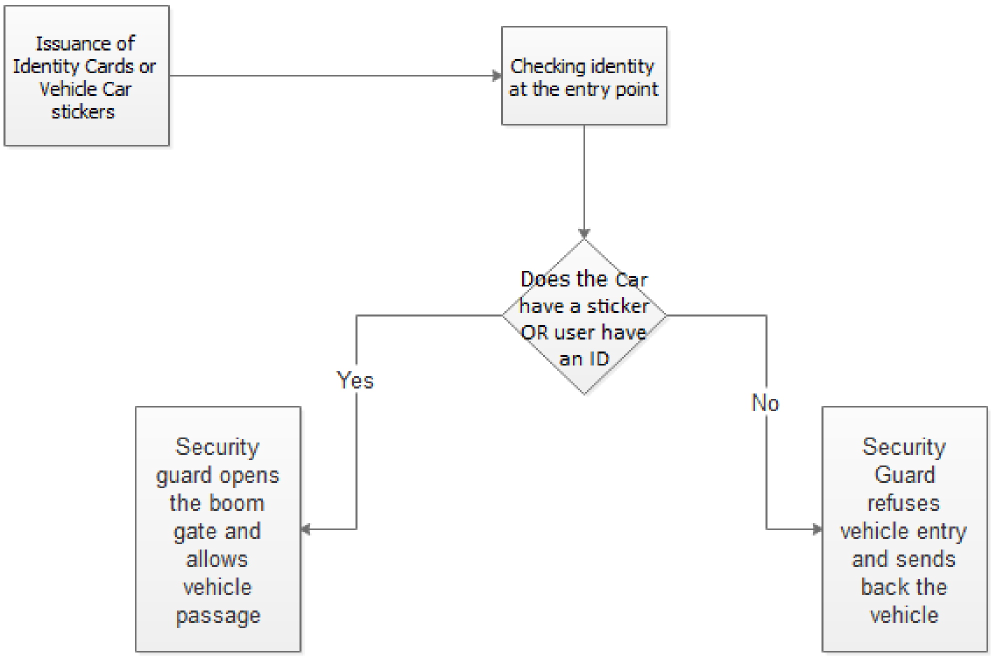


Figure 3 - 1 Manual Process of Vehicle admittance flow chart

3.3.1.1 The Great East Road Main Entrance and Exit Point

This is the main entrance and exit to the University. The point is powered by a boom gate that is being used as a barrier for vehicle inspection and recording. The entrance is manned by security officers who are mandated to inspect and authenticate entrance or exit of a car. This entrance however permits all vehicles provided they have business with the university. Passage through this entry and exit point is less restrictive. Figure 3.1 and Figure 3.2 shows the status of the gate and gives an insight of vehicle build up each time an inspection is to be carried out. Registration of vehicles during entry and exit was also a mandate but is not humanly possible.

Figure 3.1 Security personnel verifying drivers credentials

The security personnel checking the credentials of a driver to ascertain eligibility of access at the main entrance.

Figure 3 - 2 Security Check causing congestion on the GER entrance

The security personnel activity however resulted into a long congestion as demonstrated in Figure 3.2.

3.3.1.2 Kamloops Entrance and Exit Points

The Kamloops entrance is strictly for the University of Zambia identity card holders only. Other vehicles other than for those holding identity cards are not allowed to use this gate. This gate links the Kamloops Road to the Great East Road through the main entrance described above. Drivers in the Kamloops Road going to town during peak hours are usually tempted to use this point through to the Great East Road as short cut. However, officers manning the gate face a challenge to check for cards due to car frequency. Recording of vehicles also is not possible though attempt is normally made depending on the circumstances. Security officers also complain of insults and lack of patience usually exhibited by members.

Figure 3 - 3 Officers at Kamloops Entrance checking and admitting vehicles

3.3.1.3 Lufwanyama Entrance and Exit Points

Just like Kamloops entrance, this strictly for the University of Zambia identity card holders only. Similarly, no vehicle is allowed other than those holding UNZA identity cards to gain access. Officers manning the gate face a challenge to check for cards due to car frequency especially during peak hours. Recording of vehicles is not possible though attempt is ussually made depending on the circumstances. Figure 3.4 a, shows the boom wide open with no signs of attempt to enforce the rules. Figure 3.4.b shows a notice to the members of the public giving them information that only University of Zambia Card holders are allowed to use the gate.

Figure 3-4 (a) Lufwanyama entrance: application of the laid down rules almost non existence

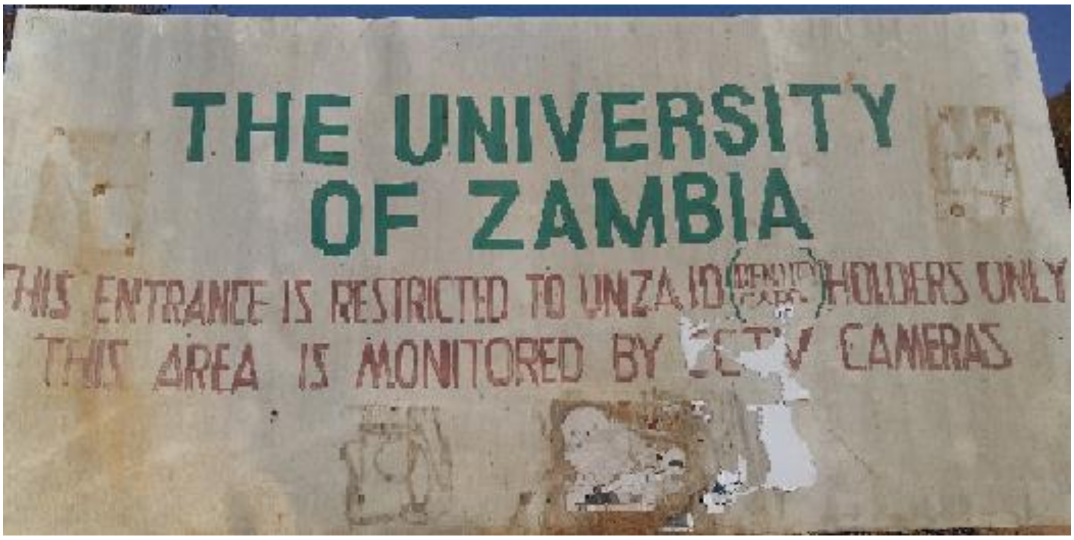


Figure 3 - 4 (b) Notice to the members of the public on Accessing the UNZA premises through Lufwanyama entrance.

3.3.1.3 Access to Car Parking Areas

There are a number of car parking areas around the University categorised into four. These are: Members of Staff, Administration, Transport yard and Visitors/Students car parks.

The survey reviewed that only members of staff are supposed to park in the Members of staff Car parks, only the top administrative staff are supposed to park in the administration car park and only UNZA vehicles are permitted to park at the transport yard while the visitors/students car parks are open to everyone around campus premises.

3.3.1.3.1 Members of Staff Car Park entrance

Figure 3.5 (a) School of Education members of staff car park

Figure 3.5 (b) School of Natural Sciences and Engineering Staff Car Park

Entrances to the Staff Car parks showing no records of vehicle-driver activities taking place.

3.3.1.3.2 Administration Car Park

Figure 3 - 5 Administration Staff Car Park

3.3.1.3.2 Transport Yard

The transport yard houses all vehicles for the University of Zambia. There are a pool of drivers who are assigned to drive specific vehicles for a specific time or days. Each time a driver picks a vehicle, authorization has to be given and details of the driver, vehicle and time are recorded.

3.3.2 Proposed Vehicle Access Control Process Model

In this research study an alternative vehicle Access control model based on ANPR and RFID has been proposed. This proposed system will automate the current manual system in order to bring efficiency and effectiveness in vehicle monitoring and controls.

The proposed model is a multifactor vehicles access control system using ANPR and RFID. The two technologies are integrated in order to meet requirements at different access points.

The proposed system offers five configurable authentication access levels;

- First Level is the record level
- Second is the card **OR** number plate authentication level
- Third is Membership Identification Card **ONLY**
- Fourth is the number plate **ONLY**
- Fifth is the number Plate **AND** Membership Identification Card

3.3.2.1 General Automated System Overview

This section outlines the general overview of the multifactor authentication proposed system. The cameras are installed beside a road to take pictures of an approaching vehicle. The sensors will be grouped into two, the entry sensors and the exit sensors. The entry IR sensors when interrupted by an approaching vehicle, awakens the cameras and triggers them to take pictures. The picture is then sent for processing. If entry is allowed by the opening of the boom gate, the boom gate will not close until the exit sensors are interrupted. The system is made up of various small unit that are integrated.

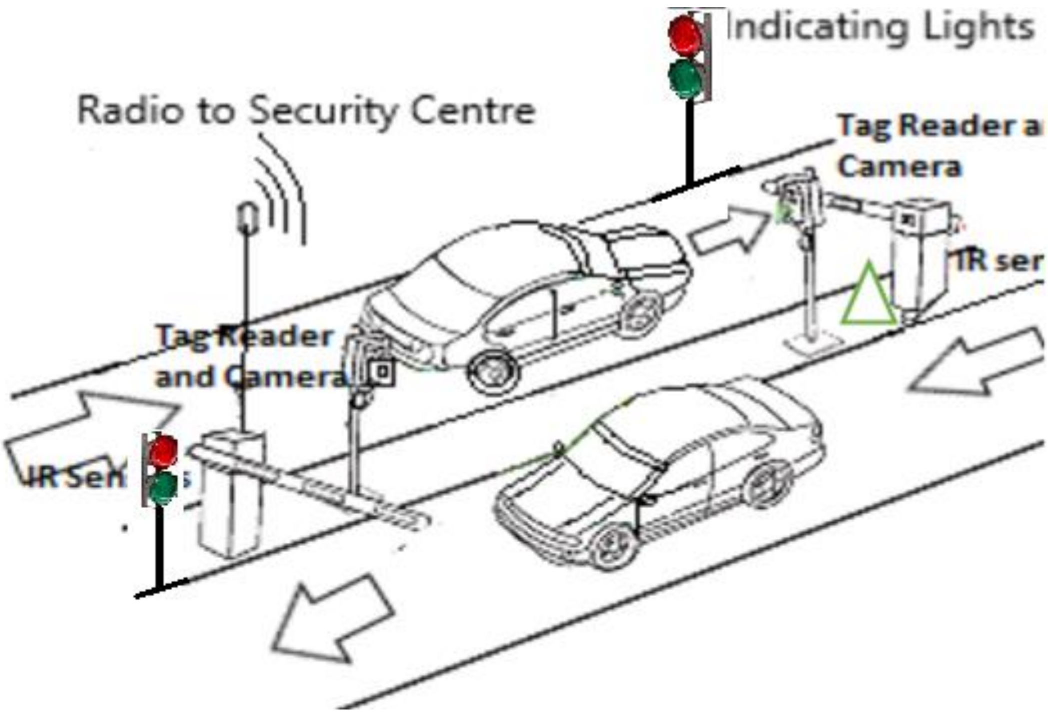


Figure 3 - 6 General system overview

The proposed system has a barrier in form of a boom gate. This is the arm that closes and opens to allow vehicle passage or closes to deny. The boom gate is hinged to a motor inside the box through gears. The rotation of the motor either clockwise or anticlockwise closes or opens the boom gate.

Technical Specification

Table 3.1 Boom Technical Specification

Features	**Specifications**
POWER	Ac 220v, 50/60HZ
BOOM GATE LENGTH	2.5m
MOTOR	50W, 220V, 50HZ
CONTROL UNIT	Arduino Uno,
SPRING	Multi Spring Balance
UP & DOWN INPUT	1 TRIG Barrier boom moves up; 0 TRIG barrier boom moves down
TRAFFIC LIGHT OUTPUT	AC 220V, 100W traffic voltage power, , relay actuates - Barrier moves up- green comes on. Relay release, Barrier boom comes down- red comes on

Table 3.1 shows the technical design specification for the hardware components that will be implemented. The *features* column names the specific hardware component while the *specifications* column gives the requirement detail.

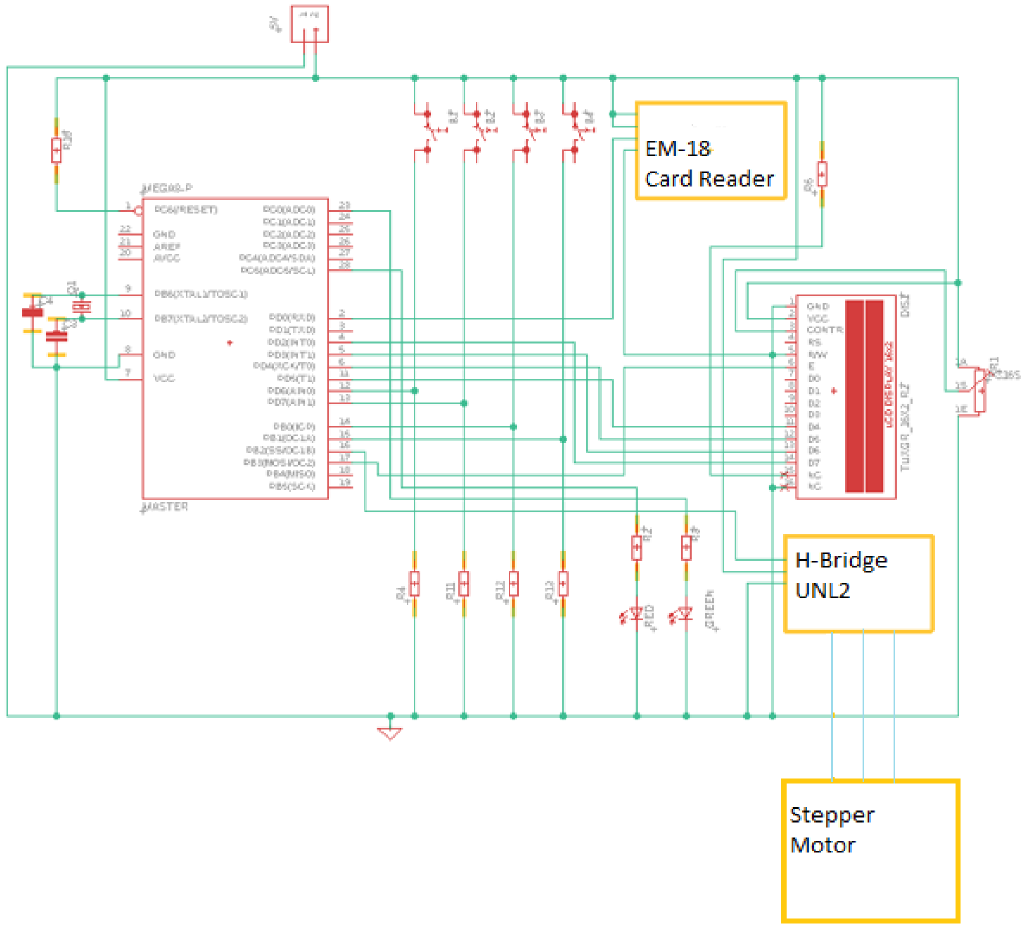


Figure 3 - 7 Circuit diagram

Figure 3.8 is a schematic circuit diagram providing detail on the linkage between the Arduino Uno, Card reader, the H-Bridge, the stepper motor and the display. The LED provides a logical display of the status of the boom gate. When the boom gate is in the open position, the Green LED comes on to indicate passage permit being granted. When the boom gate is closed, the Red LED comes on to indicate passage permit not granted or no request has been made. The two LEDs will be synchronized with the mechanically coupled traffic lights that will be operated at 220V as seen from table 3.1 above. In this circuit, the H-Bridge will be a high motor driver that will be able to handle a 5W stepper motor. It will equally control the direction of control as commanded by the controller Arduino Uno integrated circuit. The stepper motor will be meant to drive open the boom gate barrier at 90 degrees in its clockwise rotation. The display will show the status of the system during configuration as well as during operations.

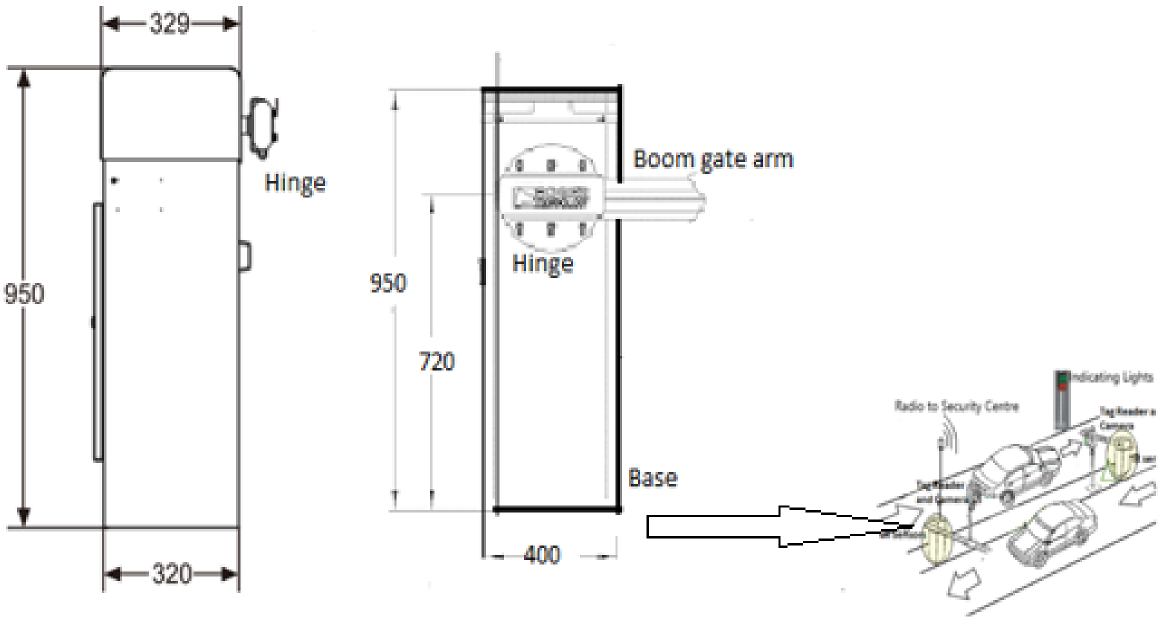


Figure 3 - 8 Dimensions of the Circuitry and motor enclosure

Figure 3.9 gives a detailed dimension of the boom gate circuitry enclosure. The boom gate barrier is attached to this unit coupled with a motor enclosed inside. Figure 3.10 shows the dimensions of a boom gate.

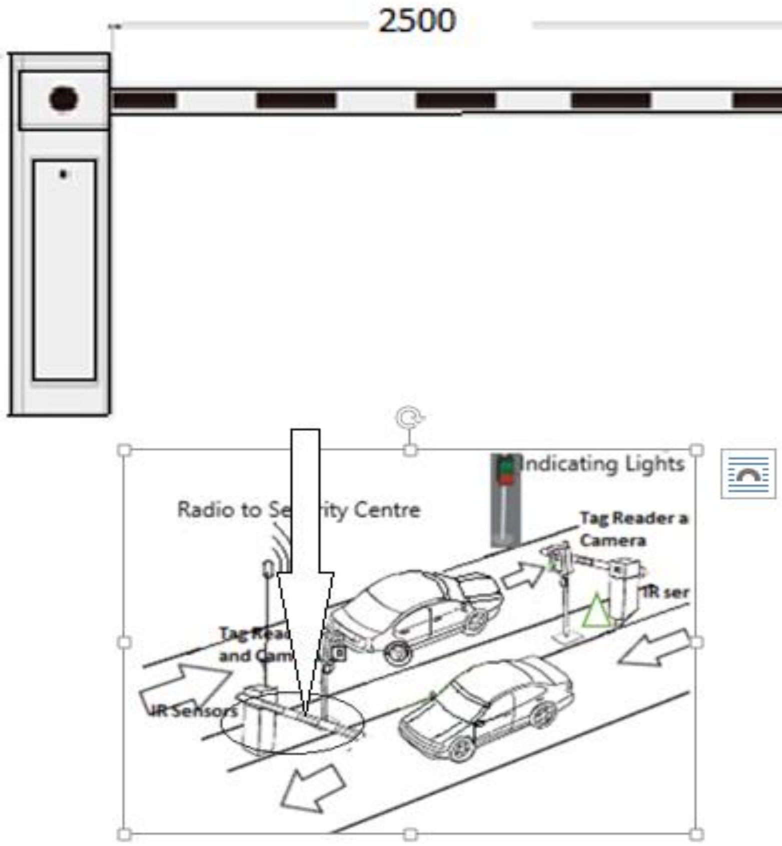


Figure 3 - 9 Boom gate dimensions

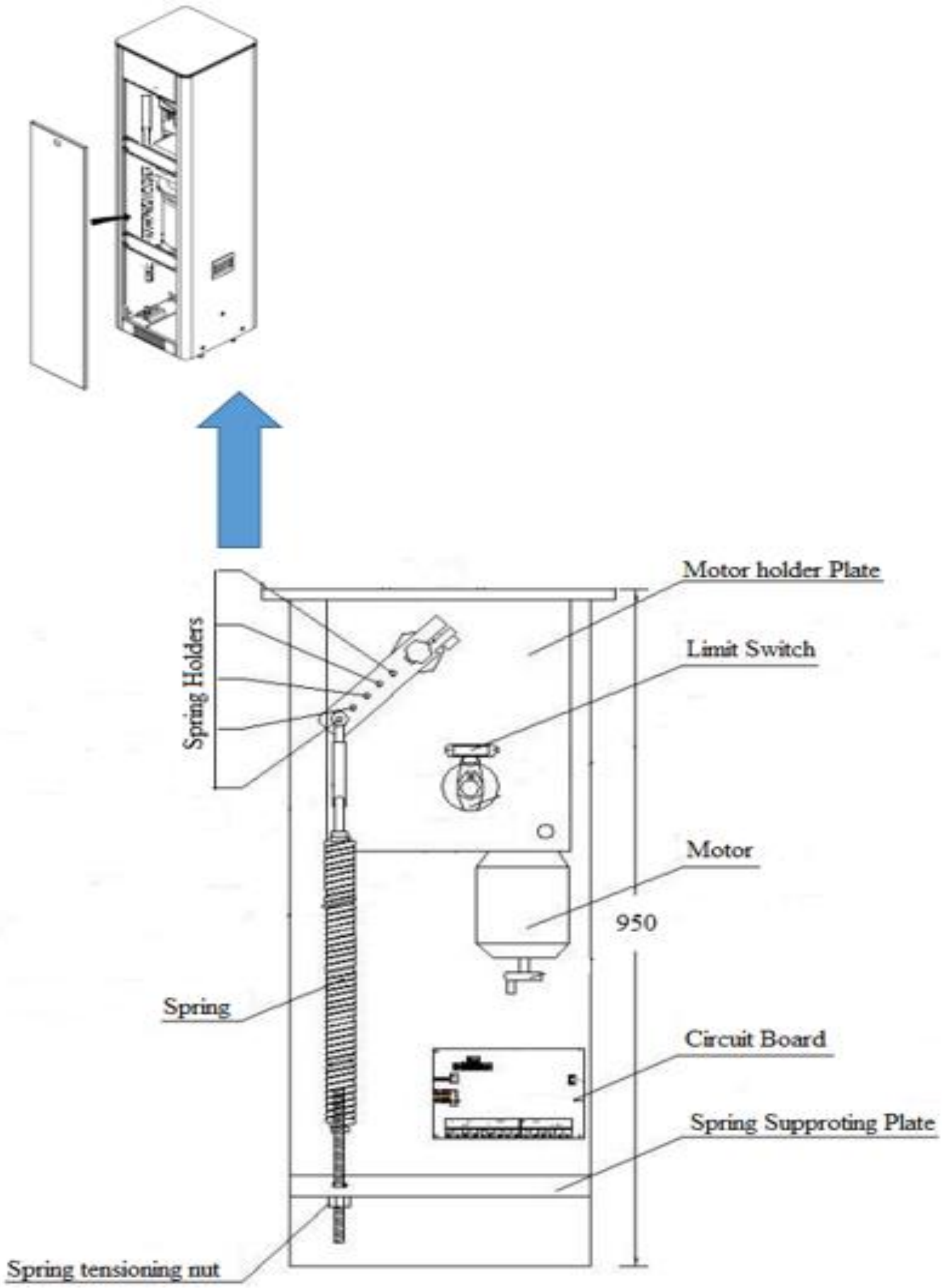


Figure 3 - 10 Boom gate enclosure accessories

The boom gate enclosure houses the boom gate circuitry, motor and accessories. Some of the accessories include the spring that makes it easier for the boom gate arm to be lifted up. It is hinged to the spring holder through to the spring adjusting nut. The motor is bolted to the enclosure through a welded motor plate holder. Within the enclosure is the photoelectric limit switch which turns off the rotation of the motor at 90 degrees clockwise and anticlockwise.

When the boom gate arm is at 90 degrees, the spring keeps it in that position until the motor is actuated to rotate in the clockwise position to close the gate. These activities are controlled by the electronic circuitry. Figure 3.7 below shows the boom gate enclosure and its accessories.

3.3.2.1.1 Arduino-Stepper Motor with Python Control

The following materials were used for building an Arduino controlled stepper motor with a Python interface.

Required Hardware

- Arduino UNO board
- Stepper Motor
- Stepper Motor Driver
- Voltage Supply
- Solderless Plug-in Bread Board

Required Software

- Python
- Arduino Software
- Arduino Control Program
- Python Instrumentation Control Module
- Python serial Arduino Module

Hardware Setup

Connected the Arduino, motor driver, and motor as seen below.

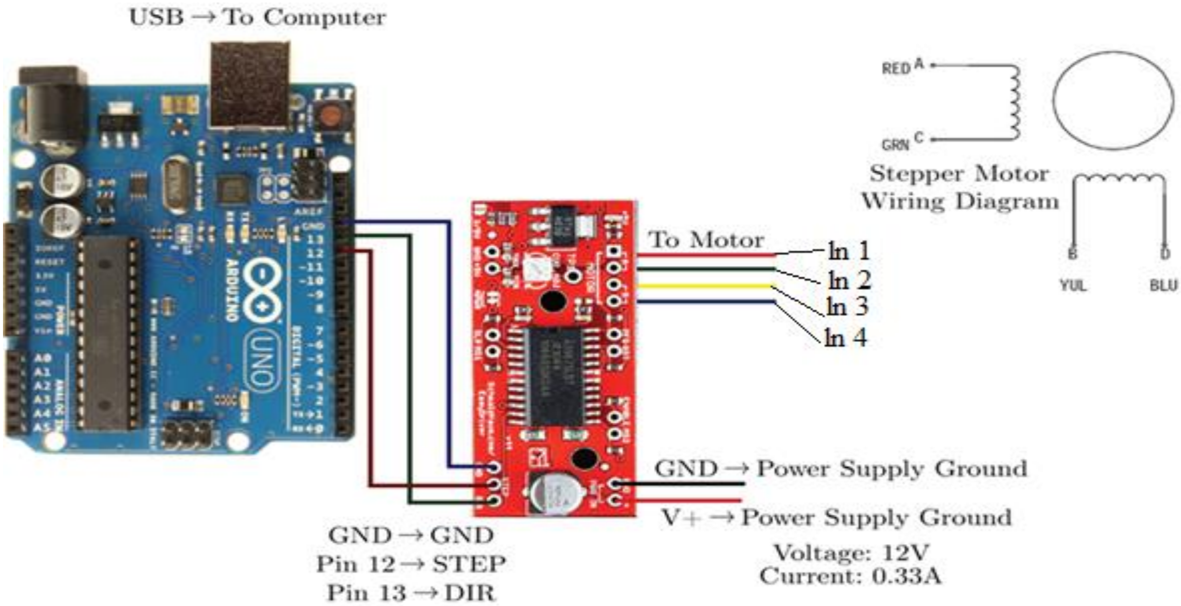


Figure 3 - 11 Arduino connections to the motor drive

Figure 3.12 shows the actual hardware connected to the motor drive. Three terminals emanate from the Arduino Uno to the motor drive. Terminal Pin 12 is a step or drive terminal. Pin 13 is a direction terminal. It determines which direction the motor should rotate (a more detail given later). The motor drive is powered by a 12volts supply at a current of 0.33 amps. The four terminals ln1 through to ln 4 connects to the stepper motor shown in figure 3.13.

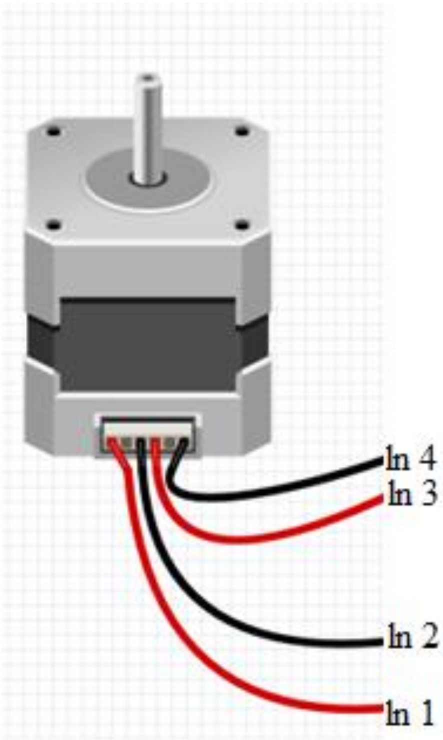


Figure 3 - 12 Stepper motor

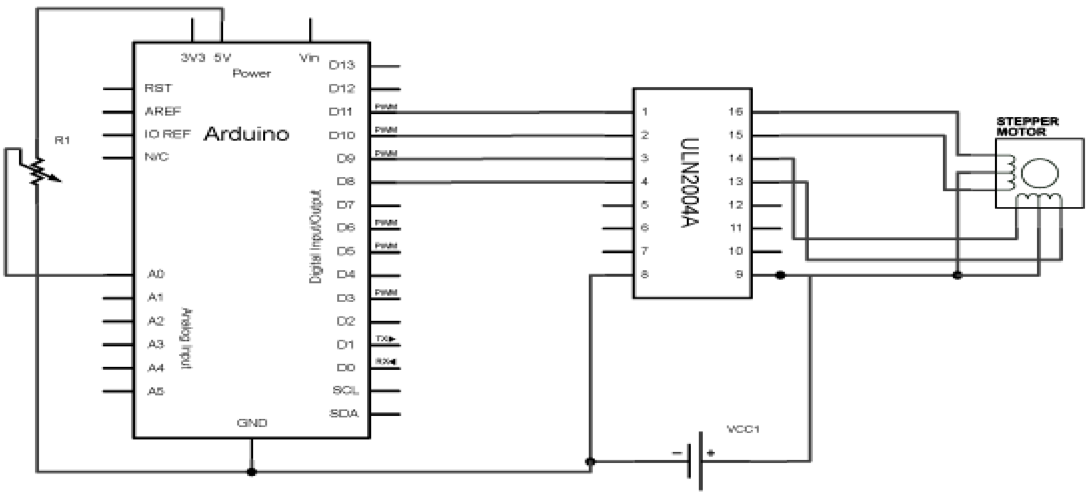


Figure 3 - 13 Arduino connection to H- Bridge Circuit diagram

There are three main cables that connect the Arduino to the stepper motor driver, the first one is a ground cable GND, to link the zero potential of the two circuits to avoid floating point. Terminal two provide the motor step pulses to control the micro steps of the motor and with each pulse sent to this pin the motor moves one step. The third terminal is the direction pin that controls the rotation direction of the motor It is connected to pin number 4 of the Arduino Board. Step and Direction terminals are the pins that are actually used for controlling the motor movements. Programing of the Arduino takes care of the motor movement such as direction, speed and limits.

3.3.2.1.2 High Power Motor Driver

For a high powered motor, a high power drive circuit is required. Below is the construction of the high power stepper motor driver.

The following is a list of components for h-bridge stepper driver module

1. Mosfet Tip-122 (4 pcs)
2. Mosfet Tip-127 (4 pcs)
3. Transistor 2222A (4 pcs)
4. Diode 4007 (8 pcs)
5. Resistor 10K (4 pcs)
6. Resistor 1k (4 pcs)

PCB design to make 5amp driver module

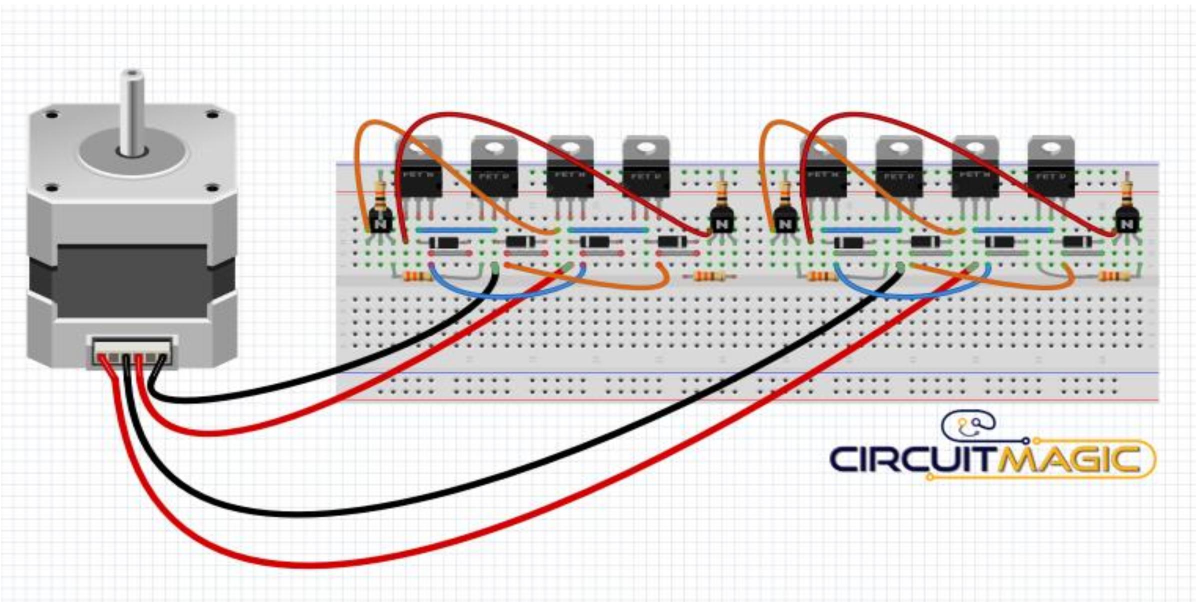


Figure 3 - 14 PCB High Power stepper motor H-Bridge design

Figure 3.16 shows a high power H-bridge using MOSFET transistors. This allows a high power motor circuit to be connected and operated smoothly without overheating or straining the logic circuit.

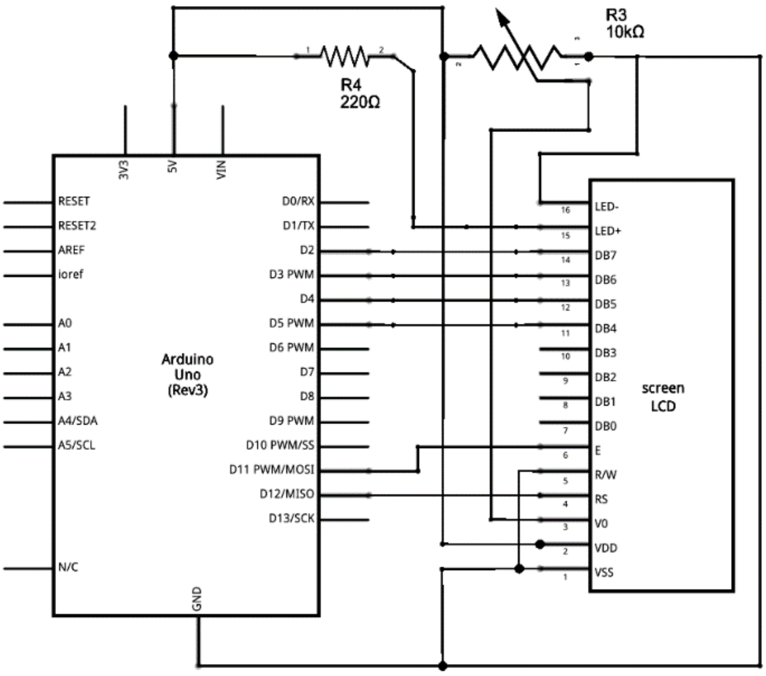


Figure 3 - 15 Connection of the Arduino to the LCD

Figure 3.17 shows LCD connection to the Arduino board. The display indicates the systems status at a particular time. It indicates whether a particular user has access granted or access denied, whether the system is ready or not. It also aids visual in the process of user enrolments, updates and deletion. The rheostat in the circuit adjusts screen brightness.

3.3.2.1.3 Traffic Lights

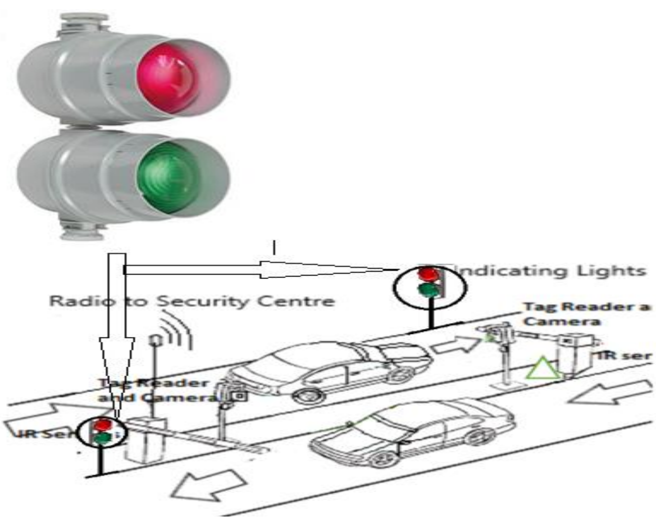


Figure 3 - 16 Traffic Lights

The traffic lights have Green and Red colors. The green color gives permission to the vehicle user to pass and would only come on when the boom gate is fully open. It is linked to the boom gate open limit switch. The moment the boom gate arm leaves the limit switch, the green light goes off and the red light comes on to give an indication of no pass to the driver.

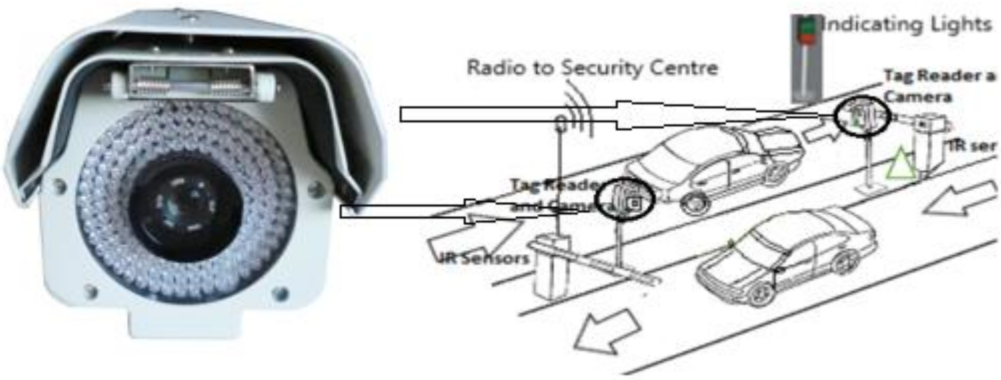


Figure 3 - 17 Infra-red sensor powered camera.

The camera is positioned by the road side to take pictures of an approaching vehicle. It is powered with an infra-red sensor that actuates the taking of a picture. The camera specifications are High Resolution High Range, Vari-Focal Array for Traffic Camera for Traffic surveillance, 3 Units of Dot Matrix Array LED Array Range of 50 meters, 9-22mm Iris Lens.

The sensors will be grouped into two, the entry sensors and the exit sensors. The entry IR sensors when interrupted by an approaching vehicle, awakens the cameras and triggers them to take pictures of the approaching vehicle. The picture is then sent for processing. If entry is allowed by the opening of the boom gate, the boom gate will not close until the exit sensors are interrupted.

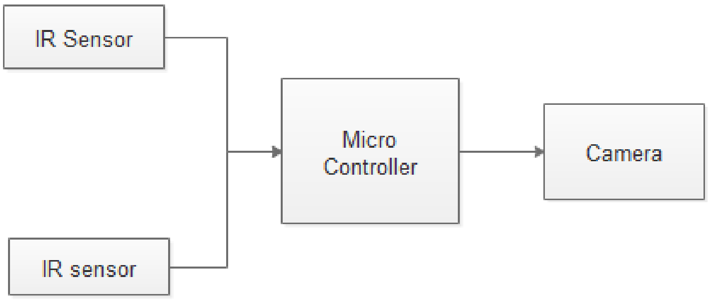


Figure 3 - 18 Simplified block diagram on the operation camera.

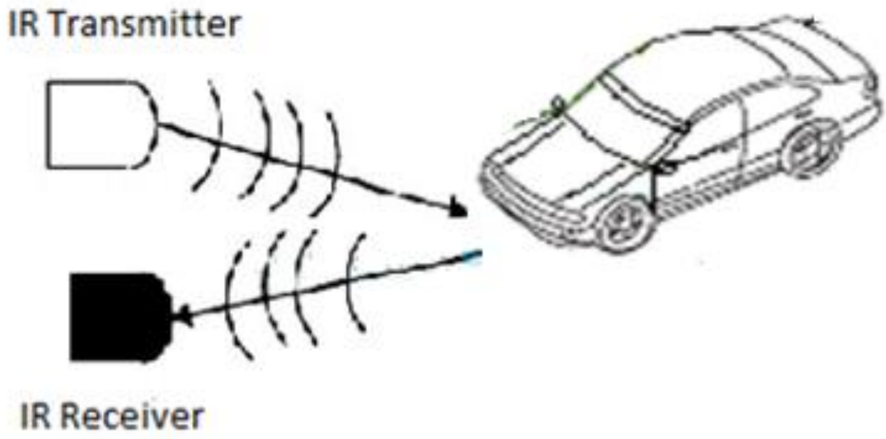


Figure 3 - 19 Simplified block diagram on the operation camera.

Figure 3.20 shows how an IR sensor propagating a signal and receives a feedback when the signal bounces back to it.

3.3.3 System Architecture

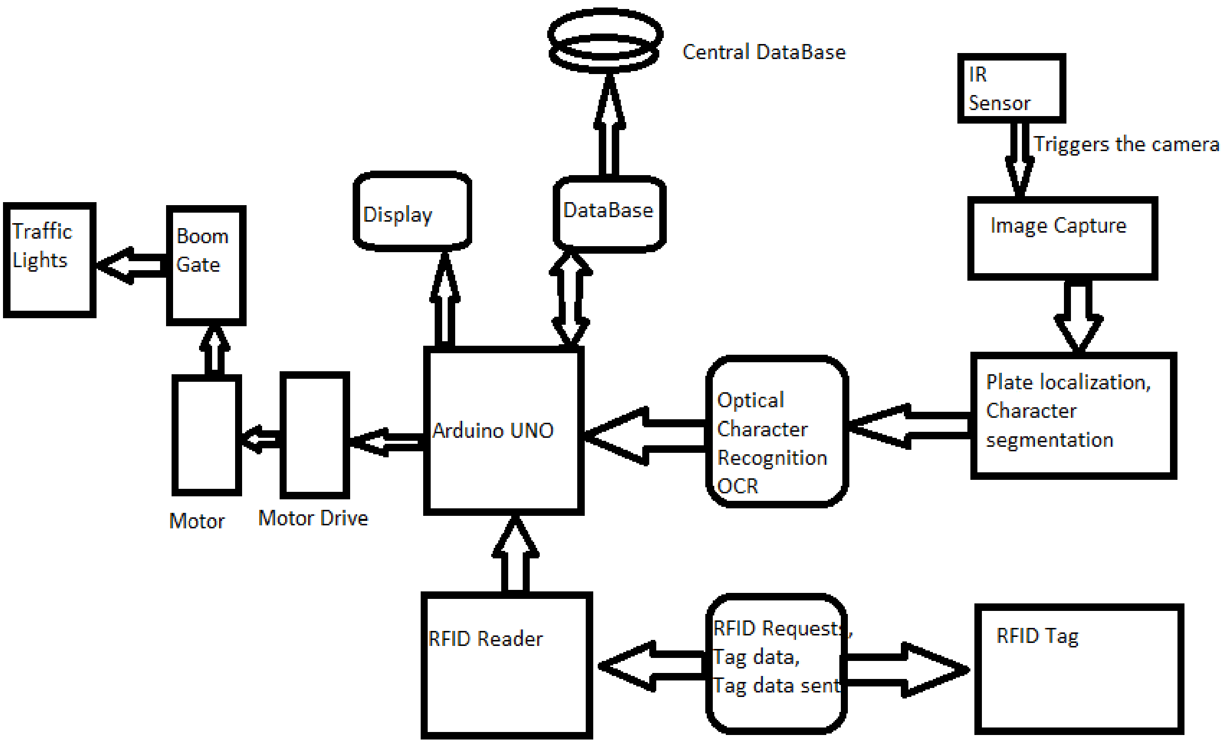


Figure 3 - 20 Proposed System Process Model

The process flow chart above shows two systems, the ANPR and RFID systems integrated through the Arduino Uno circuitry. The ANPR system captures the vehicle number plate after the IR sensors detects an incoming vehicle through the camera. The captured image is passed through four processing stages; Preprocessing where image contrast is enhanced through application of minimum filtration. License plate localization where position of the license plate is identified and sectionalized, Character segmentation being the third stage where characters are segmented and changed into binary characters and finally Character recognition where characters are recognized and classified into binary images that contain characters received from the previous one. The recognized characters are fed into the Arduino.

Likewise the RFID reader seeks and obtains details of the RFID tag and feeds the characters into the Arduino of which the two data characters are merged.

The Arduino consults the data base and thereafter gives a command to the motor circuit to either drive the motor open the boom gate or keen it closed. At the same time the aggregated data from both the ANPR and RFID is captured and stored in the database. The boom gate status determines the status of the traffic lights. At the same time, the LCD displays information of the system status.

3.3.4 Middleware Architecture

In figure 3.16, an architecture of the RFID and ANPR middleware architecture is shown. The middleware constitutes application interface, event control, data processing and device management modules.

The device management modules manages the different types of hardware communicating with the middleware. The application interface provides an interface for the middleware and the database storage to communicate. The user applications access data stored in the database for inventory management operations.

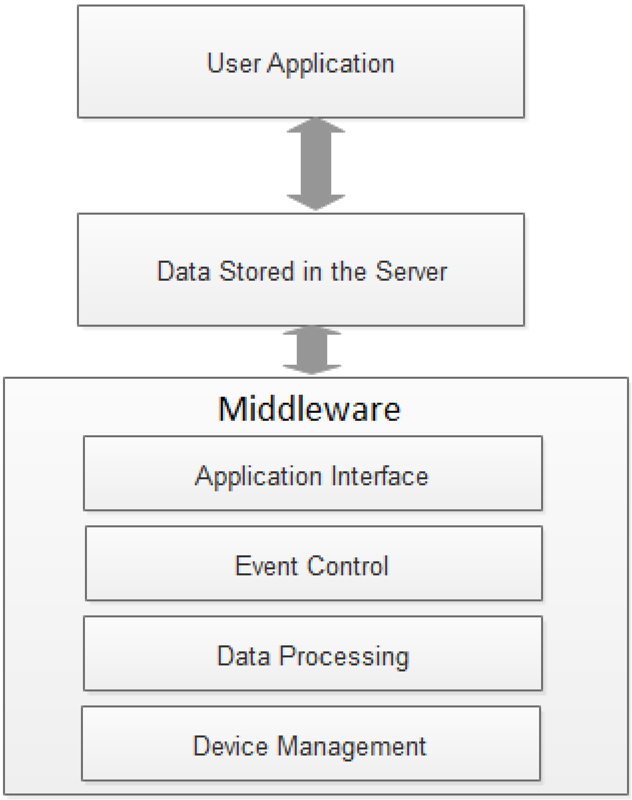


Figure 3 - 21 Middleware architecture

3.3.5 System Requirement Specification

System requirements specification are descriptions of what the system should do and services it provides. It also outlines the constraints the system may have. Requirements reflects user needs the system is intended to serve[118]. system requirement can be classified into functional and non-functional requirements. Functional requirements are statements of the service the system should provide and non-functional requirements as constraints on the services or function offered by the system[118].

The System Requirements Specification section, therefore, provides a complete description of all the functionalities and specifications for UNZA vehicle access control system using RFID and ANPR.

3.3.5.1 Functional Requirements required for application processes

Table 3 - 1 Functional requirements – Application Processes

Function Requirement 1	Systems administrators shall have relevant access rights and the ability to enroll users for access at various access points. (These will include heads of security and CICT)
Function Requirement 2	System administrators shall have the ability to edit users credentials and access rights (These will include heads of security and CICT)
Function Requirement 3	System administrators shall be able to generate reports of transaction whenever needed. (This shall be achieved by sorting the entries in the database as records were being created)
Function Requirement 4	The system shall keep records of the identification information of persons or drivers and the vehicle number plate for both exits and entering. (This shall be achieved through the capturing of the drivers RFID information at the access points manned by boom gate, by the RFID reader and number plates by the camera).
Function Requirement 5	The System shall match ANPR and RFID inputs against database data. If the card and number plate is valid in reference to the data base information, the boom gate will be opened and a transaction recorded. If the card is invalid, the system shall give an alert in form of an alarm and display to indicate the card's invalid.
Function Requirement 6	The system administrator shall have the ability to create new users.
Function Requirement 7	The system administrator shall have the ability to remove a user from the system
Function Requirement 8	The system administrator shall have the ability to edit a user's system access rights
Function Requirement 9	The system shall grant access to registered ID card holders OR registered vehicles into the, University premises using Lufyanyama or Kamloops entrances
Function Requirement 10	The system shall record and grant access to all vehicles through the main Great East Road campus.
Function Requirement 11	The system shall grant access to the car parking areas for both registered identification cards AND vehicle number plates

Table 3 - 2 functional requirements – system information and data flows

Function Requirement 12	***The system shall retrieve data from readers and cameras***
Function Requirement 13	The system shall retrieve history data when queried
Function Requirement 14	***The system middleware shall perform data filtering***

Table 3 - 3 Non-Functional Requirements

Non-Functional Requirement 1	RFID tags shall possess anti-collision capability allowing the reading of the tags within the sphere of influence at the same time.
Non-Functional Requirement 2	All the users of the premises are given RFID identity cards (IDs) containing personal information to be accessed.
Non-Functional Requirement 3	RFID tags shall be read/write chip based tags
Non-Functional Requirement 4	RFID readers/antennas shall be short range
Non-Functional Requirement 5	All hardware shall run on standard power 220V, 50HZ

Table 3.4 Details of software performance requirements the system shall abide

Table 3 - 4 Non-functional requirements – software performance requirements

Non-Functional Requirement 6	All management functions software shall take optimal advantage of all languages, compiler and system computational features
Non-Functional Requirement 7	The system shall perform tag information and optical character recognition output integration.
Non-Functional Requirement 8	The system shall be user friendly

Table 3 - 5 Non-functional requirement - reliability and availability

Non-Functional Requirement 10	The hardware part shall perform without loss of services unless in case of total failure

Non-Functional Requirement 11	In case of loss of automation due to complete loss of supply as a result of non-backup systems, the system shall be operated manually.

Table 3.6 details the systems' serviceability requirement specifications

Table 3 - 6 Non-functional requirement – serviceability

Non-Functional Requirement 12	The system processing and interconnect hardware shall be readily accessible for maintenance, repair, replacement and reconfiguration

Table 3.7 details the systems' security requirement specifications

Table 3 - 7 non-functional requirements –security

Non-Functional Requirement 13	All systems administrators shall login using their unique credentials
Non-Functional Requirement 14	All login attempts shall be in a secure manner eg encrypted passwords
Non-Functional Requirement 15	The systems' administrator shall have unrestricted access in the system

Table 3.8 details of the systems; installation and upgrade requirements specification

Table 3 - 8 Non-Functional Requirement – installation and upgrade

Non-Functional Requirement 16	The system shall continue operating though not necessarily on full scale during maintenance and upgrade.
Non-Functional Requirement 17	Modular design principles shall be employed to the maximum extent possible
Non-Functional Requirement 18	In case of total failure, the system shall be turned into manual operation.

Table 3.9 details the system's documentation requirements specifications

Table 3 - 9 Non-Functional Requirement - documentation

Non-Functional Requirement 19	Full documentation for all functionality and any user maintenance of the system shall be provided

Non-Functional Requirement 20	Any future upgrade to the system shall be accompanied with full explanatory documentation
Non-Functional Requirement 21	The software system shall be well documented and written in general familiar language.

3.3.6 System Modelling and Design

Object Oriented Design (OOD) was used to design the system model

3.3..6.1 Interaction Models – Use Cases

Use case model is used to model interactions between a system and external actors which may include users and other systems . Actors are a representation roles that people, other systems or devices take on when communicating with particular use Cases in the system. Table 3.10 shows the actors and description of each actor in the system.

Table 3 - 10 System Actors and Actors Descriptions

Actor	Description
RFID Reader	The RFID reader is responsible to capture user information by detecting user identity cards and sending that user information to the middleware.
RFID Middleware	RFID middleware sits between the hardware and the backend database. The middleware is responsible for all the computations, data retrieval from the reader, data filtering and event handling.
IR Sensors	IR sensors are responsible for actuating the camera to take pictures and sense vehicle clearance before allowing boom gate closure.
ANPR Camera	The camera is responsible for capturing vehicle number plate.
Optical Character Recognition OCR	This is the technique within the image processing process through which binary characters of the number plate are extracted.
Users	These are ordinary individuals that pursue to gain entrance to the secured premises.

Administrator	The administrator is responsible for administering the entire system and has access to all aspects of the system

RFID and ANPR Systems Management Use Cases

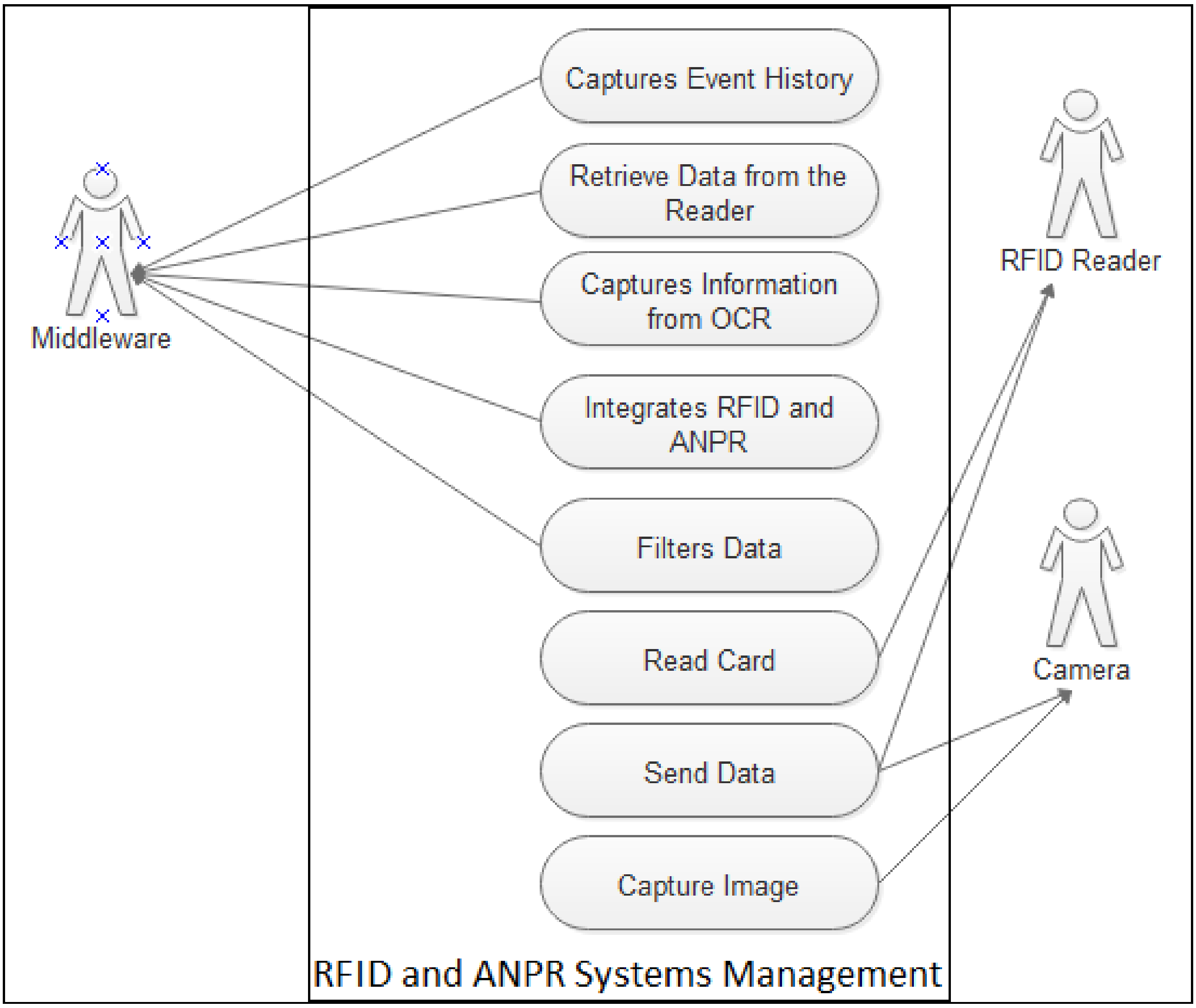


Figure 3 - 22 RFID and ANPR Systems Management Use Cases

Table 3.11 details the descriptions of each Use Case identified in the Use Case diagram

Table 3 - 11 System Actors and Actors Descriptions

Use Case	Description
User request Entry Using RFID ID	The user upon reaching the area of influence will have his or her RFID ID queried by the card reader and card information shall be matched with database content.
User request Entry Using RFID ID	The user upon reaching the area of influence will have his or her data captured by the Systems camera and number plate shall be compared to the database.
User Recognised and Permit Granted	Once a march is identified, system gives permission to the user to access the premises by opening the boom gate.
User not recognised and permission denied	If there is a mismatch on the user credentials with data base registered users, permission is not granted by a way of not opening the boom gate and sounding alarm.
User details captured	Each time a user ID of Number plate is introduced, the system captures the details and stores them
Administrator Login in	The administrator is able to login in and access configurations.
Enrol User	When a new user joins, the administrator enrols him/her by entering relevant details in the system.
Edit user	When the user details needs updating, the administrator edits the user’s details and updates the data base.
Remove a User	When the user no longer has authority to access certain restricted areas, the administrator may remove the user from the system.

User management Use Cases

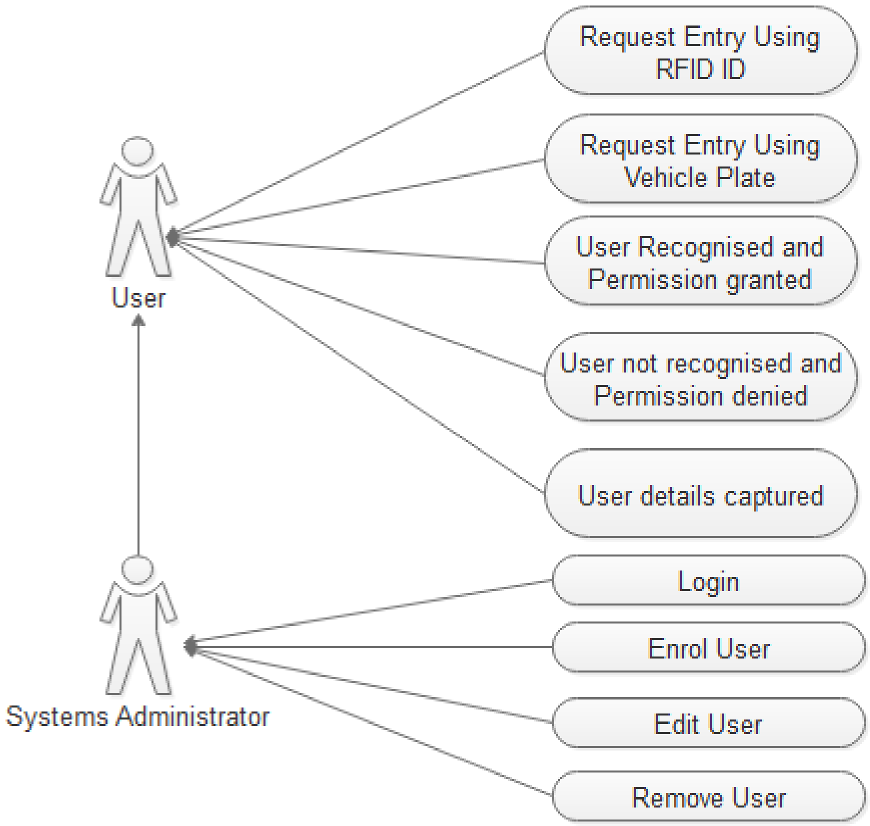


Figure 3 - 23 User management Use Cases

3.3.6.1.1 System Configurations

A system was configured with three access cards and labels where given to the cards as Tick, Circle and Cross as shown in the figure 3.26.

Figure 3.26 Access Cards

Tick card: 4900DC6F916B

Circle(O) card: 4900DC7032D7

Cross(X) card: 4900CC37DD6F

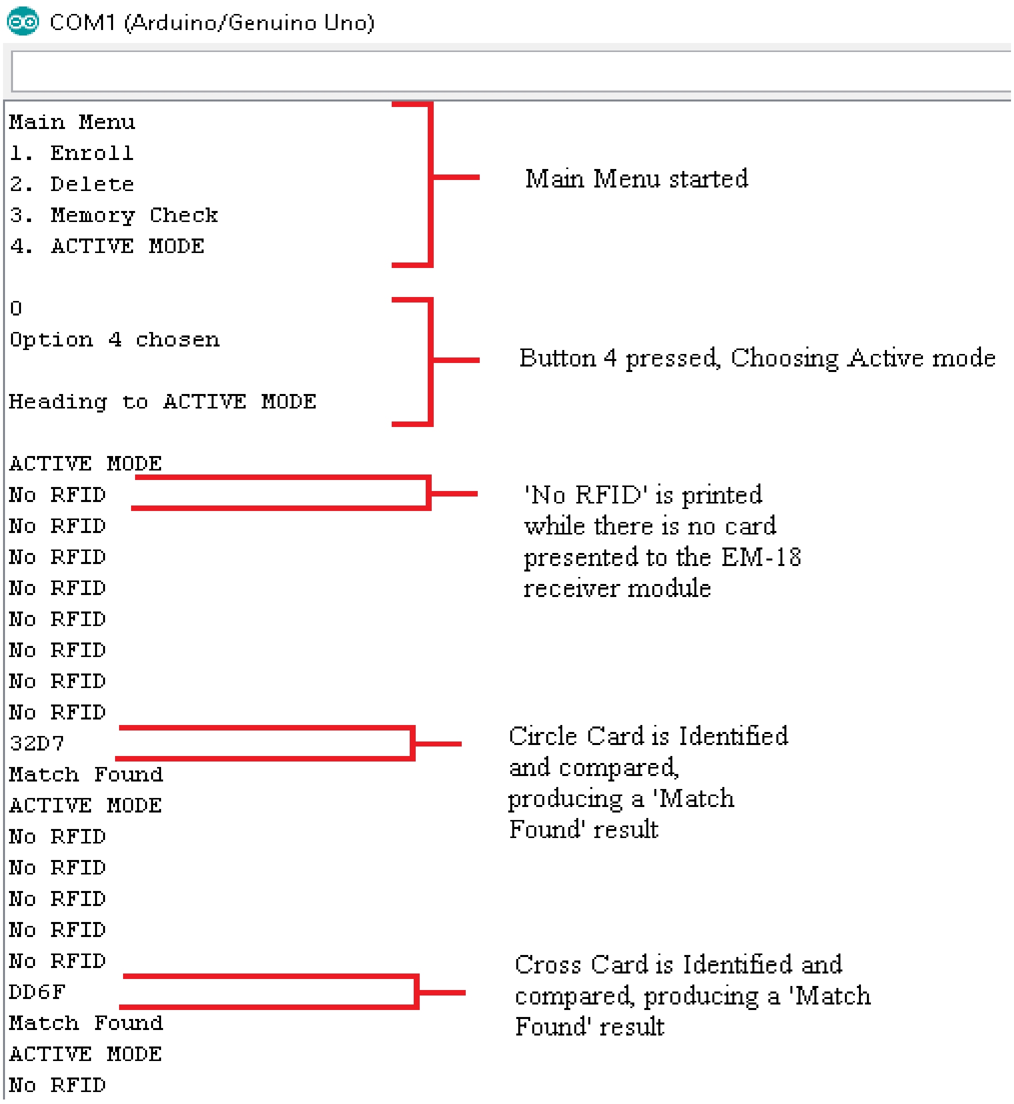
<u>CASES</u>

We went case by case to show the functionality of the system. In these examples the information to be printed on the LCD has been taken to the Serial monitor to better illustrate the step by step functionality.

Case 1: Active mode

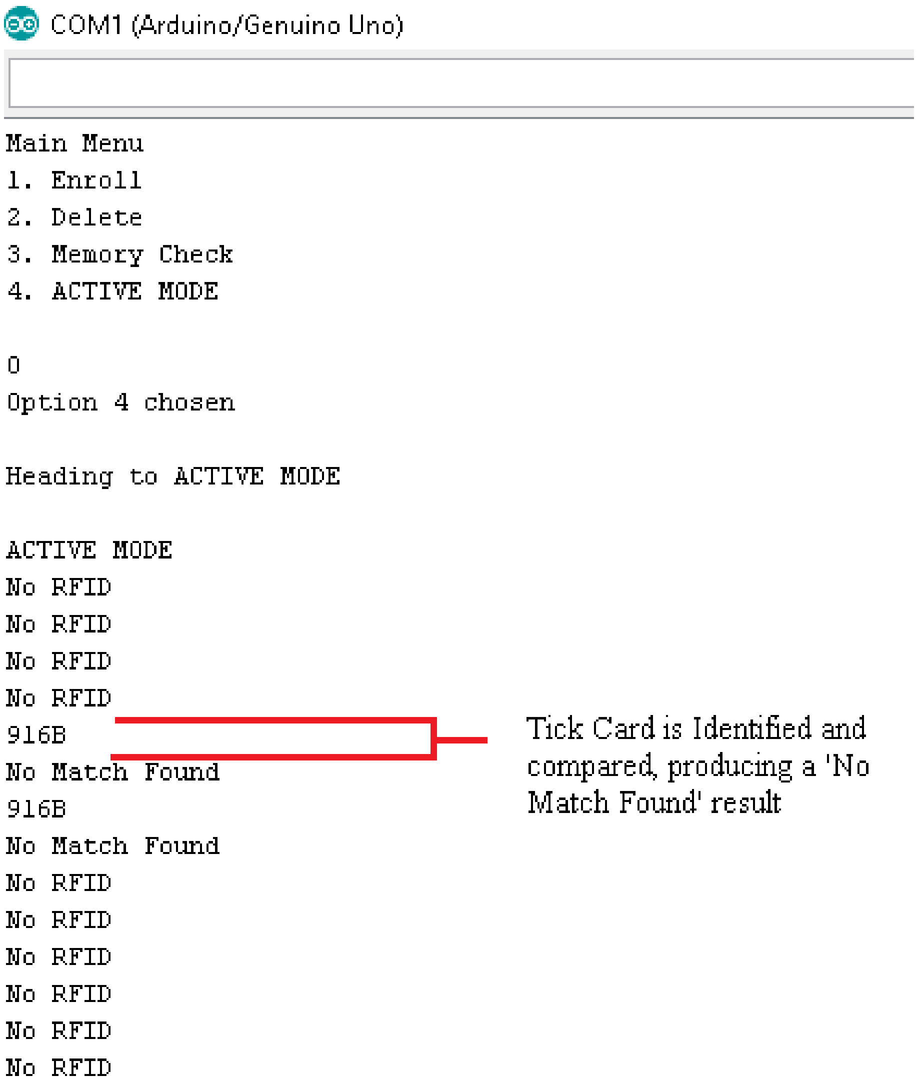
In active mode the system compared the introduced card to the ones stored in the system. In this example, the Circled and Crossed card were registered and the Ticked card was not.

1.Comparing the Circle and Cross card results in:



Case 1 showed that when a configured card with a **Circle** was introduced to the card reader, the system matched the card variables with the content of the database. When a match was found, the system actuated the running of the motor and eventual opening of the boom gate.

2.Comparing the Tick card results in:

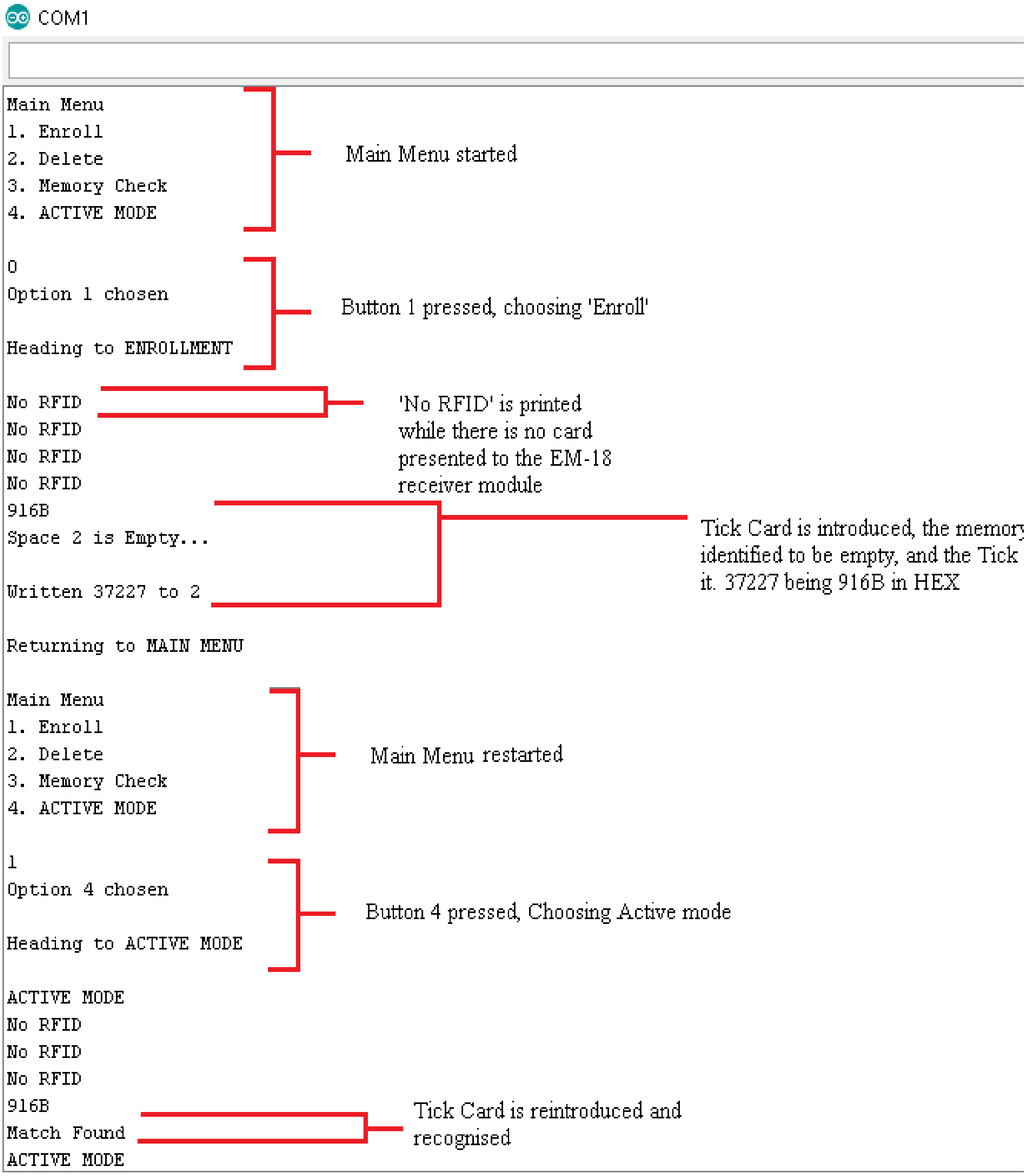


When the non-programmed Ticked card was introduced, the system could not find a match in the database. As a result, no signal to actuate the motor was sent and the boom gate remained in a closed state.

Case 2: Enrolment Mode

Here, we will enroll the Tick Card, and then see the result of passing it in Active mode.

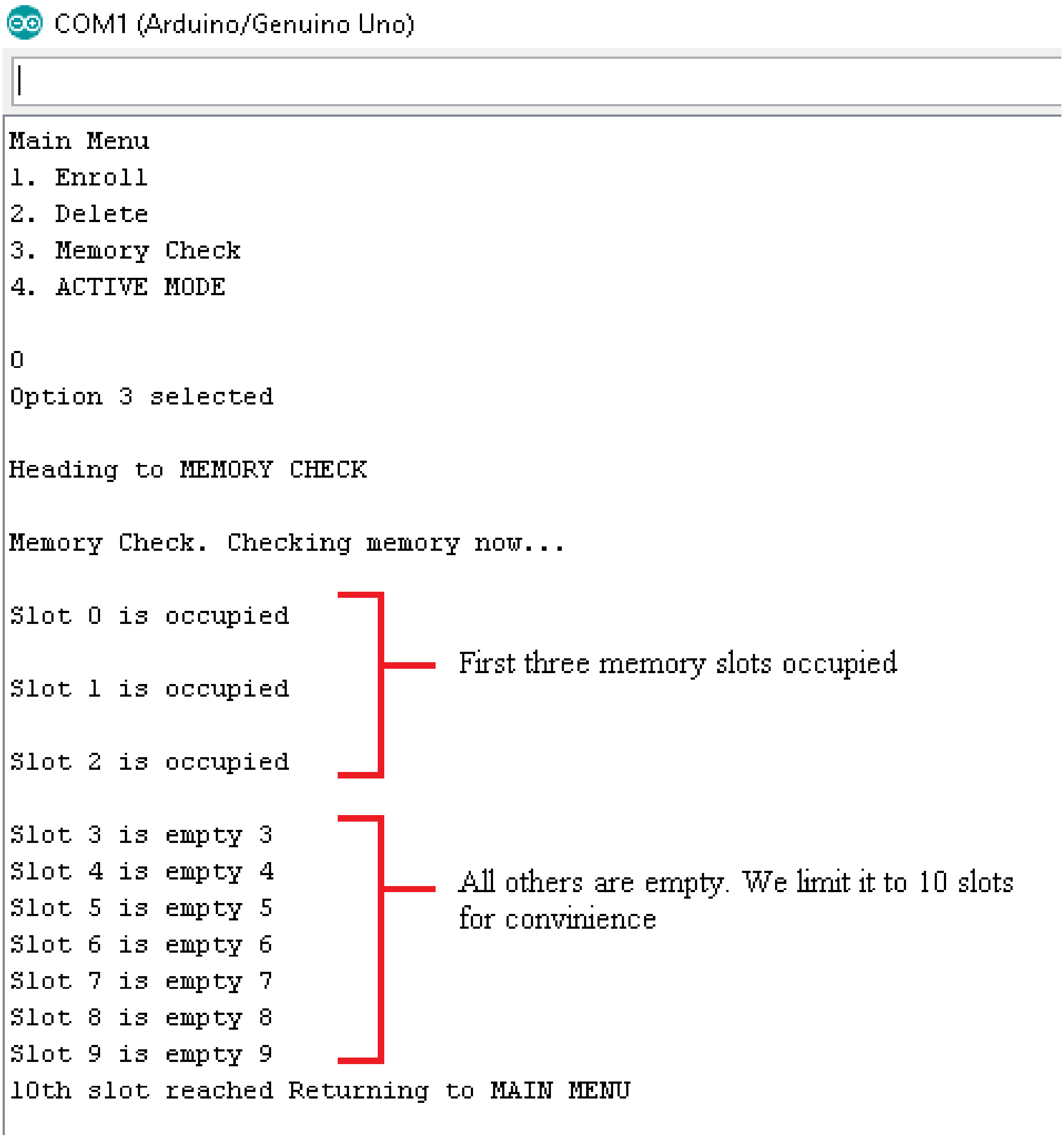
1.Enrolling the Tick Card and then comparing the Tick Card results in:



Case 2 shows the card enrolment process which is an administrative task. On the right side is an explanation of the system's response and instructions.

Case 3: Memory Check

Case 3 shows system administrative memory check. In this case, 3 slots are filled while the rest remains empty. This enables know how many users the clients can take.



```
COM1 (Arduino/Genuino Uno)

Main Menu
1. Enroll
2. Delete
3. Memory Check
4. ACTIVE MODE

0
Option 3 selected

Heading to MEMORY CHECK

Memory Check. Checking memory now...

Slot 0 is occupied

Slot 1 is occupied

Slot 2 is occupied

Slot 3 is empty 3
Slot 4 is empty 4
Slot 5 is empty 5
Slot 6 is empty 6
Slot 7 is empty 7
Slot 8 is empty 8
Slot 9 is empty 9
10th slot reached Returning to MAIN MENU
```


For case 3 the system shows how much memory is available and how much has been used up. In this case three cards have been configured as shown

Case 4: Delete

Case 4 demonstrates the system's administrative delete function, thus, deletes a single selected memory slot were as the function 'delete all' deletes all memory slots at once. This leaves the memory empty. Delete Tick Card then Check the memory results in:

COM1 (Arduino/Genuino Uno)

```
Main Menu
1. Enroll
2. Delete
3. Memory Check
4. ACTIVE MODE

0
Option 2 selected

Heading to DELETION

1. Delete All 2. Delete single ID
```

Button 2 is pressed

```
Delete slot:
0
?
1. Yes 2. No
```

Button 2 is pressed

```
Slot not deleted

Resuming Memory Check...

Delete slot:
1
?
1. Yes 2. No
```

Button 2 is pressed

```
Slot not deleted

Resuming Memory Check...

Delete slot:
2
?
1. Yes 2. No
```

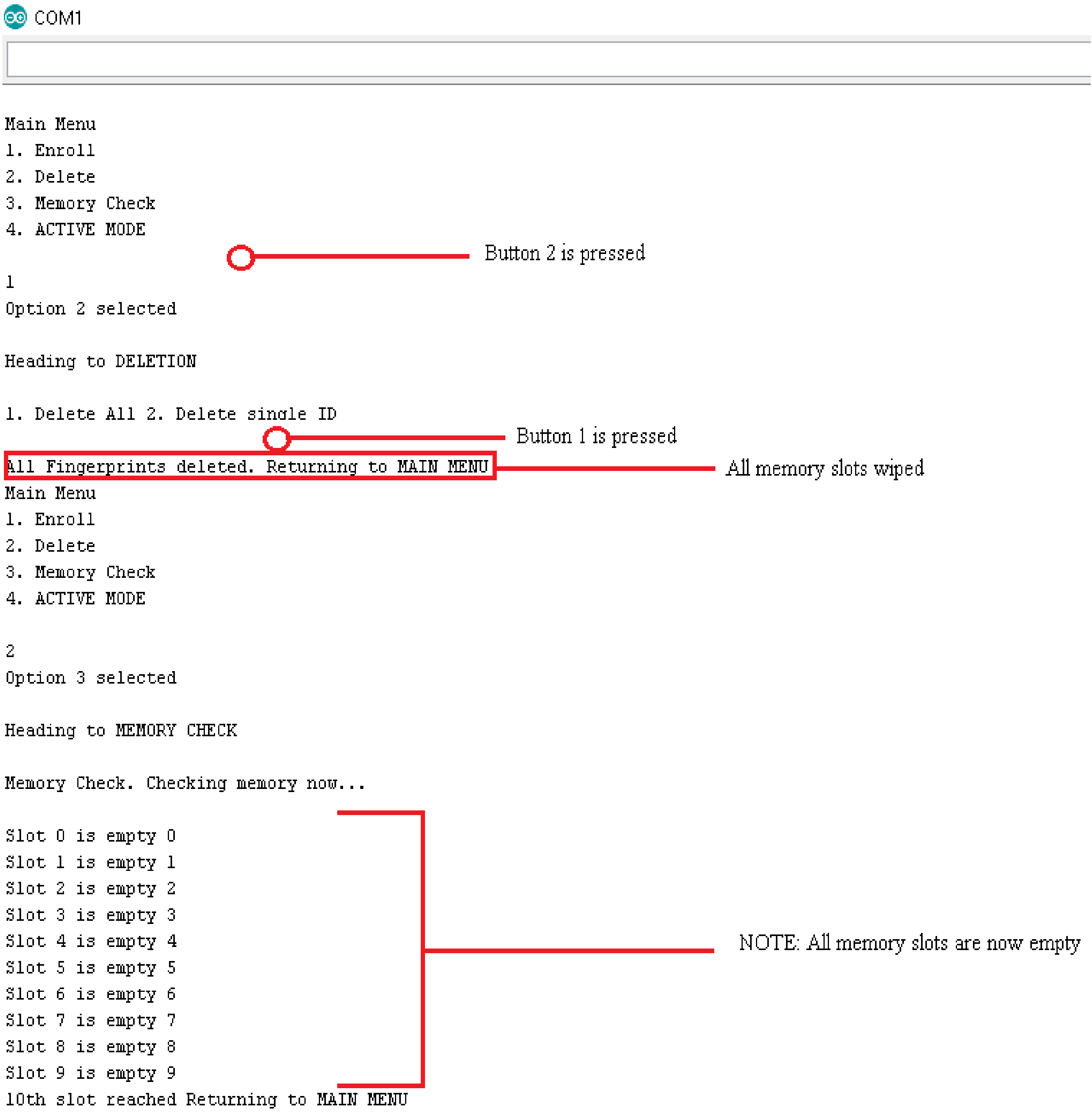
Button 1 pressed
Tick Card is deleted

```
Slot
2
 is deleted

Resuming Memory Check...

Resuming Memory Check...

Resuming Memory Check...

Resuming Memory Check...


Memory Check concluded. Returning to MAIN MENU

Main Menu
1. Enroll
2. Delete
3. Memory Check
4. ACTIVE MODE

1
Option 3 selected

Heading to MEMORY CHECK

Memory Check. Checking memory now...

Slot 0 is occupied

Slot 1 is occupied

Slot 2 is empty 2
```

NOTE: Tick Card slot is now vacant

```
Slot 3 is empty 3
Slot 4 is empty 4
Slot 5 is empty 5
Slot 6 is empty 6
Slot 7 is empty 7
Slot 8 is empty 8
Slot 9 is empty 9
10th slot reached Returning to MAIN MENU
```

2. Delete all Cards then Check the memory results in:



Case 4 shows the administrative edit and delete functions.

3.3.7 Access Control points

Figure 3.25 shows the proposed locations for the boom gates in the campus. Individual access points are linked to the central server for transaction record transmission.

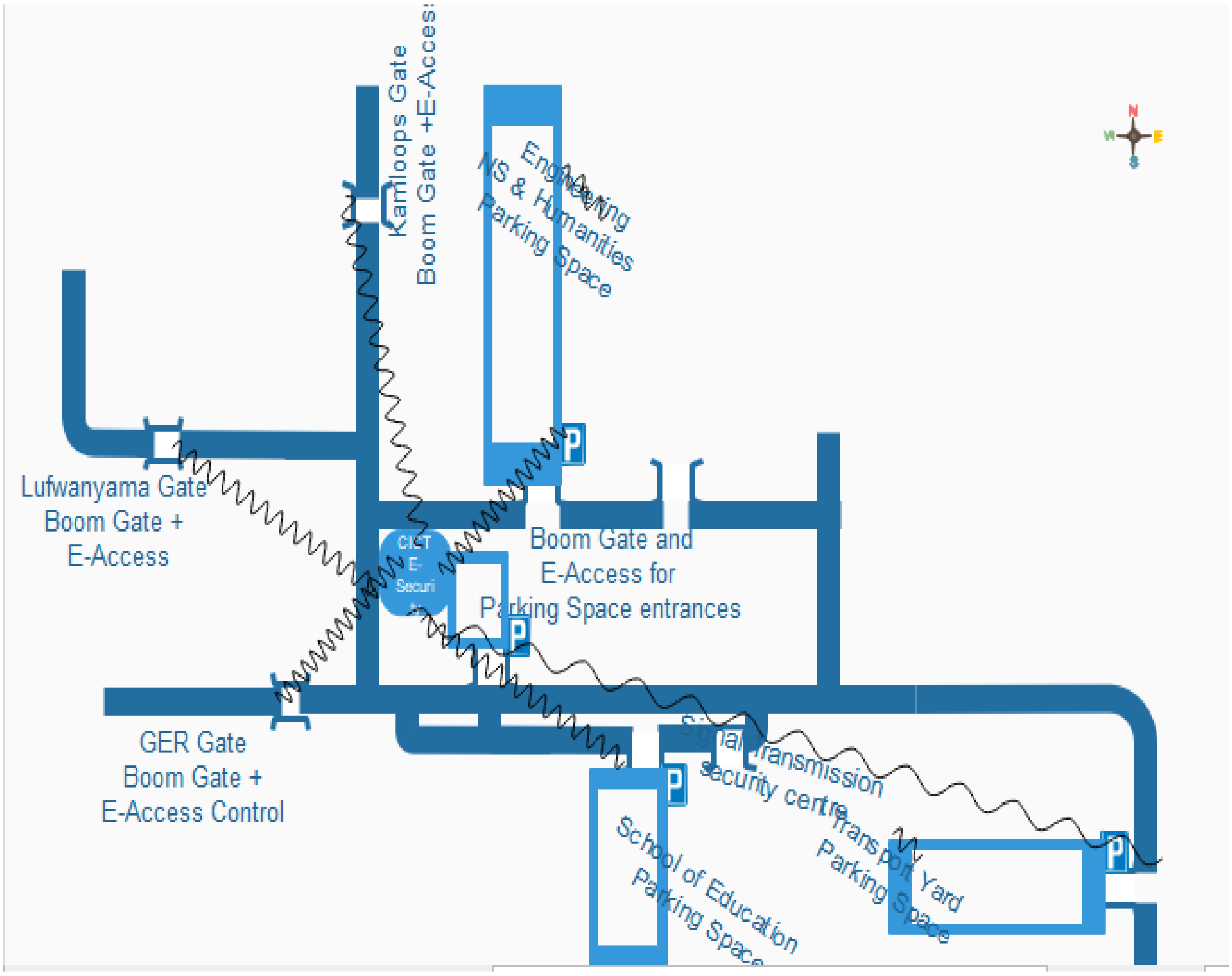


Figure 3 - 24 Access Control Points with centralized E-Security

3.3.8 Automatic Number Plate Recognition (ANPR)

Figure 3.26 is a basic system block diagram analysis using the ANPR. The Microcontroller receives information from the ANPR system, that queries the database for the availability of a match. After a query response from the database, the microcomputer sends a signal to the boom gate to either allow or deny access. When the boom gate opens, it sends a signal to the microcomputer to inform the user that access has been permitted. At the same time, the microcomputer sends a user's notification signal to the display. The exit sensors are activated to instruct the boom gate closure after the vehicle passes.

3.3.8.1 Block diagram

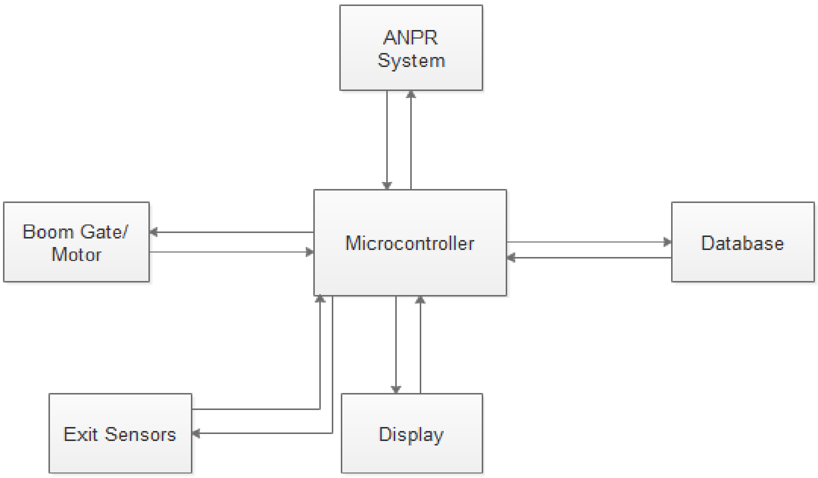


Figure 3 - 25 Block diagram for the system using ANPR

3.3.8.2 Flow Chart

Figure 3.27 shows an ANPR flow diagram, when the image is captured, it is taken for processing through to character recognition using Optical Character Recognition algorithm. When the characters are identified, they are matched with the database content. If a match is found, the user is authenticated and the boom gate is opened. However, if the match is not found the user is not authenticated and the boom gate does not open as access is not granted.

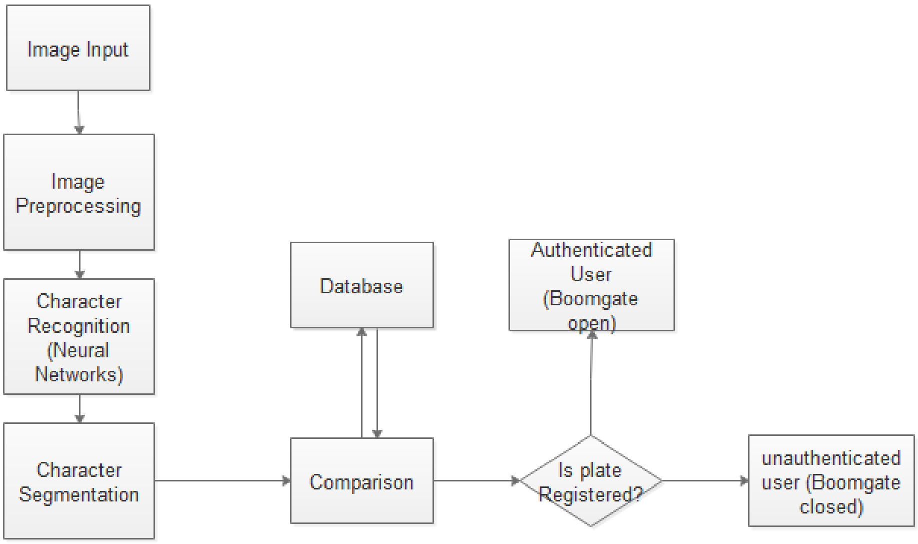


Figure 3 - 26 Flowchart diagram for the system using ANPR

3.3.8.3 Algorithm

- Step 1. Start
- Step 2. Check for the incoming vehicle

- Step 3. Take a picture
- Step 4. Define Number Plate and plate characters
- Step 5. Check characters against the data base.
- Step 6. Record vehicle number, time and date and data base status
- Step 7. If plate number is NOT available, Keep Boom gate CLOSED.
- Step 8. If plate characters are found in the database, Open Boom gate.
- Step 9. Wait for vehicle to pass OR counter time elapse and close the boom gate

3.3.8.4 System Overview

3.3.8.4.1 Image Acquisition

All images were taken using a Fujifilm 14 mega pixel camera. A total of 200 images of license plates where captured and stored in one folder. The images where divided into training and testing images. Images were taken at a distance range of 0.5-2m from the car and at different angles and lighting conditions. Out the total of 200 images, 100 were done in a poorly lit condition whose detection results was 32 percent. The other 100 images done in a well-lit environment gave 87 percent detection.

3.3.8.4.2 Plate Extraction

The input image was read using the imread function of Matlab. The image input was in RGB format as shown in Figure 3.28 and was converted to greyscale in Figure 3.29. An RGB image is referred to as an original image and is stored in a 3*3 array that defines red, green and blue color components representing individual color pixels. For greyscale image intensities of the image are represented in a data matrix.

Converting the image to grey scale makes it easy to carry out thresholding. Adaptive thresholding was used, which reduces intra class invariance in the image. The binary image is assigned values of 1s and 0s (black and white pixels). This was implemented using inbuilt threshold function.

Figure 3 - 27 original image.

Figure 3 - 28 grey image

The next action was dilating and eroding of the image to remove noise present in the image. The operation thickened objects in the binary image, it translated the origin of structuring element throughout the domain of the image. It removed regions in the image that contain the structuring element soothed object contours and filled holes in the image.

Convert from matrix to an image using the mat2gray MATLAB function and carry out edge enhancement using the convolution with an intensity scaling between the range 0-1. The imerode function was then applied to remove all possible horizontal and vertical lines from the out image that could be on the license plate.

3.3.8.4.3 Segmentation

The region props function obtained rectangles of objects on the resultant image. These rectangles were then passed to the imcrop function to obtain the license plate characters, based on the array of indices of bounding boxes of interest. The segmentation function outputs the row vector R containing the indices of the bounding boxes of interest from the matrix. The matrix of order number of regions x4. Number of regions are the total number of regions extracted from the function region props with the property 'Bounding Box'.

3.3.8.4.4 Character Recognition

Template Matching

The first stage was to create a template database, which are stored in a separate folder. The templates are inputs of binary images having numbers 0-9 and the alphabet of standard normal font. When creating the templates the system automatically crops and normalizes their size to 40x25 and is stored as its character representation. The objects obtained in the segmentation stage were normalized using the imresize command for it is a necessity prior to matching. The output is a smaller window having a character.

With templates in the system the normalized characters can therefore be matched to the templates using the correlation function shown in equation 1, which uses the equation given.

$$r = \frac{\sum_m 1 \sum_n (Amn-A)(Bmn-B))}{\sqrt{\sum_m 1 \sum_n (Amn-A)2) \sum_m 1 \sum_n (Bmn-B)2)}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

where A is the plate character and B is the template.

The template that gives the highest degree of matching is the one that gives a positive relationship in matching. The characters are assigned plates for determining the plate actual character corresponding to each extracted object. Possible character conflicts to be considered are characters like 3, 6, 8 and 9. These usually give incorrect recognition due to similarities in features. In order to differentiate the character 3 will have no holes while 6 will have one hole, 9 will have one hole, and 8 will have two holes. This should improve the recognition accuracy bearing in mind to verify character identity to avoid character conflict which is a possibility.

Graphical User Interface

All the components will be fitted in a graphical user interface for easy control of the system. The interface will

- Load and display an image
- Outline process output results
- If system has failed output appropriate message

- And finally display the result

  This interface will be implemented using MATLAB GUIDE a tool that provides elements of an interface.

Testing

All tests were taken on an Intel core i5. Images were taken in different lighting conditions. The recognition time was recorded as well as recognition rate at each stage of the system.

- Plate extraction
- Plate segmentation
- Plate recognition

  Calculations were carried out at each phase in-order to see where the system is having problems and will require improvements.

  Experiments were carried out in different situation for the system to be acceptably accurate.

- Fixed distance.
- Random distance.
- Different colours.
- Plate colour same as that of vehicle.2

3.3.4 Radio Frequency Identification (RFID)

3.3.4.1 System implementation

After each subsystem was completed they were then organized and combined to form one fully functional system per requirements. The hardware was connected in accordance with the design given for each subsystem, first in proteus, then on a breadboard and finally on the designed PCB. The code was written in embedded C language using Atmel studio as the compiler. Proteus proved very useful in seeing how it controlled the various subsystem then it was burnt into the microcontroller by using the AVR ISP MK11

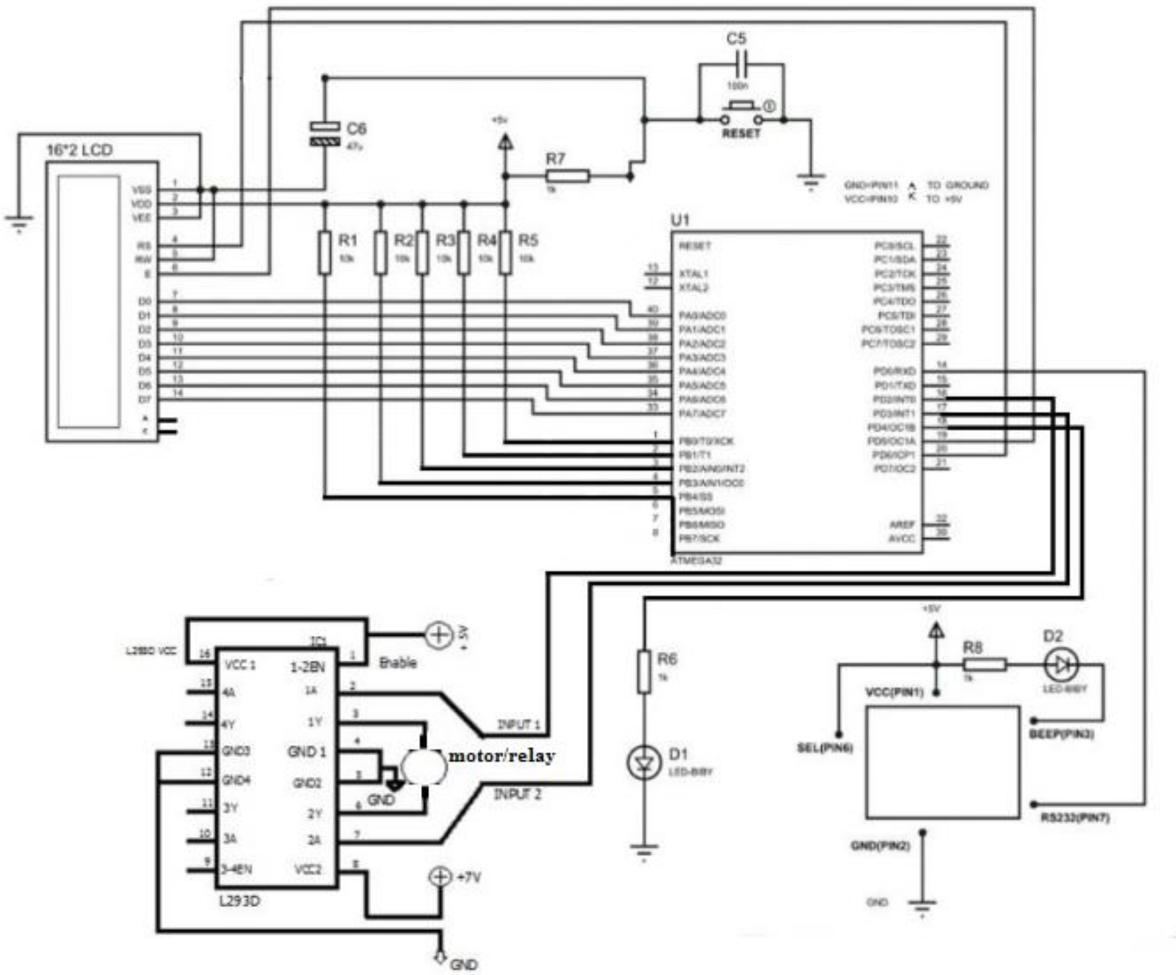


Figure 3 - 29 Circuit Diagram

3.3.4.1.1 Block Diagram

From the block diagram of Figure 3.31, the reader sends information to the microcomputer after reading the tag. Microcontroller receives information from the RFID readers and queries the database for the availability of similar information. After a query response from the database, the microcomputer send a signal to the boom gate whether to allow or deny access. When the boom gate opens, it sends a signal to the microcomputer to inform the user that access has been permitted. The microcomputer sends a signal to the display for a message to the user. At the same time exit sensors are activated to instruct the boom gate closure after the vehicle passes.

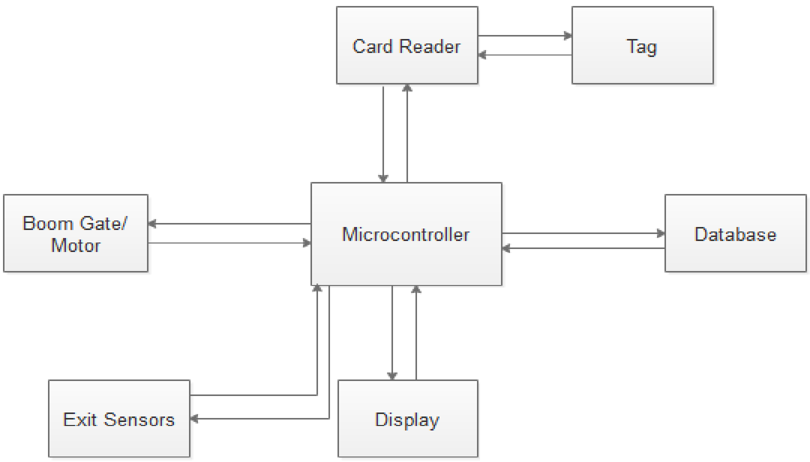


Figure 3 - 30 Block diagram for RFID System

3.3.4.2 Flow Chart

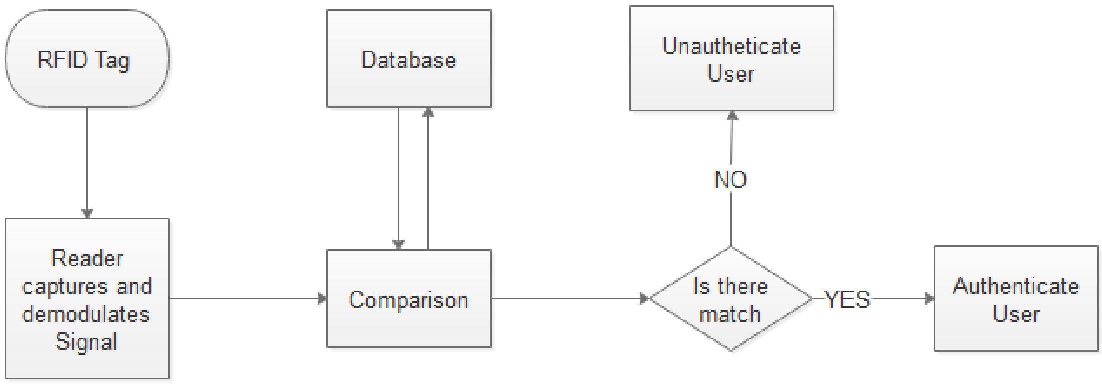


Figure 3 - 31 RFID flow Chart

Algorithm below explains the logical flow of the system as in Figure 3.32.

3.3.4.3 Algorithm

- **Step 1**. Start
- **Step 2.** Sense RFID tag
- **Step 3.** Find out if there is a vehicle if NOT process restarts
- **Step 4.** Check User details against database information
- **Step 6.** Record User details, time and date and data base status
- **Step 7.** If User details are NOT available, Keep Boom gate CLOSED.
- **Step 8.** If User details are found in the database, Open Boom gate.
- **Step 9.** Wait for vehicle to pass OR counter time elapse and close the boom gate

3.3.4.4 Database Designing And Implementation

In order to enhance the functionality of the system, a database was developed for RFID boom gate system, the database kept a log of people who entered and exited the facility as well as sound an alarm when a wrong card is continually trying to gain access to the facility. The database would be hosted on a personal computer, they are a number of ways in which a computer can be linked to an RFID system such as Bluetooth, infra-red, internet connection, RS232 cable etc. In this case, an Arduino Uno board was used with a USB cable, the two were connected to my computer and using the Arduino IDE I coded for the database, when an Arduino is connected to a computer a COM port is assigned to it and it is through this COM port that it communicates with the computer with the information being able to be viewed through the Arduino IDE Serial Monitor , how using a software called real term this information that the Arduino sends to the computer can be saved into a text document and it is through this that I made my database[119]. A buzzer was implemented in this project to sound an alarm when a wrong card is trying to gain access to the facility for a maximum number of five time and inform whoever is monitoring the database, the buzzer was connected to Pin 9 and ground

3.3.4.5 Interfacing computer to the RFID boom gate control

(Rx) was connected to the transmitter pin (Tx) of the RFID both were grounded and supplied with the same 5v as shown below[120]

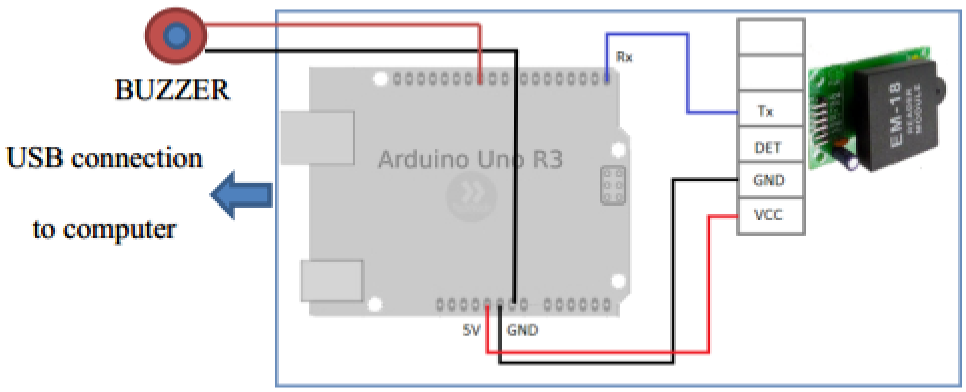


Figure 3 - 32 Arduino Uno connecting computer and RFID system[117]

3.3.4.6 Flow chart of the database code in the Arduino

The database was coded for in the Arduino Uno and using Coolterm it was saved on the host pc in form of a text document file.

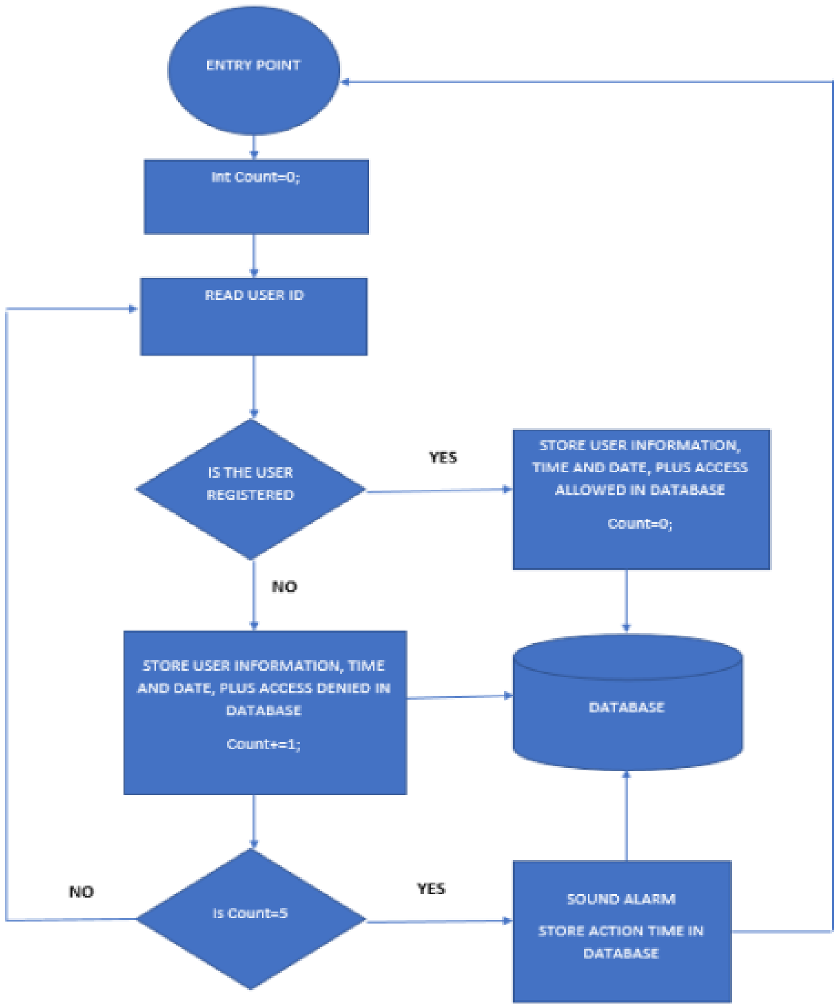


Figure 3 - 33 Code Flow chart for information storage

3.3.5 ANPR and RFID Integrated System

The ANPR and the RFID technologies were integrated to offer Five states that which would are selected to meet individual access point requirement.

First Level:	Users registered for a particular Vehicle
First Level:	Users with registered TAG **ONLY**
Second Level:	Users with registered VEHICLE only
Third Level:	Users with registered Tag **OR** Vehicle
Fourth Level:	Users with BOTH Tag AND Vehicle

3.3.5.1 Flow Chart

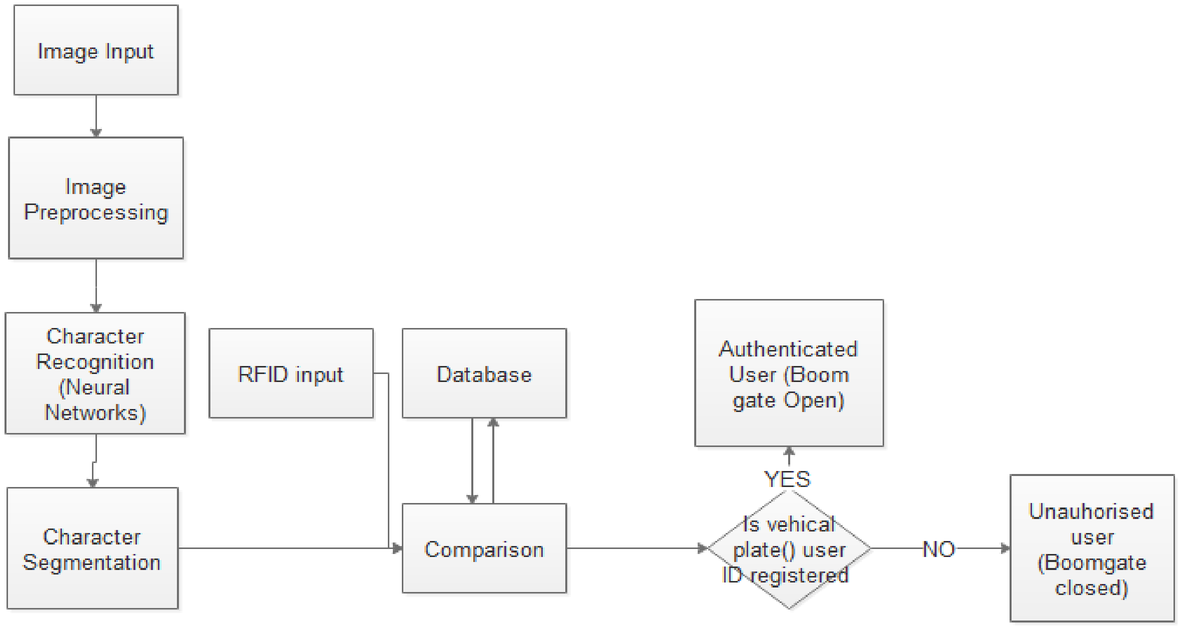


Figure 3 - 34 ANPR and RFID flow Chart

Figure 3.35 shows the system's flow chart, The image input from the vehicle is pre-processed and the number plate character are extracted and fed into the database for matching. In the same manner, the RFID Card reader content is sent to the data base for a match. The output of the boom gate will depend on the system setting as outlined on the algorithm in section 3.3.5.2.

3.3.5.2 Algorithm

- **Step 1**. Start
- **Step 2.** Sense RFID tag, Capture Vehicle Plate
- **Step 4.** Check User {/,AND,OR,} Vehicle details against database information
- **Step 6.** Record details, time and date and data base status
- **Step 7.** If User {/,AND,OR,} vehicle details are NOT available, Keep Boom gate CLOSED
- **Step 8.** If User {/,AND,OR,} vehicle details are found in the database, Open Boom gate
- **Step 9.** Wait for vehicle to pass OR counter time elapse and close the boom gate

3.4 Summary

In this chapter, a comprehensive justification for the methodology adopted has been given. The research used both qualitative and quantitative research. Questionnaires where used to collect data. SPSP was used to analyse the collected data and results were presented in the form of graphs, pie charts and tables. ANPR system was developed and simulated using MATLAB. RFID was developed and simulated in proteus software. A prototype was developed and tested.

CHAPTER FOUR:
FINDINGS AND RESULTS

4.1 Introduction

This chapter gives an overview of the system results, and an analysis of the results and functionality of the system. The raw data as presented in each table below was fed to the MATLAB model and produced curves of best fit and the governing equation in each case.

4.2 Baseline Survey Findings and Results

In this section, the results of the baseline study was derived from the variable analysis through descriptive statistics as presented. The results are presented in the form of bar charts and pie charts.

4.2.1 Demographic Data

The baseline survey was conducted on the three categories of personnel, thus the members of staff, the Security Personnel and Visitors/Students. A total of one hundred questionnaires were distributed, 50% to the members of staff, 25% of each to the Security personnel and Visitors/students.

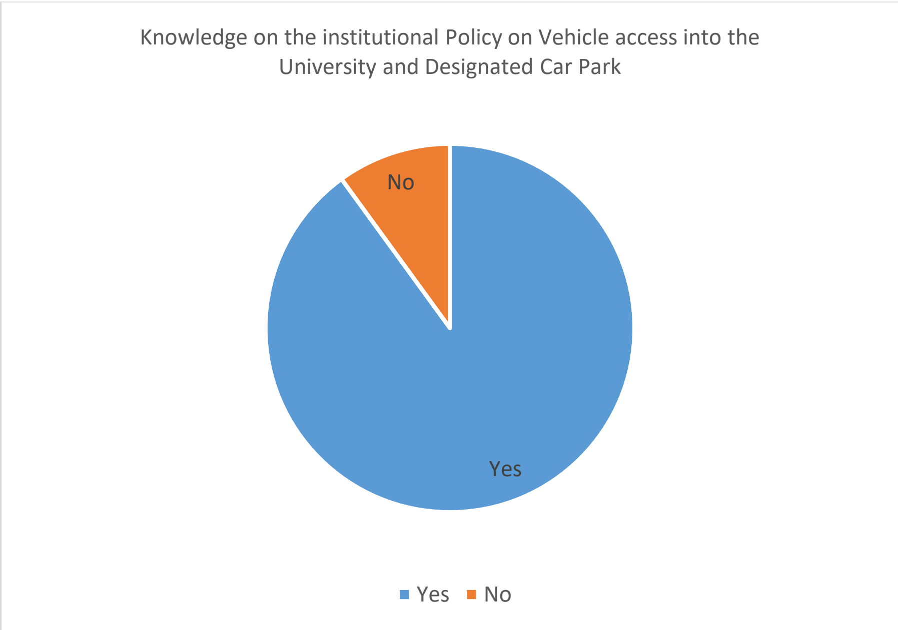


Figure 4 - 1 Respondents knowledge vehicle access

Figure 4.1 showed that most responded understood and were aware that the university had a policy on vehicle access into the University premises. They understood that not all vehicles are allowed entry but that there were restrictions as to who could access the premises and who should not and from which entrance. Most respondents were also aware that there are designated car parking areas that are accessed by a specified category of users aimed at ensuring balanced distribution of vehicle parking and control of traffic.

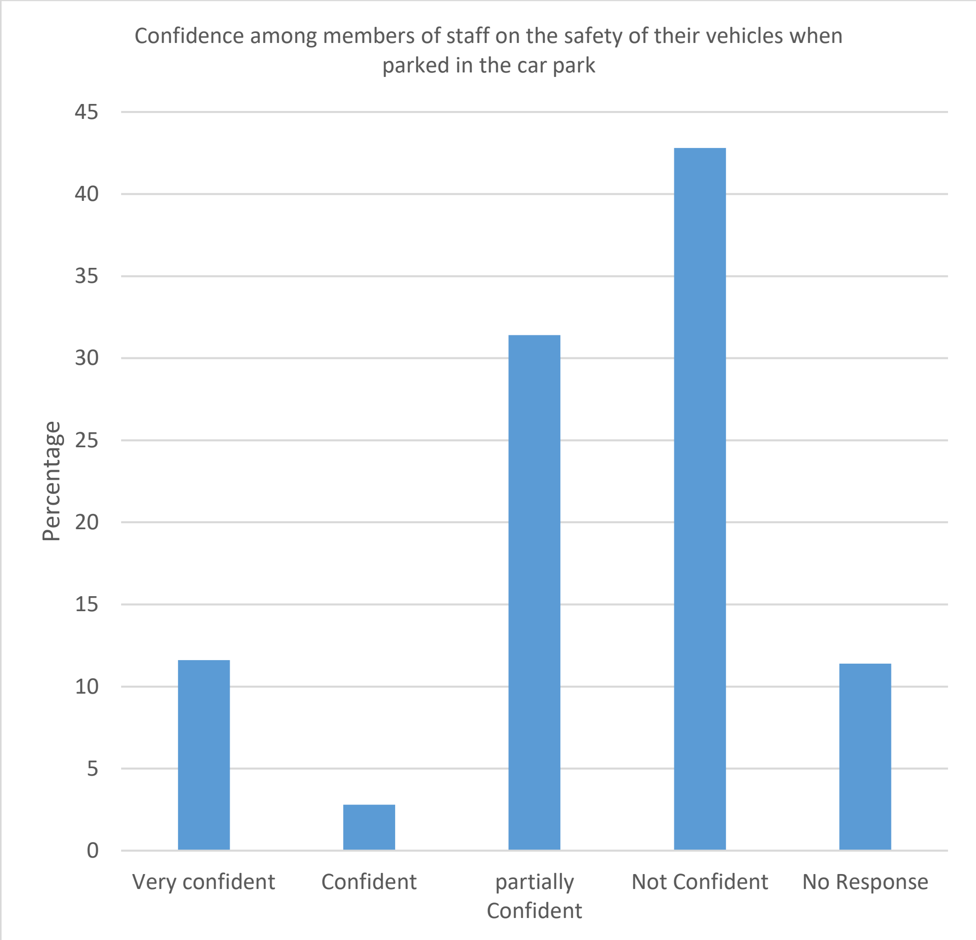


Figure 4 - 2 Members confidence on the safety of their vehicles

Figure 4.2 shows that most members of staff (43%) where not confident on the security on their vehicles while parked in the car parks. About 32% were partially confident whereas only 11% were very confident. 11% percent could neither show their confidence levels.

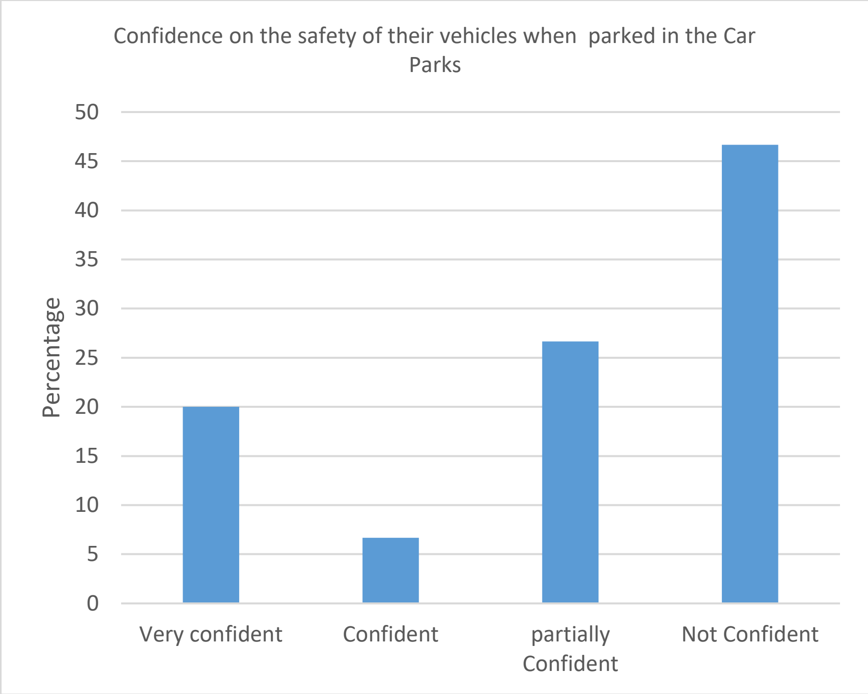


Figure 4 - 3 Visitors/students confidence on the safety of their vehicles while parked

Figure 4.3 shows the levels of confidence they have on the safety of their vehicles when parked in the car parking areas. Like their counterparts the members of staff, 47% were not confident on the safety of their vehicles while 27% where partially confident. Only 20% were very confident and 7% were confident. This gives a large representation of the people being worried about their vehicles when parked in the car parking areas.

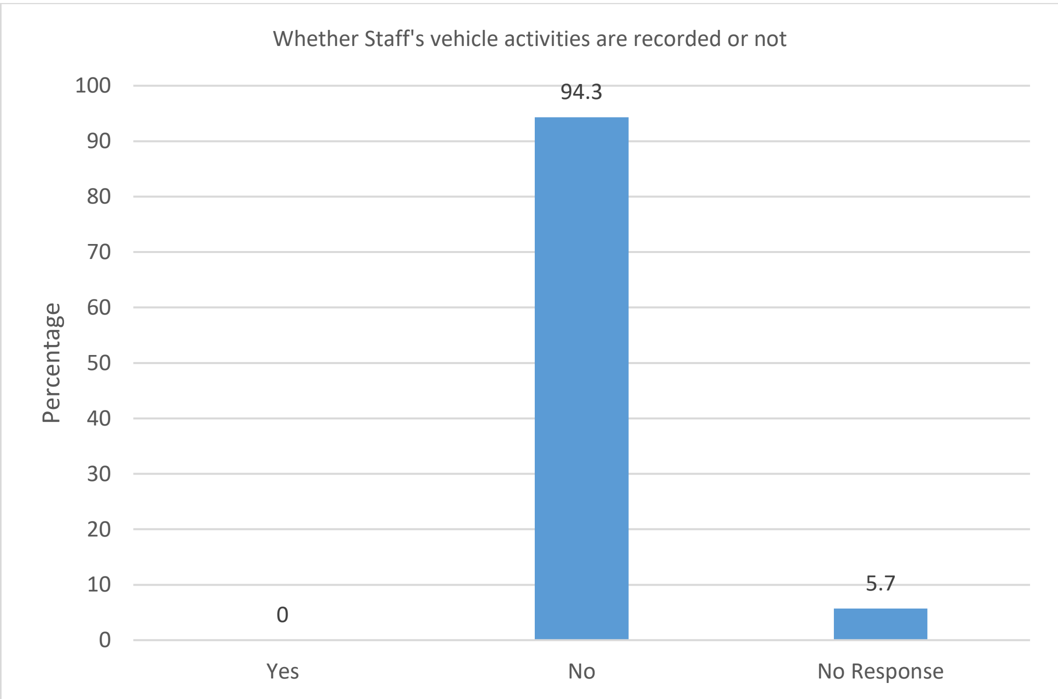


Figure 4 - 4 Visitors/students confidence on the safety of their vehicles while parked

Figure 4.4 reviewed that no record is taken on the vehicles that enter the university premises or vehicles that access the car parking areas.

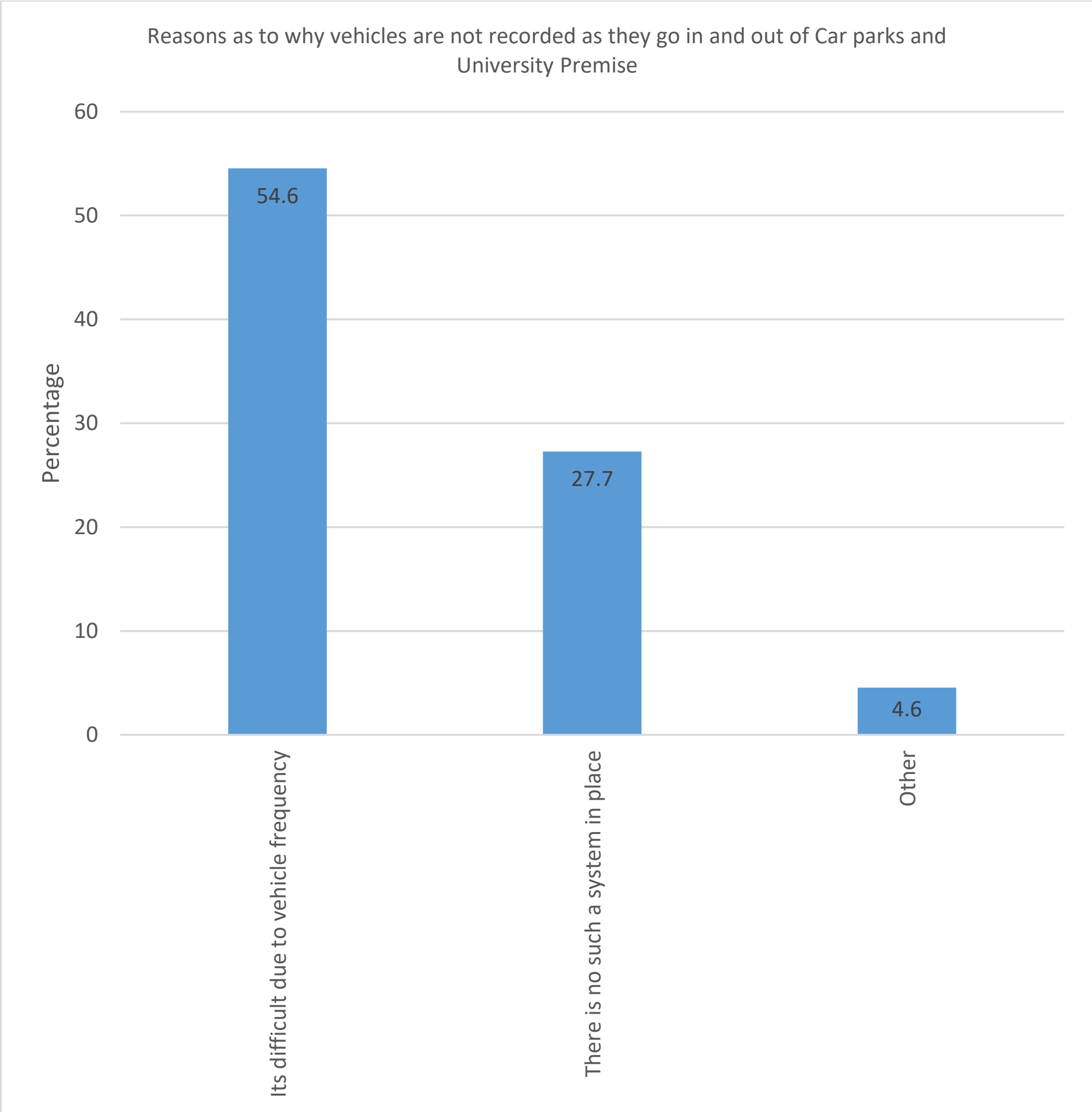


Figure 4 - 5 Reasons for not taking records of the vehicle activities

Figure 4.5 show reasons as to why records of vehicle activities are not recorded at various access points. 54.6% indicated that it was difficult to record vehicle activities due to high vehicle frequencies at access points. 27.7% however indicated that there is no such a system in place.

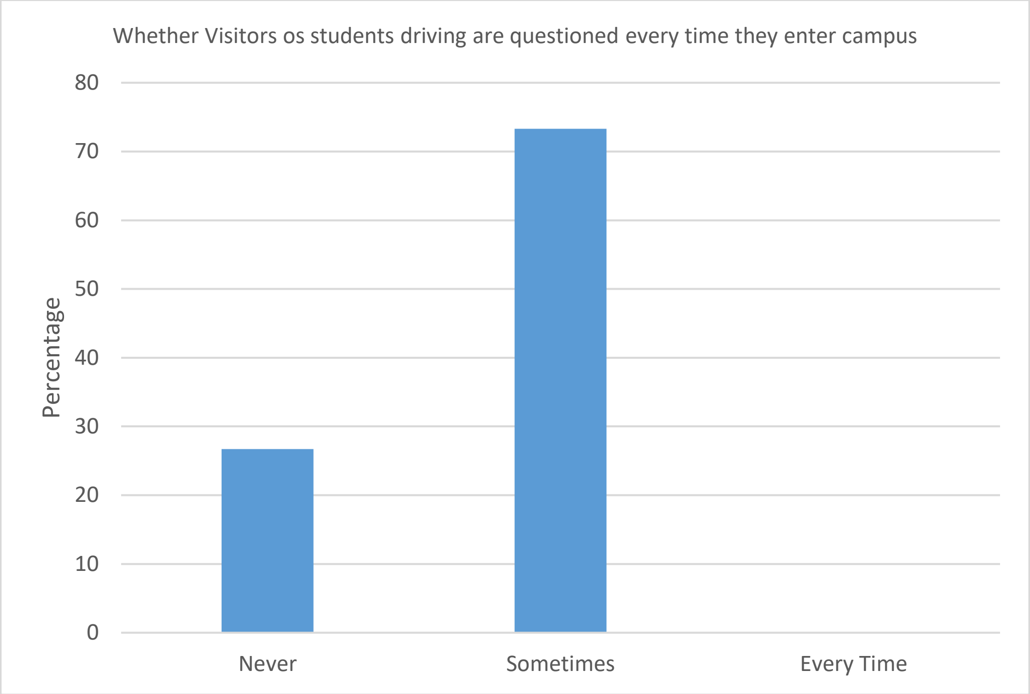


Figure 4 - 6 Whether access credentials are requested at entry points

Figure 4.6 shows whether access credentials are usually requested for every time the enter campus premises at the entry points. 72% of the respondents indicated that they are sometimes asked and 28% indicated that they have never been asked.

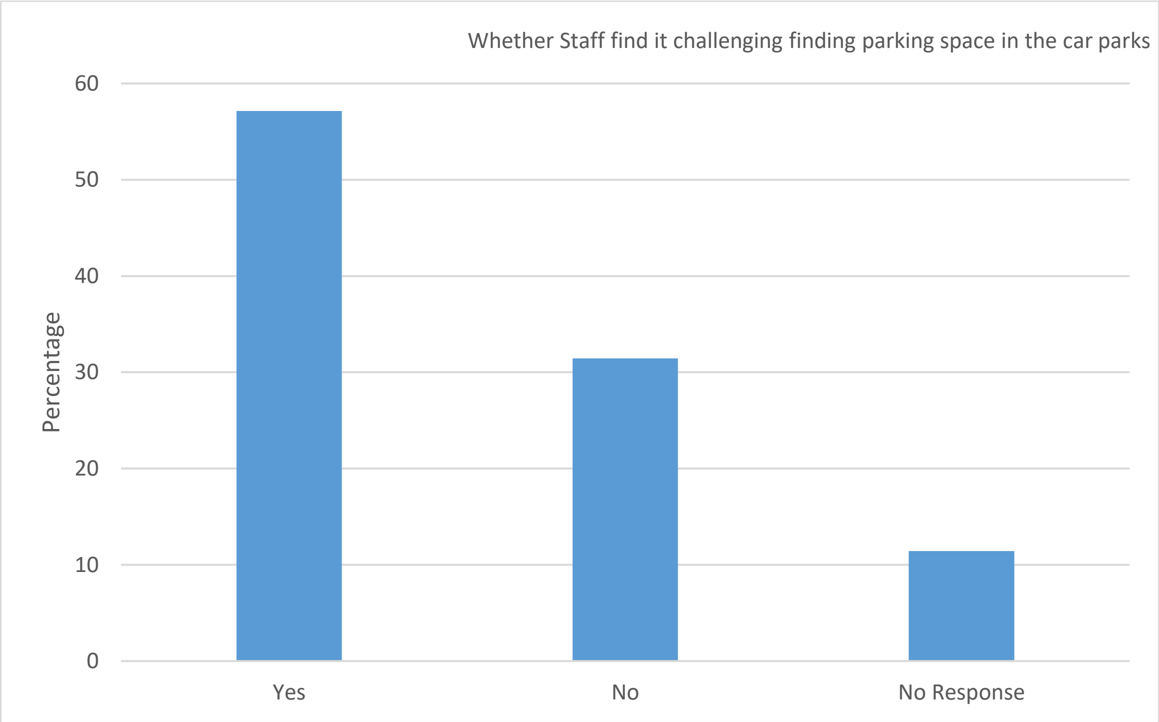


Figure 4 - 7 Easy access to parking space by the staff

Figure 4.8 show as the percentage of staff that find it difficult to find parking space within their parking areas. 58% indicated that they found it difficult to find parking slots within their designated car parks.

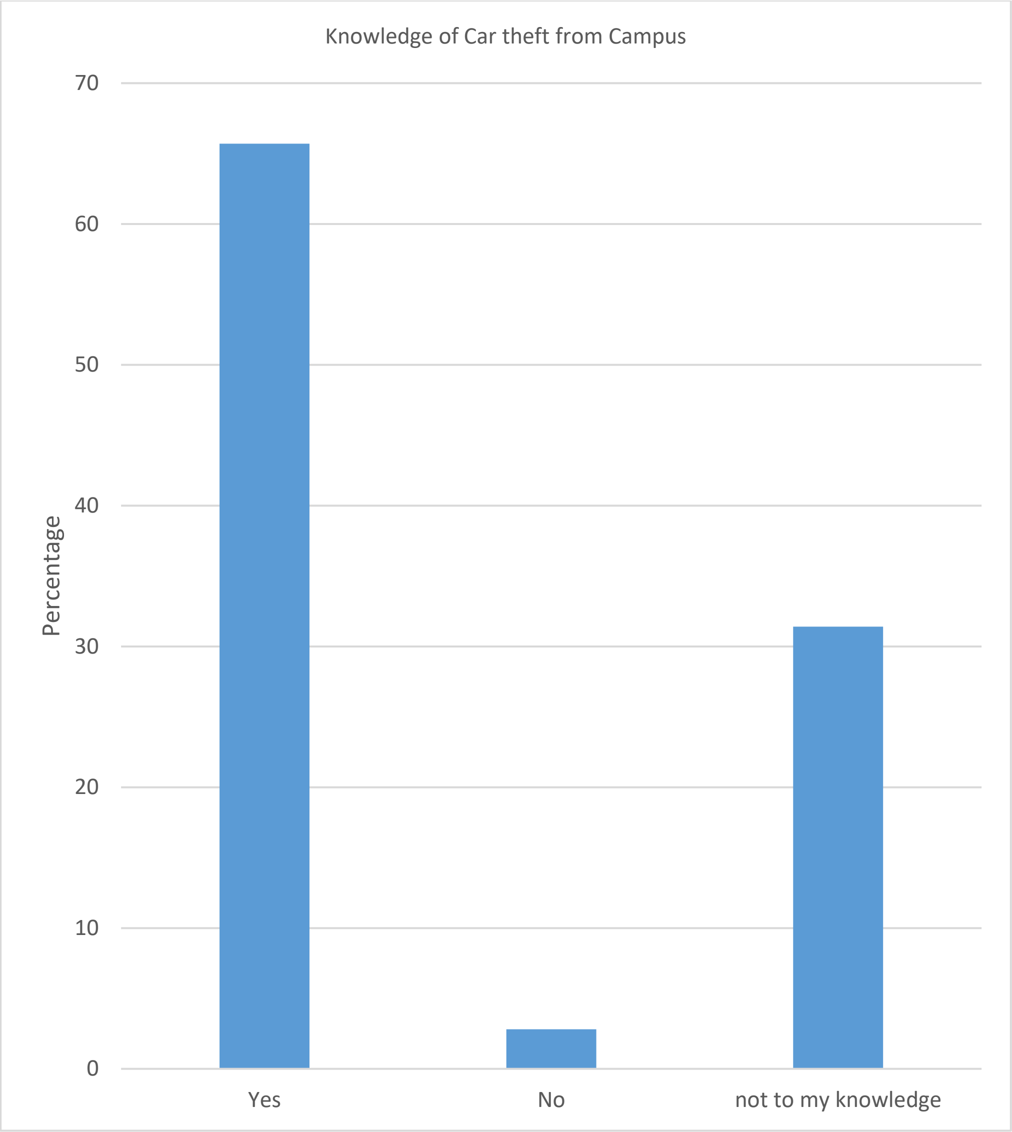


Figure 4 - 8 knowledge of car thefts

Figure 4.9 shows how many respondents had knowledge of car thefts from the campus premises. 66% indicated that they were aware of vehicles being stolen from the campus premises while 32% were not aware.

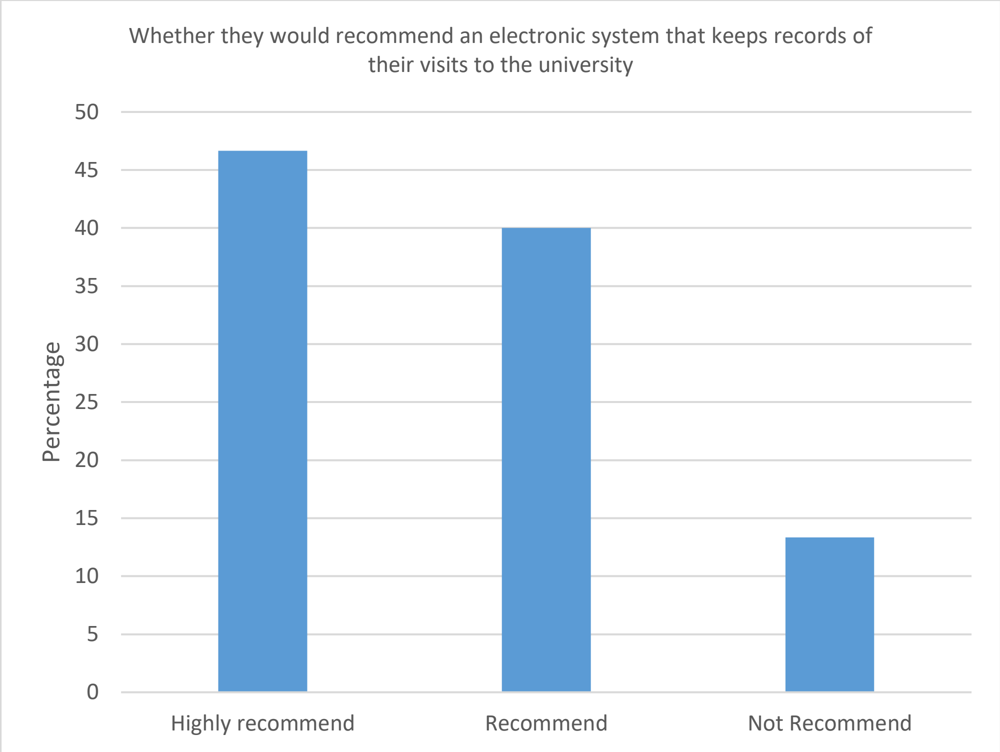


Figure 4 - 9 Recommendation of an electronic system by students and visitors

Figure 4.9 shows a recommendation of the necessity to install an electronic system that keeps records of the vehicle activities on their access into and out of campus premises. 46 percent of the students/visitors highly recommended for an electronic system while 40 percent recommended and 14 percent did not recommend.

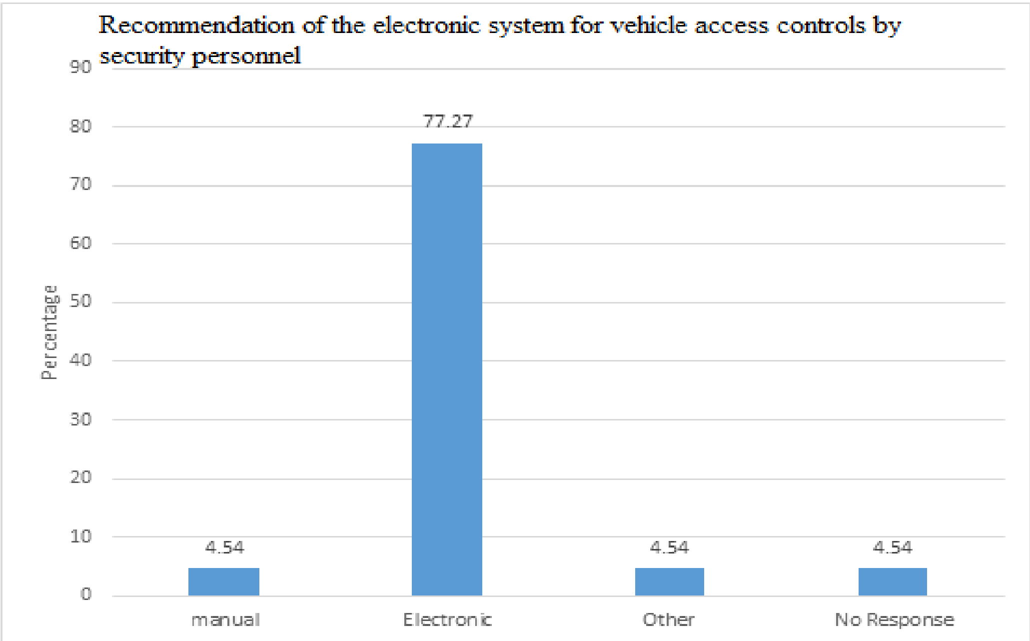


Figure 4 - 10 Electronic system recommendation by the security personnel.

Figure 4.10 shows that 77 percent of the security personnel recommended for an electronic vehicle control system. 5% recommended a manual system 5% other systems while the other 5% never gave a response.

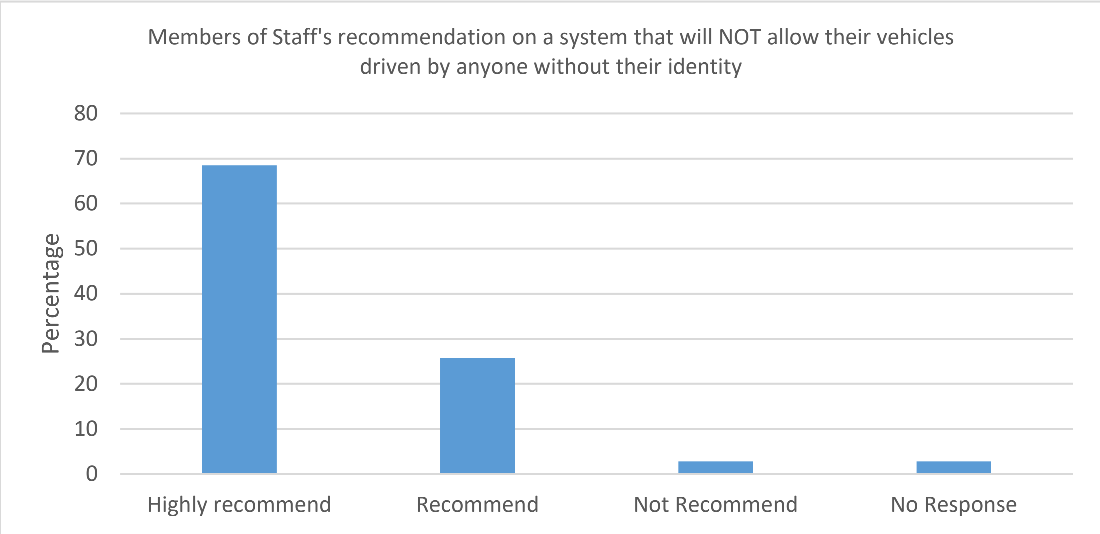


Figure 4 - 11 Electronic system recommendation by the members of staff.

Figure 4.11 indicates that 69 percent of the security personnel highly recommended for an electronic vehicle control system to be installed to monitor, control and record vehicle activities on the entry and exit points

4.2 Systems Implementation

Manual methods currently on use for vehicle access control can be replaced with automated system in order to eliminate the challenges experienced by the manual system. In order to show how the multifactor authentication system can work at the University of Zambia Great East road campus, a porotype was developed to show the proof of concept. The prototype was implemented using RFID and ANPR technology to show how the two systems can be used for multifactor vehicle access control.

This section will contain screen shots from the prototype implementation. The screenshots include the hardware setup and the software implementations. The functionalities that were implemented in the system are abilities for the ANPR system to capture, process the number and give out the binary number plate digits, the ability of the system administrator to enrol, edit, delete users to the system, the reading of the RFID tag and saving of its information in the database and the opening of the boom gate. The two systems are tested as individual entities.

4.2.1 ANPR System

This section of the chapter show results of the ANPR prototype process for a vehicle. In this instance, the results of the ANPR were collected using Recognition results of code having different bases from image input to segmentation A-I's neural networks.

Example of operation

This section gives an example of the step by step process in recognizing the number plate of the current system in operation. Figure 4.12 to 4.18 shows the system state just completion of segmentation and recognition processes with the key code for each process. The system loads an image of a car number plate after camera capture from a fixed distance of two meters. The image is converted to grayscale and horizontal and vertical edge processing is carried out to extract the edges from the image. Then filtering process is employed as shown in figure 4.12. Furthermore the system finds all possible plate regions and highlights them and plots vertical and horizontal histograms for image analysis these have proven to be effective as most unnecessary edges are removed helping identify the plate area as shown in this particular example.

After successful extraction the image is converted into its binary form. Morphological processes are carried out to ensure unnecessary components are removed. Finally, the characters are normalized and recognised by the template matching algorithm giving the result shown in the output note text.

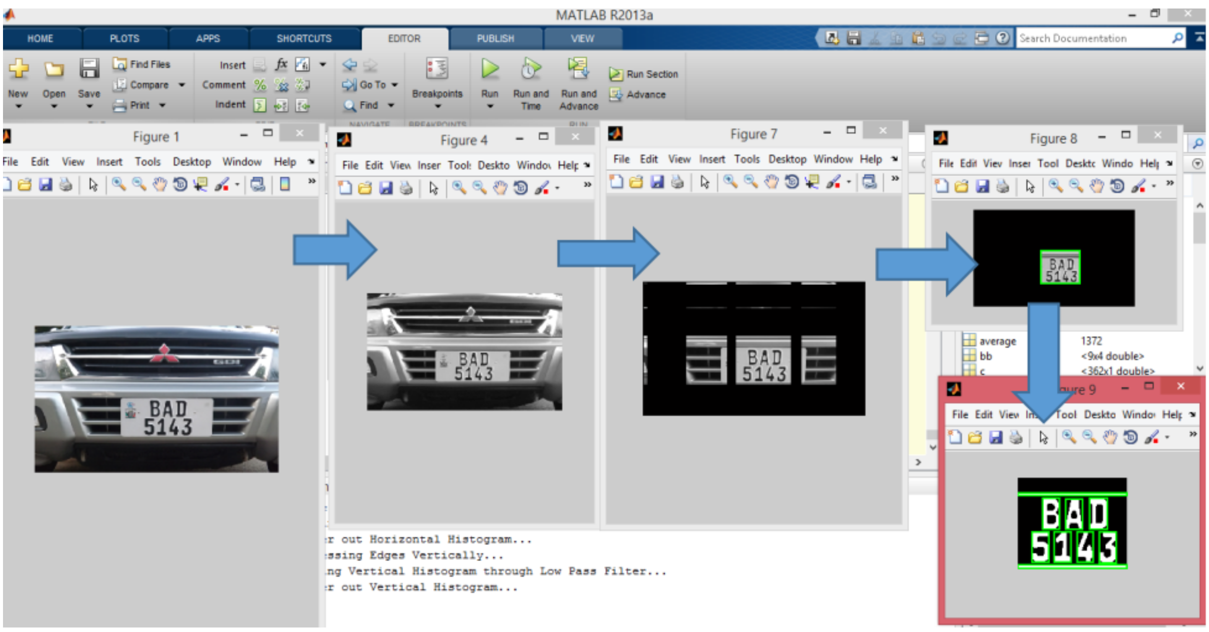


Figure 4 - 12 screenshot of morphological process till segmentation

The images shown from figure 4.13 to figure 4.18 below gives a step by step process of number plate recognition process to the final extraction of the number using neural network system. A code responsible for each stage is also included.

Figure 4 - 13 Input image in original RGB format

Figure 4 - 14 grey scale image

```
% Extract Y component (Convert an Image to Gray)
Igray = rgb2gray(n1);
[rows, cols] = size(Igray);
%% Dilate and Erode Image in order to remove noise
Idilate = Igray;
for i = 1:rows
for j = 2:cols-1
temp = max(Igray(i,j-1), Igray(i,j));
Idilate(i,j) = max(temp, Igray(i,j+1));
end
```

Figure 4 - 15 grey scale image dilated and eroded to remove noise

```
imshow(Igray); imshow(Idilate);imshow(n1);
```

Figure 4 - 16 image after edge processing;

```
for i = 2:cols
Sum = 0;
for j = 2:rows
if(n1(j, i) > n1(j-1, i))
difference = uint32(n1(j, i) - n1(j-1, i));
else
difference = uint32(n1(j-1, i) - n1(j, i));
end
if(difference > 20)
Sum = Sum + difference;
end
```

Figure 4 - 17 extracted plate region.

```
for i = 1:2:row_size
for j = 1:2:column_size
```

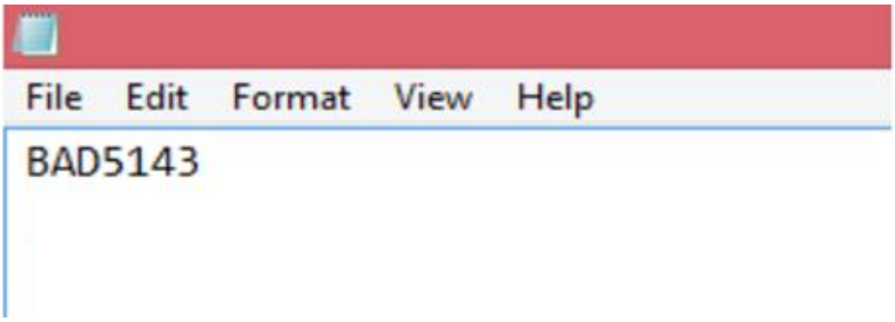


Figure 4 - 18 segmented extracted plate and final license plate output.

```
result=~im2bw(n1,graythresh(n1));
imshow(result);
```

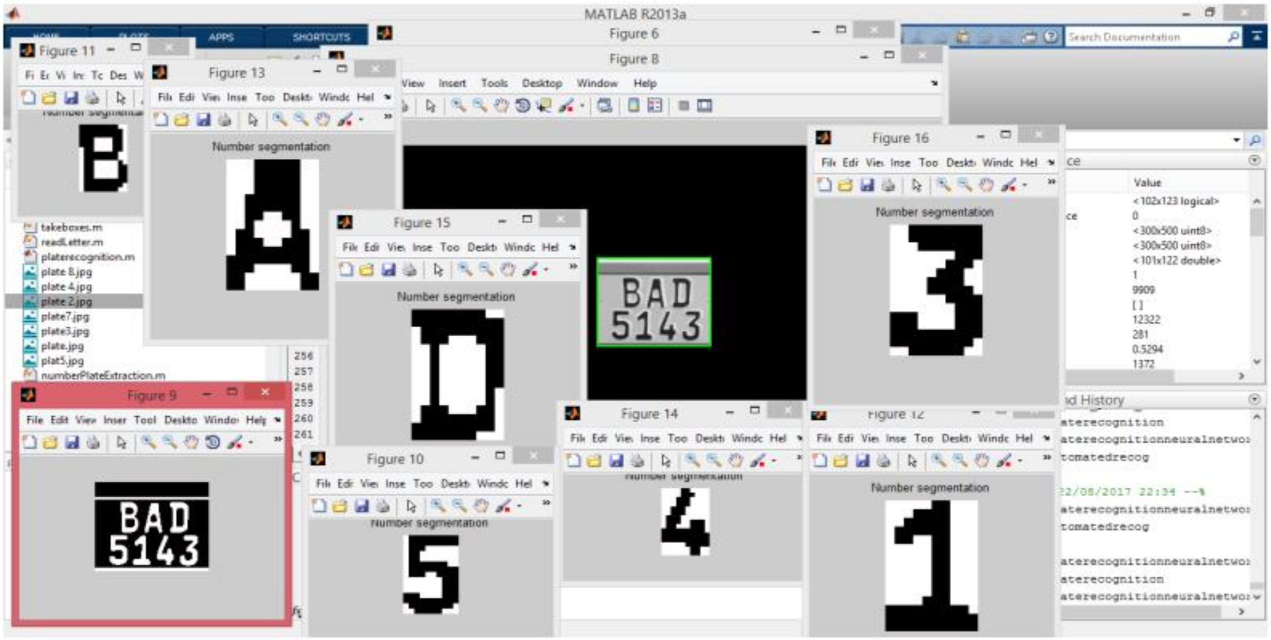


Figure 4 - 19 Screenshot of the system just after segmentation of the characters.

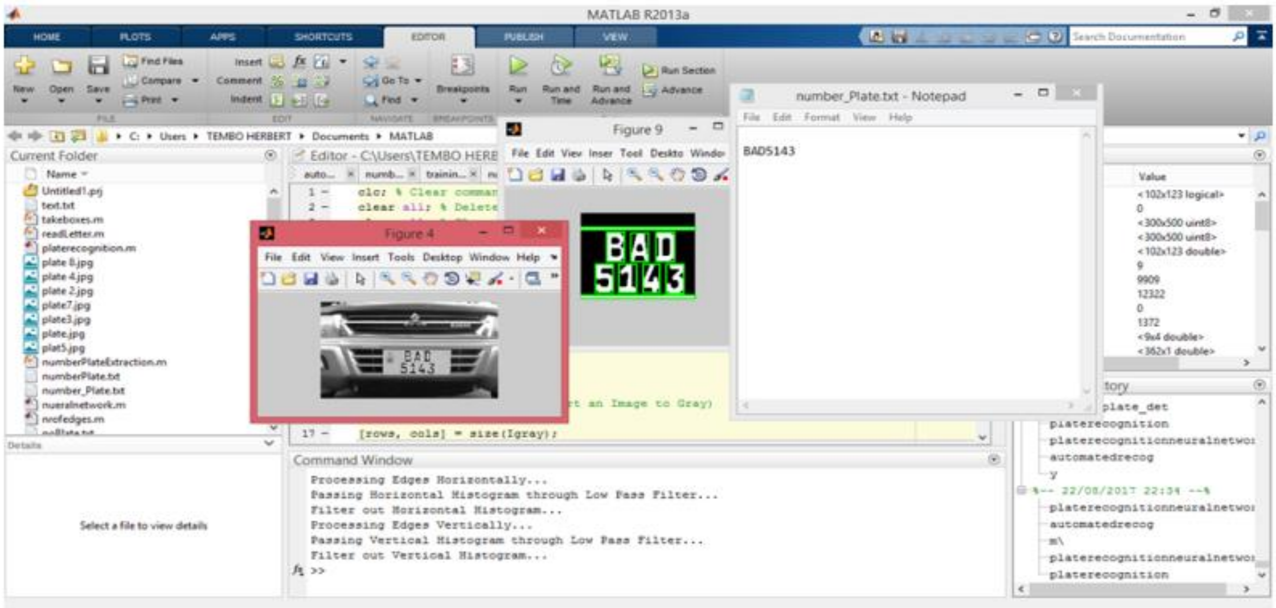


Figure 4 - 20 Screenshot of system showing segmentation and recognition

4.2.2 RFID System

4.2.2.1 Hardware implementation

The prototype system was constructed, allows card configurations, denies entry to non-programmed cards and allows entry to cards that are programmed.

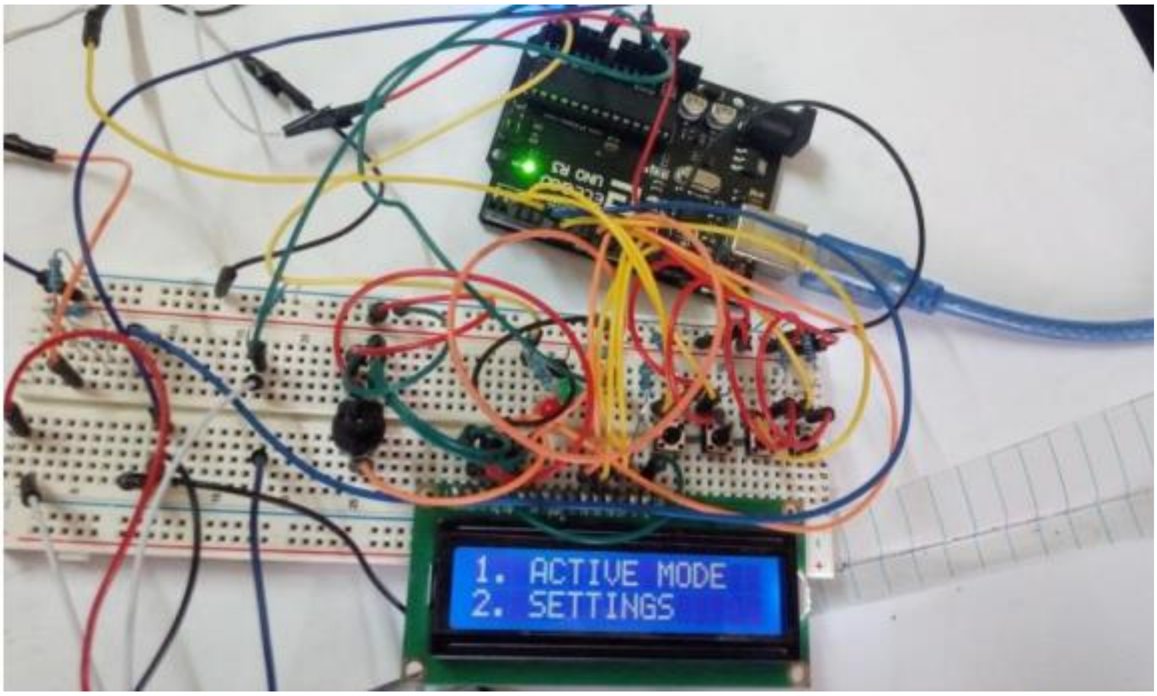


Figure 4 - 21 Prototyping set-up

This shows that at the beginning of the program, the user is prompted either to go directly to active mode or choose settings which is handled by the operators.

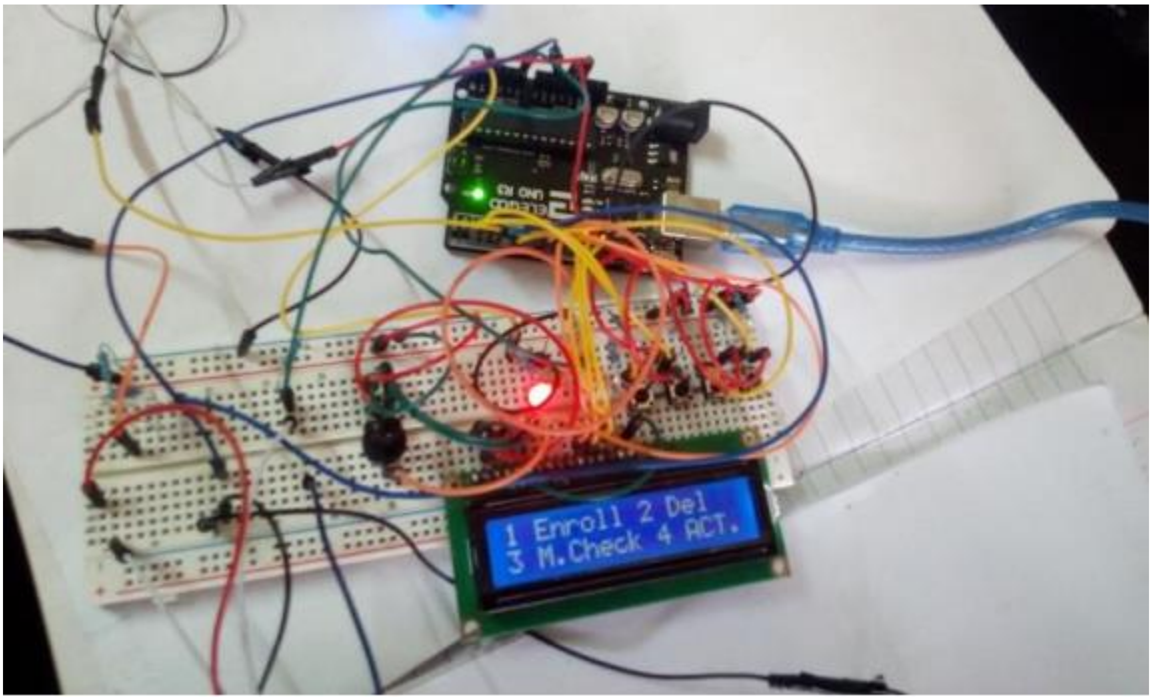


Figure 4 - 22 Prototyping set-up at main menu

This shows the main menu from the "Settings" option that allows you to do what was previously described in Software implementation.

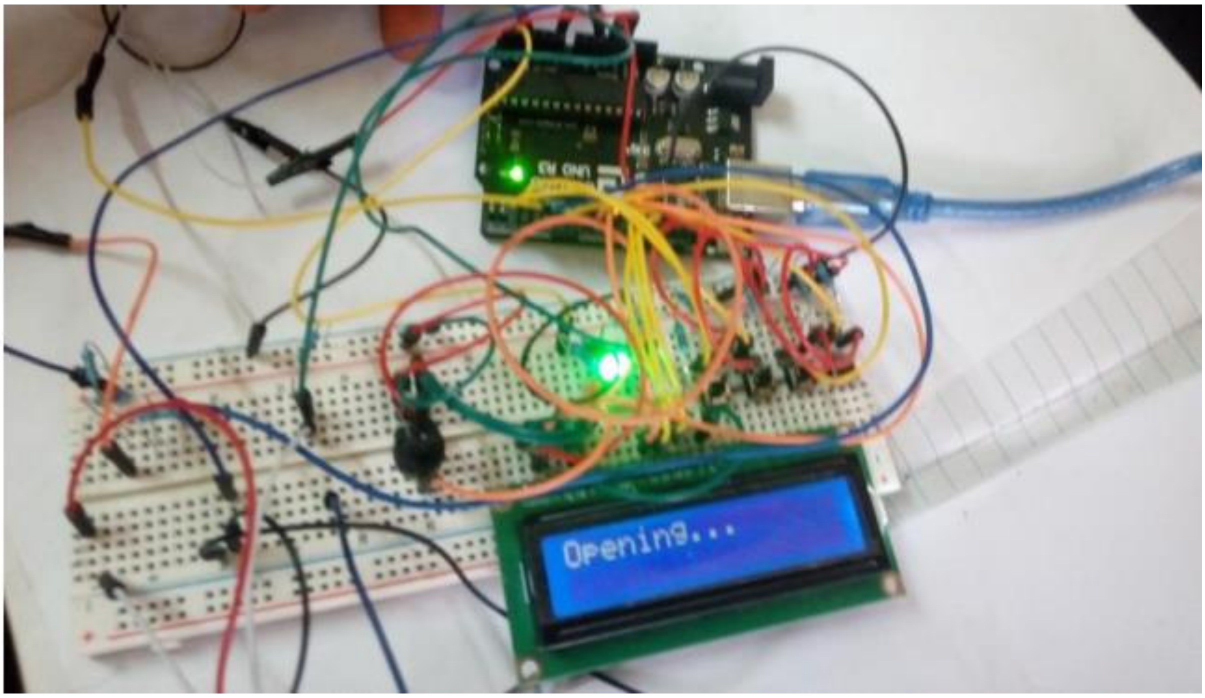


Figure 4 - 23 ID verified, open command issued

When pre-programmed card is introduced to the RFID card reader and the system verifies its authenticity, the system opens the boom gate to allow passage of the vehicle.

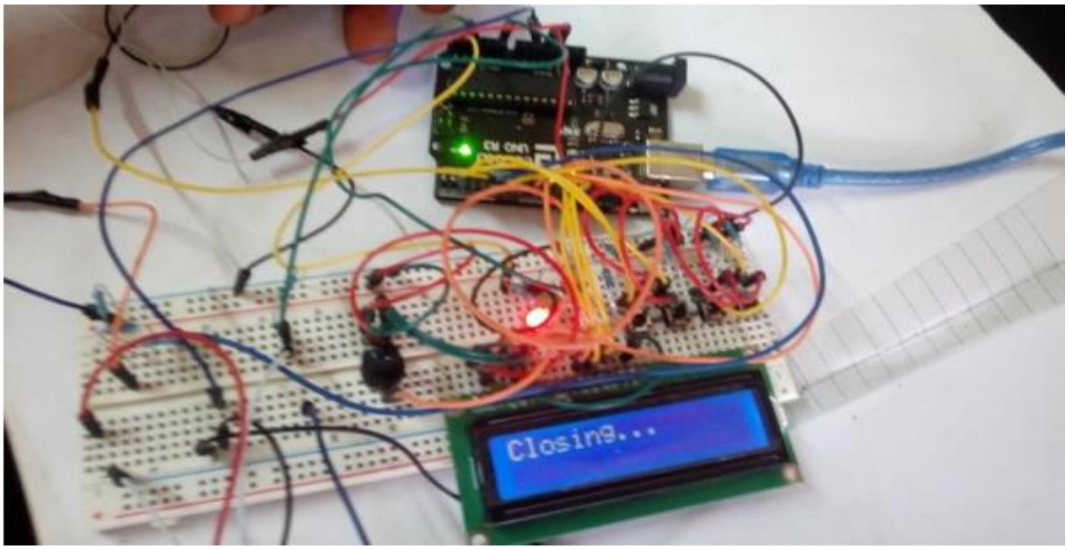


Figure 4 - 24 ID verified, close command issued

If the ID is accepted, the access barrier opens and then closes after the vehicle passes

4.2.2.2 Integrated System

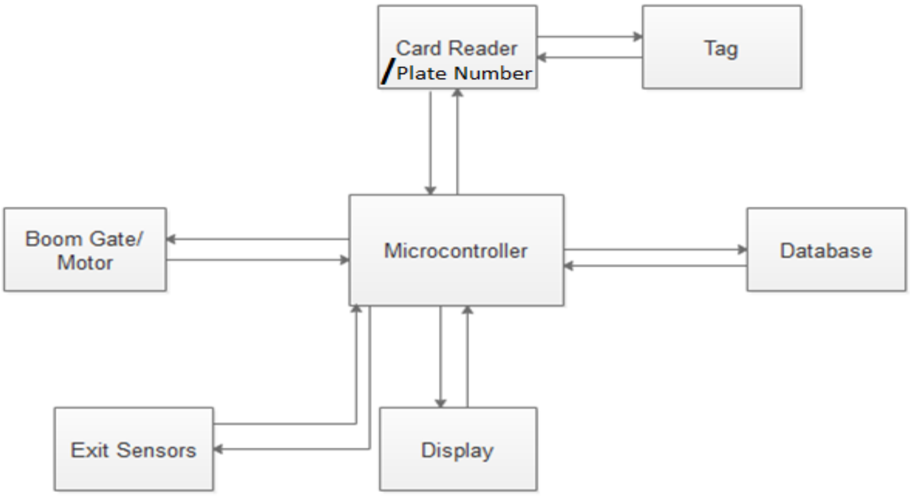


Figure 4 - 25 block diagram for the integrated system

Figure 4.25 shows a block diagram of the integrated system. The microcontroller makes logic decisions depending on the input combinations and settings. Figures 4.26 to figures 4.30 show the different five state system configurations suitable for different access points.

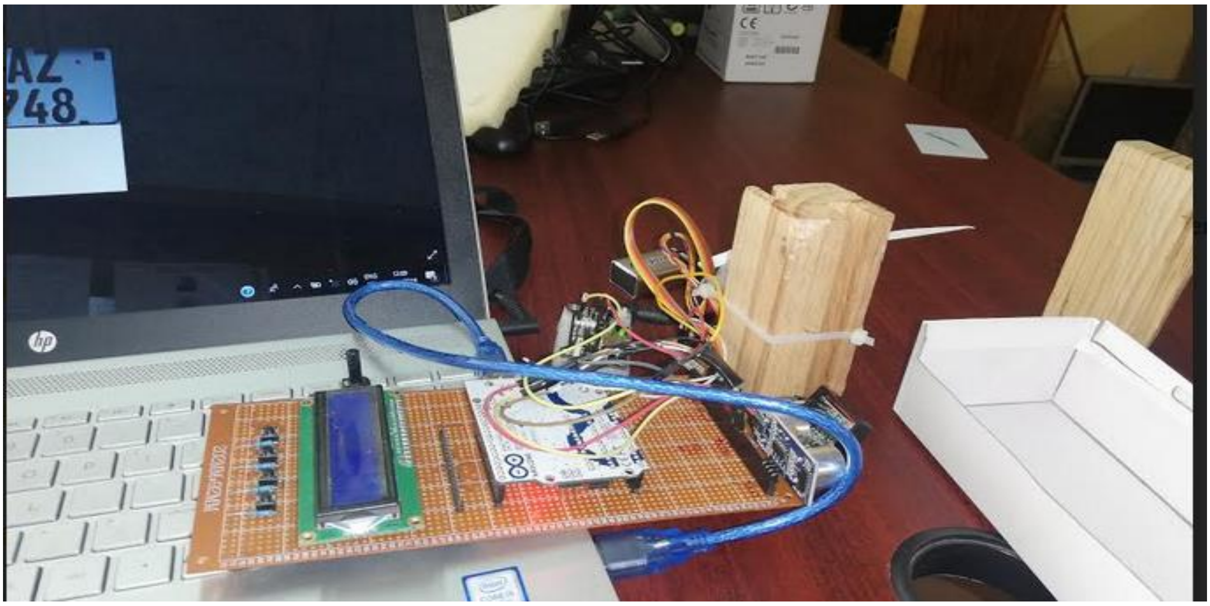


Figure 4 - 26 ANPR and RFID system integration

Figure 4.26 illustrates the integration of the two technologies, the ANPR and the RFID. In this case, the number plate is fed from the computer into the Arduino board as opposed to a high definition camera capturing the number plate. Figures 4.27 to 4.31 demonstrates different configuration states the system is able to provide.

First State

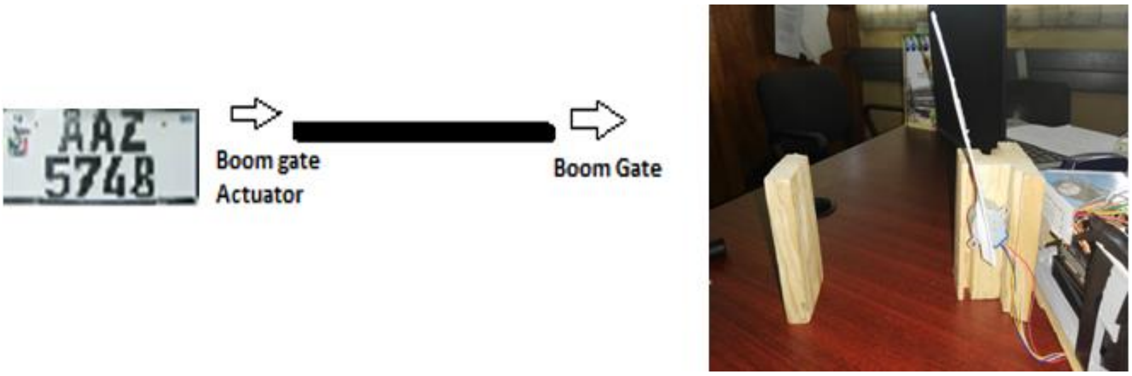


Figure 4 - 27 Gate kept open - camera capturing the number plate of every passing vehicle

Figure 4.27 shows the first state which provided the recording of vehicle passages while keeping access less restricted.

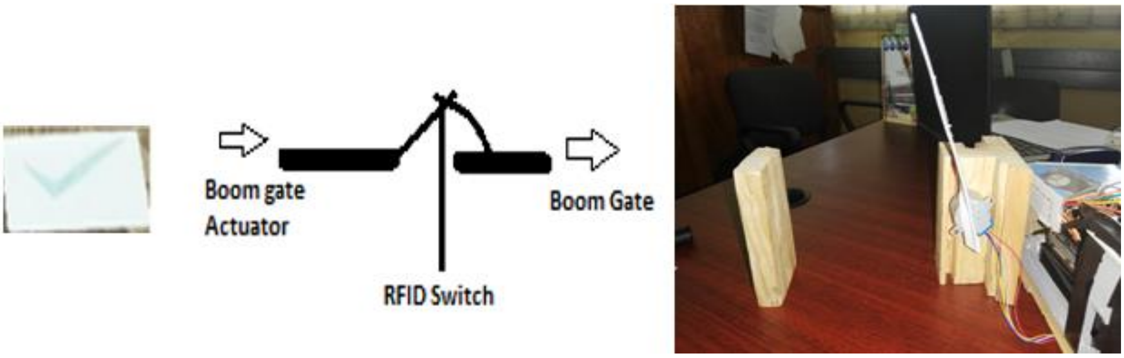


Figure 4 - 28 Switch actuated by RFID identification tag ONLY

Figure 4.28 illustrates the second state were RFID card is the only identification required to gain access. The RFID switch linked the boom gate actuator to the boom gate for opening or closing

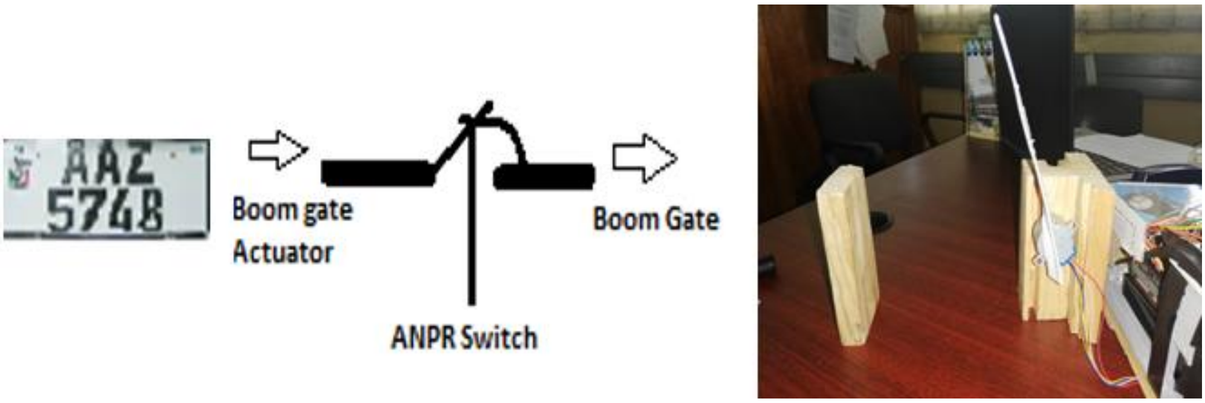


Figure 4 - 29. Switch actuated by number plate identification ONLY.

The third state was were the only identification required to gain access was the vehicle number plate (Figure 4-29). The ANPR switch linked the boom gate actuator to the boom gate for opening or closing

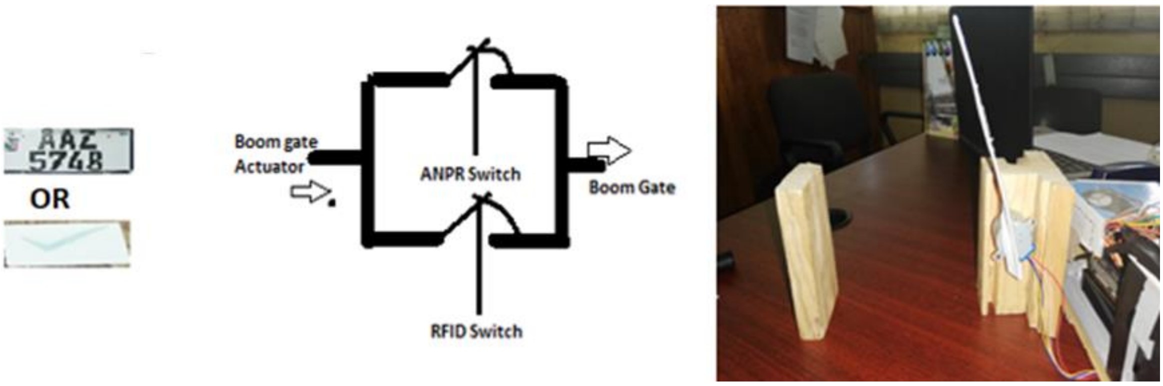


Figure 4 - 30 RFID and ANPR switches 'ORed'

Figure 4-30 illustrates the fourth state which gave access through either the number plate **OR** the identification RFID card. The setup is ideal for Lufyanyama and Kamloops entrances. These two entrances are only used by University of Zambia card holders.

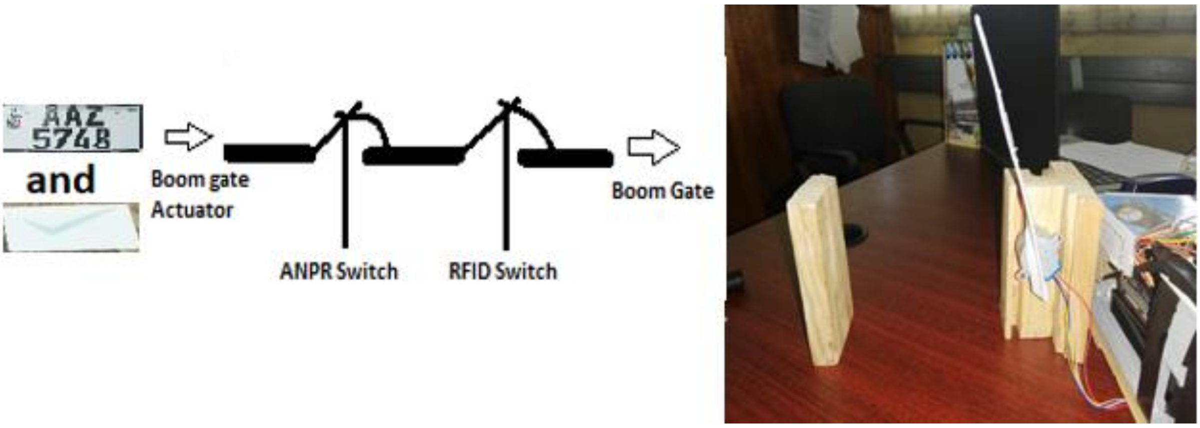


Figure 4 - 31 RFID and ANPR switches 'ANDed'

The fifth state was a more secure state that 'ANDed' the two technologies as illustrated in figure 4-31. It required both the RFID identification card and the vehicle number plate matched for access to be granted. The state is ideal to be used for authentication entrances in the car parks.

4.2.2.2 Data base

The System matches time and date to the RFID's that attempt to use the scanner. It is stored in a 'txt' document created using the application '**Coolterm**'. **Coolterm** is installed and kept running as long as the scanner is operational to properly log the data.

The Coolterm application was directly linked to the Arduino's serial port and synchronises with the Arduino's Serial.print and Serial.println functions. Because of this, we are able to extract various amounts of information from the system allowable by the command and with special setting, can attach time and date to the information.

In the example below the Cross Card is enrolled and the other two are not.

4.2.2.2.1 Results:

Card Information:

Tick card: 4900DC6F916B

Circle(O) card: 4900DC7032D7

Cross(X) card: 4900CC37DD6F

Figure 4.32 shows the serial information to be logged is shown on the Coolterm applications serial monitor:

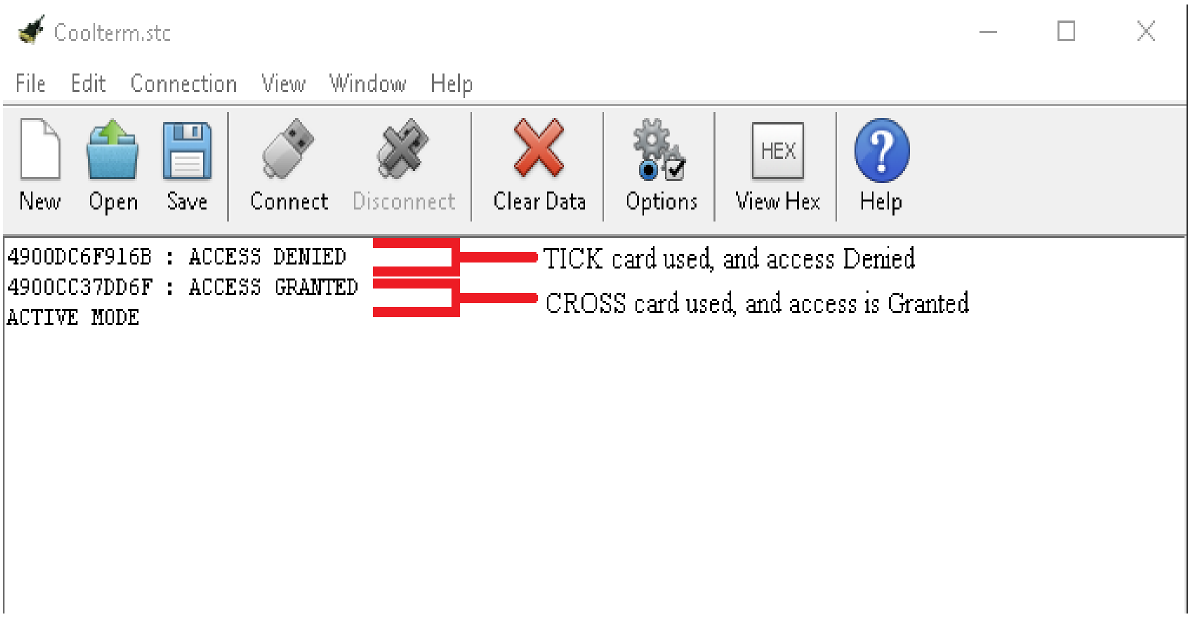


Figure 4 - 32 Serial information

Next, below shows the txt file called RFID_log.txt and the corresponding Times and Dates of access:

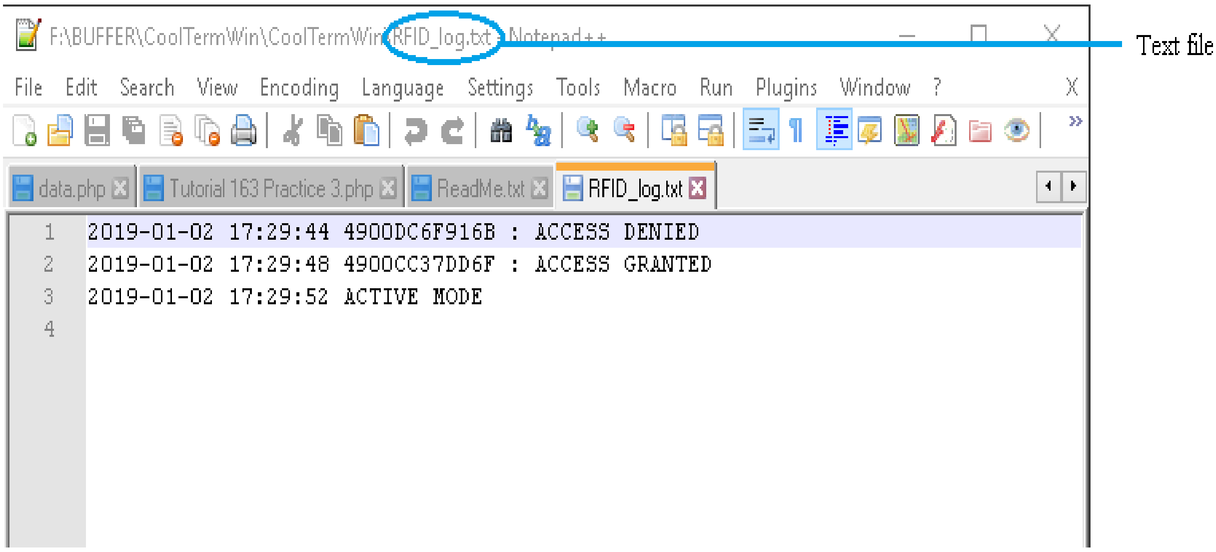


Figure 4 - 33 Access information report

4.2.3 Administrative Tasks

4.2.3.1 Creation Of Supplementary Online Database

To supplement the full operation of the system, the use of online databases is necessary. In this project a possible alternative to this was created using a local server for demonstration purposes using xampp. The database was created using xampp's Apache and MySQL data modules to facilitate data storage.

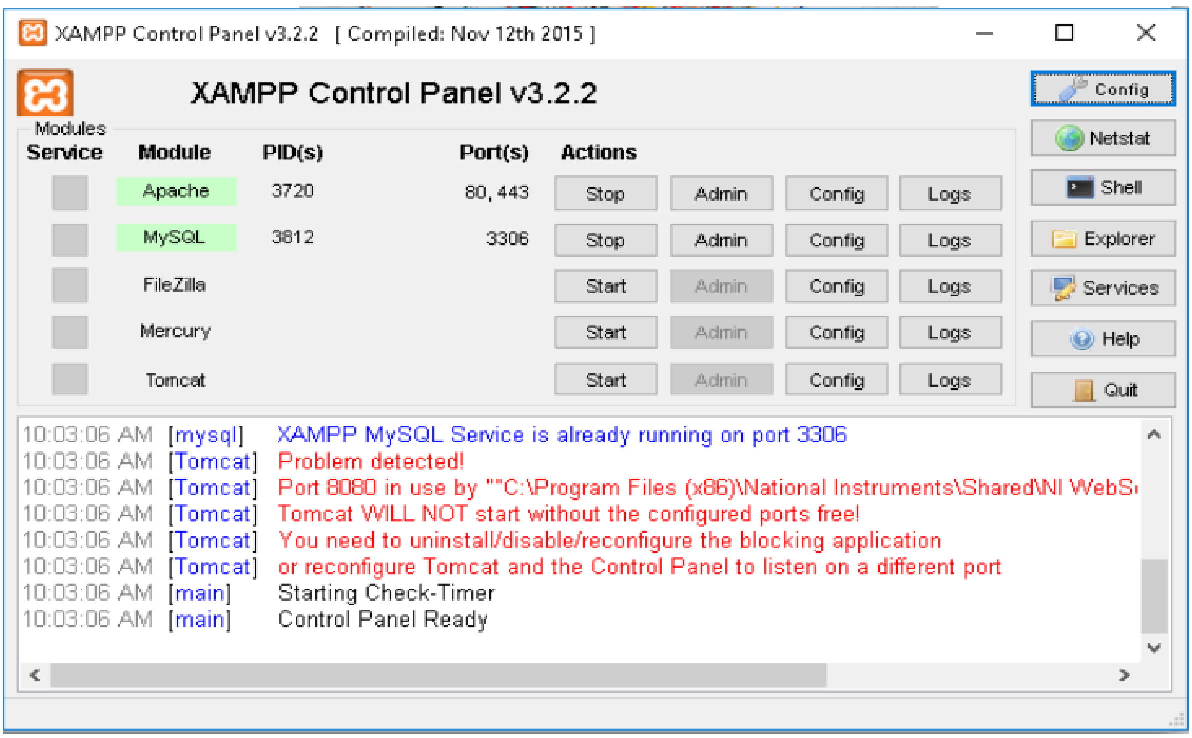


Figure 4 - 34 : xampp control panel

The rest of the database was described using MySQL to cover the back end, PHP programming to link the front end and back end and finally HTML, CSS and bootstrap to facilitate the creation of the front end. The database is on a local server on the PC used to create it and is robust enough to allow for easy inclusion of registered ID‟s, their deletion from the system and their edit in the case that a new ID is registered in the place of a specific spot. The frontend presents the operator with a variety of fields that store the most basic of data of the systems users.

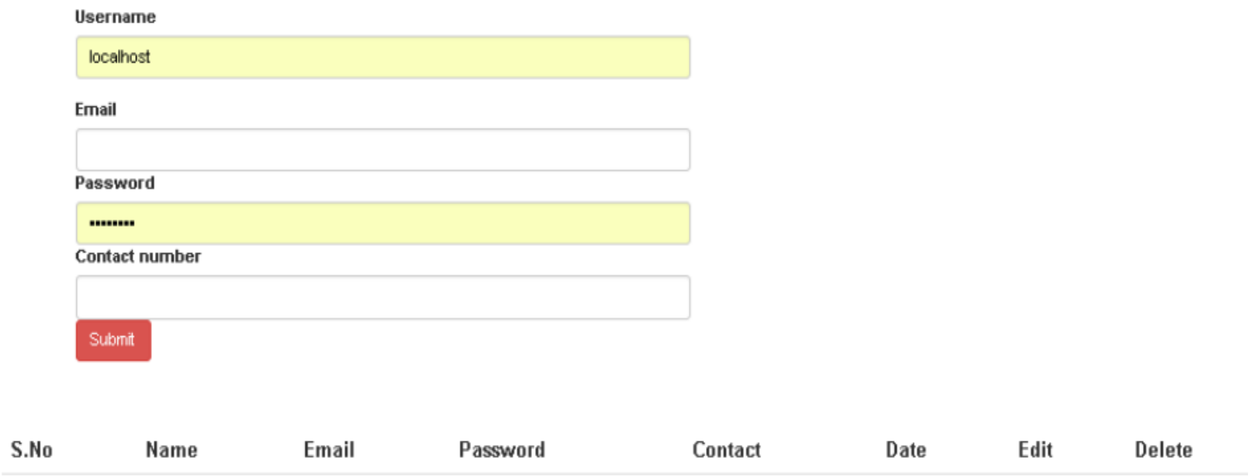


Figure 4 - 35 Database front end after login

S.No represents the slot number on the scanner, corresponding to the memory slot in the MySQL database. Below shows how the operator enters the details of the first enrolled user, „Bill Gates‟, and how once the „Submit‟ button is clicked, his details are saved to the database.

Figure 4 - 36 Insertion of data

S.No	Name	Email	Password	Contact	Date	Edit	Delete
1	Bill Gates	bgates@gmail.com	imadewindows	+260978000001	2018-11-07	Edit	Delete

Figure 4 - 35 Inserted data

S.No	Name	Email	Password	Contact	Date	Edit	Delete
1	Bill Gates	bgates@gmail.com	imadewindows	+260978000001	2018-11-07	Edit	Delete
2	Mahatma Gandhi	mgandhi@gmail.com	notallindiansarespicy	+260978000002	2018-11-07	Edit	Delete
3	Marie Curie	mcurie@gmail.com	sciencebelongstowomen	+260978000003	2018-11-07	Edit	Delete
4	Catherine the Great	Cat_the_great@gmali.com	thefirstczarwifebaby	+260978000004	2018-11-07	Edit	Delete

Figure 4 - 37 database content

4.3 Summary

In this part of the chapter, a successful analysis of data collected from the survey and the presentation of results was done in form of graphs, pie and tables. The research reviewed threats of vehicle theft, un authorised entry of vehicles into the campus and in designated car parking areas as well as non-recording of vehicle/driver activities. The mandated security personnel are unable to stop these vices due to a number of factors some of which have been reviewed in the survey. Under system implementation, the researcher successfully implemented the system prototype. The researcher successfully programed the Arduino board for its full implementation in the prototype and enabled it save information in MySQL database, update and delete records. The researcher further managed to obtain an output from an automatic number plate recognition system.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter discuss the results that have been outlined in chapter four. The baseline survey results have been discussed in section 5.2. This was followed by discussion of the business mapping process in section 5.3 Section 5.4 discussed the system implementation and finally recommendation in section 5.6.

5.2 Baseline Study

With an ever increasing volume of vehicles that enter and leave the University of Zambia (UNZA) campus premises; monitoring and control of vehicles' access using the traditional ways through manual admittance and recording has become impractical. This inability to control vehicle access has led to struggle for parking spaces in most staff car parks as well as the University premises being used as a pass way. In order to improve efficiency and accuracy in the vehicle access controls, monitoring vehicle activities and theft detection, a baseline survey was conducted to establish the specific challenges the university is facing regarding access control, monitoring and security of vehicles in the campus. The purpose of the survey was to find out about the challenges faced by use of manual monitoring and authentication of vehicles. The survey brought out the challenges through the analysis of questionnaire responses and interviews conducted. A discussion of the results obtained from the survey is done in this section.

5.2.1 Manual Vehicle Authentication System

All categorise of respondents indicated that the system used for vehicle access controls at the main entrances and parking areas was manual and ineffective to fulfil the intended objectives. In section 4.2.1 figure 4.1, most respondents acknowledged having knowledge of the existence of university vehicle access policy into the campus premises and in certain designated car parking areas. As regards to authenticating only authorised vehicles into the university premises and designated car parking areas, respondents noted deficiencies in the personnel manning the boom gates. It's been noted that very few users are asked to produce their identities to ascertain their eligibility of access to the premises. Figure 4.7 showed that about 72% of visitors are not questioned neither are they requested to produce identity cards to access premises or car parking areas. This failure has brought about the use of some of the drive ways within campus premises by non-authorised users as a short cut between Kamloops road and the great east main entrance (Figure 4.7 verifies that fact). The research also reviewed that security officers manning the gates are easily bribed to grant access. This trend of non-authorised vehicles accessing designated areas has led to scramble of parking spaces, Some members of staff in parking areas such as the School of education find it difficult to find parking slots(Figure 4.8). It was also indicated that no record of vehicle activities is kept 94.3% of the visitors and students said that they are never questioned at the entrances nor are they requested to produce identities at the entrances (Figure 4.5). Security Officers however attributed this failure to the frequency of vehicles (Figure 4.4). As previously shown [1] literature review, manual methods of vehicle access control are ineffective and inefficient use of time and is prone to human error. According to [3] as reviewed, the use of RFID and ANPR was an effective method for access control of vehicles at Amkkah in the pilgrimage season, restricting specific vehicles from accessing the premises on particular days and tracking the offenders. The University of Zambia, can therefore also use RFID and ANPR to effectively and efficiently control vehicle access into and within the university premises from being accessed by non-authorised vehicles. All categories of participants showed no confidence on the safety of their vehicles when parked in the car park. For instance 44% of members of staff where not confident on the safety of their vehicles while parked in the car parks while only 11% felt confident (Figure 4.2). Equally 47% of visitors and students where not confident on the safety of their cars being parked in the car parking areas, the same pattern of response was given by the security officers as most of them felt it was not easy to whether someone is driving his or her vehicle or not (Figures 4.2, 4.3 and 4.7). 65% of the respondents acknowledged having knowledge of car thefts from within campus premises (Figure 4.9). To overcome these challenges, all categories of respondents recommended for an electronic system that would control access to vehicles, keep track and records of vehicle driver activities as well as deny access to non-permitted drivers to leave the car parking areas (Figure 4.9). It's evident from the literature reviewed that these challenges can be overcome by the introduction of an electronic system, particularly using versatile technologies such as RFID and ANPR. [48] cited the use of RFID in toll collection. The RFID would be detected as the RFID tag powered vehicle passes through an RFID reader. An RFID tag contains the details of the vehicle and owners bank account details and the charge is automatically deducted. In the same vain [28]

ANPR technology has been widely used for automatic toll collection. In this system, a boom gate is made as a barrier and the vehicle would not be granted passage until a fee is paid. The transaction and details of the vehicle are kept in the database. Integrating the two technologies would be answer to the challenges that are currently faced by UNZA on vehicles access controls and vehicle thefts in the University of Zambia (UNZA) has experienced increasing challenge of car parking space control and vehicle access controls to campus premises. In a survey that was conducted to ascertain the need for an electronic system, three categories of personnel were interviewed. Indications are that vehicles have been stolen undetected by the security personnel. It has also been reviewed that some vehicles use the UNZA premises as a pass way linking Kamloops and the great east road. The trend has seen over speeding cars in the campus premises posing danger to the students and staff. Respondents from designated car park areas such as education have experienced high levels of shortage in parking spaces due infiltration by un authorised users. The implementation of the proposed system will provide five authentication levels to meet various entry and exit points. In some areas such as the car parks, the system is tailored to allow exit and entry of vehicles into the premises only when both the driver AND the vehicle are authenticated. The system therefore protects vehicles from being driven away by non-owners hence protecting them from being stolen or accessing areas where they are not supposed to. Entry/exit to the University premises through Lufwanyama and Kamloops gates may require either the vehicle OR the drivers' authentication. The system records every vehicle that seeks to pass through, giving details of the number plate and driver in some cases. Data is sent to the ICT security centre and saved in a data base to allow an effective retrieval and analysis of information.

5.2 System Process mapping and Modelling

This section discusses the System processes that were mapped and the models that were designed in chapter 3 section 3.3. Based on the findings of chapter 4 section 5.2 , the system processes were mapped and the models were designed for automation.

In chapter 3 section 3.3.1 the system process as designed by the University of Zambia is manual. The researcher mapped system in a flow chart as given in figure 3.1. Based on the analysis of the system findings as presented in chapter 4.2, the researcher proposed an automated system process for vehicle authentication to gain access to restricted premises presented in chapter 3 Section 3.3.3. Automating system processes greatly improves operational efficiency, saves time and reduces on human error[1] [27]. This section equally give the system architecture. Generally, Section 3.3 serve as the building blocks upon which the firmware for the integrated system of RFID and ANPR is based

5.3 System Implementation

The section discusses the system implementation presented in chapter 4 sections 4.2 . The challenges that the manual vehicle access control system such as inefficiency, time wastage leading to vehicle convey, inability to detect vehicle theft, inability to keep records of vehicle activities, among others is being addressed in this implementation. While all System process models were mapped, the scope of the prototype implementation was to build an integrated system using AI technologies.

In this thesis study, RFID and ANPR multifactor vehicles access control system model were developed and a prototype system was implemented that shows how the system concept will work.

To begin with, information was gathered, analysed and formulated into useful system requirement according to Chapter 3 section 3.3. The requirement was obtained from questionnaire responses with different stake holders that included members of staff, visitors/students and security personnel.

Secondly, these obtained requirement helped in the design phase of the implementation. Models were designed accordingly in single units as seen in chapter 3 section 3.3 and formed the basis of the prototype development.
Thirdly the individual units where integrated to for a multifactor vehicle access control system. A data base was developed using cool term software package which was later enhanced by MySQL database engine. The prototype was successfully developed and it shows how the RFID and ANPR technologies integrated can be used as vehicle access controls for the university of Zambia at different access points with five configurable levels. Under a developed stem, an incoming car will be photographed and the number plate is processed for the extraction of the binary digits that are verified in the database. If the number is matched, permission is granted to access the premises else access is denied. In the same manner, the RFID tag

embedded in the drivers identity card is ready by the RFID card reader, drivers information is equally sent to the data base and compared with database information, if there is a match access is granted or else access is denied. Depending on the configuration access can be granted when;

- EITHER the *Tag* **OR** *Number plate*,
- *Tag* **AND** *Number plate*
- *Tag* **ONLY**
- *Number Plate* **ONLY**
- *Clear access* but recording **ONLY**

5.4 Conclusion

In this study, a baseline survey was conducted in order to establish the challenges faced by the university of Zambia regarding vehicle access controls in the university premises. A detailed literature review was conducted to review different aspects of the use of RFID and ANPR technologies. Other aspects such as the IR sensors, Arduino, Neural Networks, motors, microcontrollers, cameras, LCD and multifactor authentication. The findings from the baseline study and interviews with key informants where a basis for the design of the development of a multifactor vehicle access control using RFID and ANPR. The models were used as a blueprint to inform the system prototype development.

The following conclusions were arrived at based on the objectives of the study.

a. The University of Zambia faced a lot of challenges in providing motor vehicle access controls into and within campus premises, included keeping records of vehicle activities and prevention of vehicle thefts. Manual operations have proved to be inefficient and prone to human error.
b. From the literature review that has been scrutinised and presented, the results gotten from the baseline survey and the system prototype obtained constructed, it is clear that an automated system built out of the integration of RFID and ANPR technologies will provide UNZA with a more reliable and dependable vehicle access control system. An automated system helps in good rime management, reductions of human error and maintaining accurate vehicle records.

The initial cost of building the integrated system may be costly but the benefits in the long run out ways it. The deployment of security personnel will drastically reduce as the system will not need human interference during its normal operations. RFID market has grown and RFID tags have become cheaper and easily accessible.

5.6 Recommendations

The following recommendations are forwarded to the University of Zambia for an efficient and effective management of vehicle access controls within and into the University premises.

a. Implementing the versatile developed two-factor authentication for vehicle parking space control using automatic number plate recognition (ANPR) and radio frequency identification (RFID) will provide access controls that suits requirements for access point. For instance;

    i. The Great East Road Campus takes the first configuration which require the capturing of vehicle number plates as the cross over the access point.

    ii. The Lufwanyama and Kalingalinga entrances takes the ORed configuration where users should either have an ID or registered vehicle to gain access.

    iii. The car parking areas takes up the ANDed configuration where the user would need both the ID and Vehicle number plate configured.

b. Further, the system will bring about effective vehicle monitoring, avoid time wastage, will prevent vehicle thefts, and enable the availability of parking space for the members of staff.

5.7 Future Works

A more robust security prototype system can be constructed to enable the registered vehicle owner receive notifications when the vehicle is crossing any of the access points. This will enhance motor vehicle security. The system can further be enhanced to notify the driver on an empty space within the designated car parking area. Further the system record storage can be changed from local servers to the cloud and vehicle activity reports can be accessible or viewed by security personnel and vehicle owner with log on credentials. With the evidence of the systems feasibility, the system awaits physical implementation as proposed.

5.8 Summary

This chapter discussed the results presented in chapter four. The baseline survey results were discussed as well as system implementation. Further, the conclusion of the study was done, recommendations and lastly future works in section 5.8.

REFERENCES

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APPENDICES

APPENDIX A: Data Collection Questionnaires

The University of Zambia

School of Natural Science

Development of a Two Factor Authentication for Vehicle Parking Space Control Based on Automatic Number Plate Recognition and Radio Frequency Identification

---

Friday Chisowa Chazanga (Student ID: 2016146148)

MSc in Computer Science,

For more information or any queries, kindly get in touch on 0977-519221

Dear Respondent,

I am a student at the University of Zambia in my final stage pursuing a Master of Science in Computer Science. As partial fulfillment for the award of a Master of Science degree, I am conducting a baseline study on: "**Development and Implementation of a Two Factor Authentication for Vehicle Parking Space Control Based on Automatic Number Plate Recognition and Radio Frequency Identification**"

You have been purposively sampled to provide information for the topic indicated above. The information being collected is purely for academic purposes as such, it will be treated with maximum confidentiality. Subsequently, you are not supposed to indicate your name or any personal information that can lead to revealing of your identity.

Your co-operation will be greatly appreciated.

For more information or any queries, kindly get in touch with the following:

Project Supervisor: Dr. Jackson Phiri (0966 693 731) or

Head of Department: Mrs. Monica M. Kalulmbilo - Kabemba (0211 293901)

Kindly circle your answer

SECTION A: Bio Data

1. Gender
   i. Male
   ii. Female
2. Age
   i. Below 25
   ii. Between 26 and 35
   iii. Between 36 and 45

iv. Above 45

3. a. Which School of the University of Zambia (UNZA) are employed in?

i. Agricultural Sciences
ii. Education
iii. Engineering
iv. Humanities & Social Sciences
v. Law
vi. Medicine
vii. Mines
viii. Natural Sciences
ix. Veterinary Medicine
x. Graduate School of Business

b. Kindly indicate the department in your School where you are stationed
…………………………………………………………………

4. For how long have you been employed at UNZA?

i. Less than one (1) year
ii. Between one (1) and five (5) years
iii. Above five (5) years

5. Which Category of member of staff are you?

i. Lecturer
ii. Support Staff

SECTION B: Parking Convenience and Security

6. Do you come with your own car for work?

i. Yes
ii. No

7. If YES, where do you normally park?

i. In the staff car park within my School
ii. In the Visitors Car Park
iii. Other (Specify) ………………………………

8. Do you find it challenging to get a parking space in the Staff car park?

i. Yes
ii. No

9. Are there any non-Staff cars that are usually parked in the staff car park?
   i. Yes
   ii. No
10. How confident are you on the security of your car when it's parked?
   i. Very Confident
   ii. Confident
   iii. Partially confident
   iv. Not Confident
11. Is there any record kept when your car is driven out of the car park by yourself or another person?
   i. Yes
   ii. No
12. If your answer to question 11 is 'NO' why?
   i. Its difficulty due to frequency of traffic.
   ii. There is no need to record.
   iii. There is no such system in place.
   iv. Others (Specify) ………………………………………….
13. Would you recommend a system that will NOT ALLOW your car being driven out of car park/campus by anyone else except with your identity or permission?
   i. Highly recommend
   ii. Recommend
   iii. Not Recommend
14. Has there been any car theft around campus?
   i. Yes
   ii. No
   iii. Not to my knowledge
15. Would you recommend a system that keeps records of vehicle traffic and driver activities?
   i. Yes
   ii. No
16. If your answer is YES to question 15, which system would you recommend?
   i. Manual
   ii. Electronic
   iii. Other (Specify) ………………………………………………………..
17. Give reasons to your answer in question 16 ……………………………………………………………………………………………… ……………………………………………………………………

Thank you for your time

The University of Zambia

School of Natural Science

Development of a Two Factor Authentication for Vehicle Parking Space Control Based on Automatic Number Plate Recognition and Radio Frequency Identification

---

Friday Chisowa Chazanga (Student ID: 2016146148)

MSc in Computer Science,

For more information or any queries, kindly get in touch on 0977-519221

Dear Respondent,

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For more information or any queries, kindly get in touch with the following:

Project Supervisor: Dr. Jackson Phiri (0966 693 731) or

Head of Department: Mrs. Monica M. Kalulmbilo - Kabemba (0211 293901)

kindly circle your answer

SECTION A: Bio Data

1. Gender
   i. Male
   ii. Female
2. Age
   i. Below 25
   ii. Between 26 and 35
   iii. Between 36 and 45
   iv. Above 45

3. Are you directly employed by UNZA or another Company contracted by UNZA?
   i. UNZA
   ii. Another Company Contracted by UNZA

4. How long have you been stationed at UNZA?
   i. Less than one (1) year
   ii. Between one (1) and five (5) years
   iii. Above five (5) years

5. What time do you normally operate?
   i. Night
   ii. Day
   iii. Alternate Day and Night

<u>SECTION B: Access Convenience and Security</u>

6. Where are you usually stationed?
   i. Entrance gates to the University (Specify) ………………..…………..
   ii. Entrance gates to School units (Specify) ………………………………
   iii. At School premises overseeing car parks (Specify) ……………………
   iv. Other (Specify)……………………………….
7. If your answer to question 6 is 'i' or 'ii', which vehicles are allowed to use the gate you are manning?
   i. UNZA staff vehicles ONLY
   ii. All vehicles that have business in the university
   iii. Any vehicle
8. Which areas do you pay most attention when on duty?
   i. Office equipment
   ii. Vehicles entering and leaving
   iii. Vehicles parked in the car parks.
   iv. Other (Specify)………………………………..
9. Does the institution have a policy to restrict vehicles that enter campus premises?
   i. Yes
   ii. No
10. Does the institution have restricted parking areas specifically meant for staff or certain category of staff?
    i. Yes
    ii. No
11. If the answer to question 10 is YES, what system/s is used to allow or deny vehicle entry?
    i. guards/manual

ii. Electronic security system
iii. Others (Specify………………………………….
12. Do you have occasions when a non-authorised person/s Park in restricted areas such as staff car parks or on a higher category staff car park?
i. Yes
ii. No
13. Do you record all vehicles that enter or leave the premises?
i. Yes
ii. No
14. If your answer to question 13 is 'NO' why?
i. Its difficulty due to frequency of traffic.
ii. There is no need to record.
iii. Others (Specify) ……………………………………………
15. Are there any incidences of car theft you may be aware of?
i. Yes
ii. No
16. If the answer to question 15 is 'YES', how often?
i. Nearly every year
ii. Nearly every two years
iii. Nearly every after five years
iv. Other(Specify)…………………………………………..
17. Has there been a struggle for parking spaces in the premises?
i. Yes
ii. No
18. Would you recommend a system that keeps records of vehicle traffic and driver activities?
i. Yes
ii. No
19. If your answer is YES to question 18, which system would you recommend?
i. Manual
ii. Electronic
iii. Other (Specify) ………………………………………………………..
20. Give reasons to your answer in question 19 …… …… …………….

Thank you for your time

The University of Zambia

School of Natural Science

Development of a Two Factor Authentication for Vehicle Parking Space Control Based on Automatic Number Plate Recognition and Radio Frequency Identification

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Friday Chisowa Chazanga (Student ID: 2016146148)

MSc in Computer Science,

For more information or any queries, kindly get in touch on 0977-519221

Dear Respondent,

I am a student at the University of Zambia in my final stage pursuing a Master of Science in Computer Science. As partial fulfillment for the award of a Master of Science degree, I am conducting a baseline study on: "**Development and Implementation of a Two Factor Authentication for Vehicle Parking Space Control Based on Automatic Number Plate Recognition and Radio Frequency Identification**"

You have been purposively sampled to provide information for the topic indicated above. The information being collected is purely for academic purposes as such, it will be treated with maximum confidentiality. Subsequently, you are not supposed to indicate your name or any personal information that can lead to revealing of your identity.

Your co-operation will be greatly appreciated.

For more information or any queries, kindly get in touch with the following:

Project Supervisor: Dr. Jackson Phiri (0966 693 731) or

Head of Department: Mrs. Monica M. Kalulmbilo - Kabemba (0211 293901)

Kindly circle your answer

SECTION A: Bio Data

1. Gender
   i. Male
   ii. Female
2. Age
   i. Below 25
   ii. Between 26 and 35
   iii. Between 36 and 45
   iv. Above 45
3. Are you employed?
   i. Yes
   ii. No
4. If your answer to question 3 is YES, with which company do you work for?
   ………………………………………………………………………..

SECTION B: Access Convenience and Security

5. If your answer to question 3 is NO, what do you do at UNZA.
   i. Business
   ii. Tax Driver
   iii. Contracted
   iv. Student
   v. Other (Specify) ……………………………………………..
6. How often do you come into UNZA campus?
   i. Very often
   ii. Often
   iii. Rarely
7. Are you questioned each time you enter into campus at the entrance?
   i. Never
   ii. Sometimes
   iii. Every time
8. Which entrance do you normally use?
   i. Main Great East Road Entrance
   ii. Kalingalinga entrance
   iii. Mashlands / hands Worth Entrance
   iv. Other (Specify) …………………………………………
9. How easy do you find parking space in the campus?
   i. Very easy
   ii. Easy
   iii. Not Easy
10. Do you at times have an opportunity to park in the staff car park?
    i. Always
    ii. At times
    iii. Never

11. Do you feel you have at any point been harassed by the security personnel at any time?
   i. Yes
   ii. No
12. If your answer to question 11 is Yes, kindly explain briefly …… …… ……………………………………………………
13. How confident are you on the security of your car when it's parked?
   i. Very Confident
   ii. Confident
   iii. Partially confident
   iv. Not Confident
14. Would you recommend a system that will enable you interact electronically instead of security guards?
   i. Highly recommend
   ii. Recommend
   iii. Not Recommend
15. Would you recommend a system that keeps records of your vehicle visits in the University?
   i. Yes
   ii. No
16. If your answer is YES to question 15, which system would you recommend?
   i. Manual
   ii. Electronic
   iii. Other (Specify) ……………………………………………………..
17. Give reasons to your answer in question 16 …… …… …………….

Thank you for your time

APPENDIX B Stepper Motor Arduino Code

Arduino code to test stepper motor driver

```
#include <Stepper.h>

const int stepsPerRevolution = 200;  // change this to fit the number of steps per revolution
// for your motor

// initialize the stepper library on pins 8 through 11:
Stepper myStepper(stepsPerRevolution, 8, 9, 10, 11);

void setup() {
  // set the speed at 60 rpm:
  myStepper.setSpeed(60);
  // initialize the serial port:
  Serial.begin(9600);
}

void loop() {
  // step one revolution  in one direction:
  Serial.println("clockwise");
  myStepper.step(stepsPerRevolution);
  delay(500);

  // step one revolution in the other direction:
  Serial.println("counterclockwise");
  myStepper.step(-stepsPerRevolution);
  delay(500);
}
```

APPENDIX C Neural Network Code

```
clc; % Clear command window.
clear all; % Delete all variables.
close all; % Close all figure windows except those created by imtool.
imtool close all;% Close all figure windows created by imtool.
workspace; % Make sure the workspace panel is showing.
% Read Image
[fname, path]=uigetfile('*.jpg','select an image');
fname=strcat(path,fname);
n1=imread(fname);
[~,cc]=size(n1);
figure(1);
n1=imresize(n1,[300 500]);
imshow(n1);
% Extract Y component (Convert an Image to Gray)
Igray = rgb2gray(n1);
[rows, cols] = size(Igray);
%% Dilate and Erode Image in order to remove noise
Idilate = Igray;
```

```
for i = 1:rows
for j = 2:cols-1
temp = max(Igray(i,j-1), Igray(i,j));
Idilate(i,j) = max(temp, Igray(i,j+1));
end
end
n1 = Idilate;
figure(2);
imshow(Igray);
figure(3);
title('Dilated Image')
imshow(Idilate);
figure(4);
imshow(n1);
difference=0;
total_sum = 0;
Difference = uint32(difference);
%% PROCESS EDGES IN HORIZONTAL DIRECTION
disp('Processing Edges Horizontally...');
max_horz = 0;
maximum = 0;
for i = 2:cols
Sum = 0;
for j = 2:rows
if(n1(j, i) > n1(j-1, i))
difference = uint32(n1(j, i) - n1(j-1, i));
else
difference = uint32(n1(j-1, i) - n1(j, i));
end
if(difference > 20)
Sum = Sum + difference;
end
end
horz1(i) = Sum;
% Find Peak Value
if(Sum > maximum)
max_horz = i;
maximum = Sum;
end
total_sum = total_sum + Sum;
end
average = total_sum / cols;
figure(5);
% Plot the Histogram for analysis
subplot(3,1,1);
plot (horz1);
title('Horizontal Edge Processing Histogram');
xlabel('Column Number ->');
ylabel('Difference ->');
%% Smoothen the Horizontal Histogram by applying Low Pass Filter
```

```
disp('Passing Horizontal Histogram through Low Pass Filter...');
sum=0;
horz = horz1;
for i = 21:(cols-21)
Sum = 0;
for j = (i-20):(i+20)
Sum = Sum + horz1(j);
end
horz(i) = Sum / 41;
end
subplot(3,1,2);
plot (horz);
title('Histogram after passing through Low Pass Filter');
xlabel('Column Number ->');
ylabel('Difference ->');
%% Filter out Horizontal Histogram Values by applying Dynamic
Threshold
disp('Filter out Horizontal Histogram...');
for i = 1:cols
if(horz(i) < average)
horz(i) = 0;
for j = 1:rows
n1(j, i) = 0;
end
end
end
subplot(3,1,3);
plot (horz);
title('Histogram after Filtering');
xlabel('Column Number ->');
ylabel('Difference ->');
%% PROCESS EDGES IN VERTICAL DIRECTION
difference = 0;
total_sum = 0;
difference = uint32(difference);
disp('Processing Edges Vertically...');
maximum = 0;
max_vert = 0;
for i = 2:rows
Sum = 0;
for j = 2:cols %cols
if(n1(i, j) > n1(i, j-1))
difference = uint32(n1(i, j) - n1(i, j-1));
end
if(n1(i, j) <= n1(i, j-1))
difference = uint32(n1(i, j-1) - n1(i, j));
end
if(difference > 20)
Sum = Sum + difference;
end
```

```
end
vert1(i) = Sum;
%% Find Peak in Vertical Histogram
if(Sum > maximum)
max_vert = i;
maximum = Sum;
end
total_sum = total_sum + Sum;
end
average = total_sum / rows;
figure(6)
subplot(3,1,1);
plot (vert1);
title('Vertical Edge Processing Histogram');
xlabel('Row Number ->');
ylabel('Difference ->');
%% Smoothen the Vertical Histogram by applying Low Pass Filter
disp('Passing Vertical Histogram through Low Pass Filter...');
Sum = 0;
vert = vert1;
for i = 21:(rows-21)
Sum = 0;
for j = (i-20):(i+20)
Sum = Sum + vert1(j);
end
vert(i) = Sum / 41;
end
subplot(3,1,2);
plot (vert);
title('Histogram after passing through Low Pass Filter');
xlabel('Row Number ->');
ylabel('Difference ->');
%% Filter out Vertical Histogram Values by applying Dynamic Threshold
disp('Filter out Vertical Histogram...');
for i = 1:rows
if(vert(i) < average)
vert(i) = 0;
for j = 1:cols
n1(i, j) = 0;
end
end
end
subplot(3,1,3);
plot (vert);
title('Histogram after Filtering');
xlabel('Row Number ->');
ylabel('Difference ->');
figure(7), imshow(n1);
%% Find Probable candidates for Number Plate
j = 1;
```

```
for i = 2:cols-2
if(horz(i) ~= 0 && horz(i-1) == 0 && horz(i+1) == 0)
column(j) = i;
column(j+1) = i;
j = j + 2;
elseif((horz(i) ~= 0 && horz(i-1) == 0) || (horz(i) ~= 0 && horz(i+1)
== 0))
column(j) = i;
j = j+1;
end
end
j = 1;
for i = 2:rows-2
if(vert(i) ~= 0 && vert(i-1) == 0 && vert(i+1) == 0)
row(j) = i;
row(j+1) = i;
j=j+2;
elseif((vert(i) ~= 0 && vert(i-1) == 0) || (vert(i) ~= 0 &&
vert(i+1) == 0))
row(j) = i;
j = j+1;
end
end
[~, column_size] = size (column);
if(mod(column_size, 2))
column(column_size+1) = cols;
end
[temp, row_size] = size (row);
if(mod(row_size, 2))
row(row_size+1) = rows;
end
%% Region of Interest Extraction
%Check each probable candidate
for i = 1:2:row_size
for j = 1:2:column_size
% If it is not the most probable region remove it from image
if(~((max_horz >= column(j) && max_horz <= column(j+1)) &&
(max_vert >=row(i) && max_vert <= row(i+1))))
%This loop is only for displaying proper output to User
for m = row(i):row(i+1)
for n = column(j):column(j+1)
n1(m, n) = 0;
end
end
end
end
end
figure(8), imshow(n1);
[L,Ne]=bwlabel(n1);
propied=regionprops(L,'BoundingBox');
```

```
hold on
pause(1)
for n=1:size(propied,1)
rectangle('Position',propied(n).BoundingBox,'EdgeColor','g','LineWidth
',2)
end
hold off
figure
%final_output=[];
%t=[];
for n=1:Ne
[r,c] = find(L==n);
n1=n1(min(r):max(r),min(c):max(c));
imshow(n1)
pause(0.2)
end
imshow(n1);
L = logical(n1);% Calculating connected components
stats = regionprops(L,'basic');%determine basic properties
allArea = [stats.Area];
[max_val,loi] = max(allArea);% Qualifier Criteria
%final_roi = imadjust(imcrop(gray,stats(loi).BoundingBox));
result=~im2bw(n1,graythresh(n1));% Final Binary image
imshow(result);
global op
if([op ,'y']==[ op,'Y'])
figure, imshow(result), title('Plate localization');
end
[L,num] = bwlabel(result,8);
stats = regionprops(L,'basic');%determine basic image properties
dim = size(result);% Plate area in pixel square
plate_area = dim(1)*dim(2);
% Number extraction is based on following criterion
% Bounding box area Must be 1% or more of total plate area
% Bounding box width ~ Bounding box height
s=regionprops(result,'BoundingBox');
bb=round(reshape([s.BoundingBox],4, []).');
result=mat2gray(result); % Converting the class to double.
result=conv2(result,[1 1;1 1]); % Convolution of the double image for
brightening the edges.
result=imadjust(result,[0.5 0.7],[0 1],0.1); % Intensity scaling
between the range 0 to 1.
B=logical(result); % Conversion of the class from double to binary.
% Eliminating the possible horizontal lines from the output image of
regiongrow
% that could be edges of license plate.
% Selecting all the regions that are of pixel area more than 100.
result1=bwareaopen(result,100);
imshow(result1);
cntr = 1;
```

```
global y
global Y
for x=1:num,
area = stats(x).Area;
boun_area = stats(x).BoundingBox(3)*stats(x).BoundingBox(4);
aspect = stats(x).BoundingBox(3)/stats(x).BoundingBox(4);
if(area > 0.001*plate_area && boun_area > 0.01*plate_area &&
aspect>0.05 && aspect < 2)
input(:,:, cntr) =
~imresize(imcrop(result1,stats(x).BoundingBox),[15 10]);
if(isequal(y,Y))
figure, imshow(imresize(input(:,:,cntr),[150 100],'nearest')),
title('Number segmentation');
end
cntr = cntr+1;
end
end
load('network.mat');% Read network from disk
for i=1:cntr-1,
for j=1:150,
[x,y]=ind2sub([15 10],j);
input_vector(j,i)= double(input(x,y,i));
end
[val,plate_no(i)] = max(sim(network,input_vector(:,i)));%Output final
numberplate
plate_no(i) = plate_no(i)-1;
end
file = fopen('number_Plate.txt', 'wt');
fprintf(file,'%s\n',plate_no(i));
fclose(file);
winopen('number_Plate.txt')
```

APPENDIX D RFID Code

```
#include <FPS_GT511C3.h>
//Libraries
#include <EEPROM.h>
#include <SoftwareSerial.h>
#include <FPS_GT511C3.h>
#include <Servo.h>
#include <LiquidCrystal.h>
//Inputs defined *
//...for the FPS
FPS_GT511C3 fps(4, 5); //4 = Tx, 5 = Rx
//...for the Servo motor (Door)
Servo myservo;
int pos = 0;
//...for LCD
LiquidCrystal lcd(8, 9, 10, 11, 12, 13);
//...for the Buttons and LED's
#define button1 2
#define button2 3
```

```
#define button3 6
#define button4 7
#define LEDRED A5
#define LEDGREEN A0
//SETUP
void setup()
{
//Set up variables
Serial.begin(9600);
delay(100);
//fps initialization
fps.Open();
fps.SetLED(true);
//...for servo motor
myservo.attach(A3);
//...for LCD
lcd.begin(16, 2);
//...for pins and LED's
pinMode(button1, INPUT);
pinMode(button2, INPUT);
pinMode(button3, INPUT);
pinMode(button4, INPUT);
pinMode(LEDGREEN, OUTPUT);
pinMode(LEDRED, OUTPUT);
//Program Setup begins
digitalWrite(LEDGREEN, HIGH);
digitalWrite(LEDRED, LOW);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, HIGH);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, LOW);
digitalWrite(LEDGREEN, HIGH);
digitalWrite(LEDRED, LOW);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, HIGH);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, LOW);
}
void loop()
{
lcd.setCursor(0, 0);
lcd.print(F("1. ACTIVE MODE"));
lcd.setCursor(0, 1);
lcd.print(F("2. SETTINGS"));
do
{}
```

```
while (digitalRead(button1) == LOW && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW);
lcd.clear();
if (digitalRead(button1) == HIGH && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW)
{
lcd.setCursor(0, 0);
lcd.print(F(" Heading to"));
lcd.setCursor(0, 1);
lcd.print(F(" ACTIVE MODE"));
delay(1000);
lcd.clear();
Active();
}
else if (digitalRead(button2) == HIGH)//doop
{
lcd.clear();
delay(1000);
int count = 0;
//Program Start
lcd.setCursor(0, 0);
lcd.print(F("1 Enroll 2 Del"));
lcd.setCursor(0, 1);
lcd.print(F("3 M.Check 4 ACT."));
do
{}
while (digitalRead(button1) == LOW && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW);
lcd.clear();
if (digitalRead(button1) == HIGH)
{ //1
lcd.setCursor(0, 0);
lcd.print(F("Option 1 chosen"));
delay(2000);
lcd.clear();
digitalWrite(LEDGREEN, HIGH);
digitalWrite(LEDRED, LOW);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, HIGH);
delay(1000);
Serial.println(F("Heading to ENROLLMENT"));
Serial.println(F(""));
lcd.setCursor(0, 0);
lcd.print(F("Heading to"));
lcd.setCursor(0, 1);
lcd.print(F("ENROLLMENT"));
delay(2000);
lcd.clear();
count++;
```

```
Enroll();
}//1*
else if (digitalRead(button2) == HIGH)
{ //2
lcd.setCursor(0, 0);
lcd.print(F("Option 2 chosen"));
delay(2000);
lcd.clear();
delay(1000);
digitalWrite(LEDGREEN, HIGH);
digitalWrite(LEDRED, LOW);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, HIGH);
delay(1000);
lcd.setCursor(0, 0);
lcd.print(F(" Heading to"));
lcd.setCursor(0, 1);
lcd.print(F(" DELETION"));
delay(2000);
lcd.clear();
count++;
Delete();
}//2*
else if (digitalRead(button3) == HIGH)
{ //3
lcd.setCursor(0, 0);
lcd.print(F("Option 3 chosen"));
delay(2000);
lcd.clear();
digitalWrite(LEDGREEN, HIGH);
digitalWrite(LEDRED, LOW);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, HIGH);
delay(1000);
lcd.setCursor(0, 0);
lcd.print(F(" Heading to"));
lcd.setCursor(0, 1);
lcd.print(F(" MEMORY CHECK"));
delay(2000);
lcd.clear();
count++;
Serial.println(count);
MemoryCheck();
}//3*
else if (digitalRead(button4) == HIGH)
{ //4
delay(1000);
digitalWrite(LEDGREEN, HIGH);
```

```
digitalWrite(LEDRED, LOW);
delay(1000);
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, HIGH);
delay(1000);
int count = 0;
}//4*
else {loop();}
delay(1000);
if (count >= 1)
{
do
{}
while (digitalRead(button1) == LOW && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW);
delay(1000);
}
else
{
lcd.setCursor(0, 0);
lcd.print(F(" Welcome to"));
lcd.setCursor(0, 1);
lcd.print(F(" ACTIVE MODE"));
delay(2000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("Press any button"));
lcd.setCursor(0, 1);
lcd.print(F( "for MAIN MENU"));
delay(2000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("--PLACE FINGER--"));
lcd.setCursor(0, 1);
lcd.print(F("----------------"));
Active();
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Returning to"));
lcd.setCursor(0, 1);
lcd.print(F(" Main Menu"));
digitalWrite(LEDGREEN, HIGH);
digitalWrite(LEDRED, HIGH);
delay(2000);
lcd.clear();
loop();
}
}
//boop
}
```

```
//DELETION
void Delete()
{
lcd.setCursor(0, 0);
lcd.print(F("1. Delete All"));
lcd.setCursor(0, 1);
lcd.print(F("2. Delete single ID"));
do
{}
while (digitalRead(button1) == LOW && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW);
lcd.clear();
if (digitalRead(button1) == HIGH && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW)
{
fps.DeleteAll();
lcd.setCursor(0, 0);
lcd.print(F("All Fingerprint's"));
lcd.setCursor(0, 1);
lcd.print(F(" deleted"));
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Returning to"));
lcd.setCursor(0, 1);
lcd.print(F(" Main Menu"));
delay(1000);
lcd.clear();
delay(500);
loop();
}
else
{
lcd.setCursor(0, 0);
lcd.print(F("Select ID to be"));
lcd.setCursor(0, 1);
lcd.print(F(" deleted"));
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("Checking memory"));
lcd.setCursor(0, 1);
lcd.print(F(" slots occupied"));
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
bool usedid;
for (int i = 0; i <= 20; i++)
{
usedid = fps.CheckEnrolled(i);
```

```
if (usedid == true)
{
lcd.print(i);
}
else
{ }
}
delay(2000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("Memories viewed"));
lcd.setCursor(0, 1);
lcd.print(F("Choose deletion"));
for (int i = 0; i <= 20; i++)
{
usedid = fps.CheckEnrolled(i);
if (usedid == true) //If space is occupied
{
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(i);
lcd.setCursor(0, 1);
lcd.print(F("is occupied"));
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("Delete "));
lcd.setCursor(7, 0);
lcd.print(i);
lcd.setCursor(10, 0);
lcd.print(F("?"));
lcd.setCursor(0, 1);
lcd.print(F("1 Yes 2 No"));
do
{}
while (digitalRead(button1) == LOW && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW);
lcd.clear();
if (digitalRead(button1) == HIGH && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW)
{
fps.DeleteID(i);
lcd.setCursor(0, 0);
lcd.print(F("Fingerprint"));
lcd.setCursor(12, 0);
lcd.print(i);
lcd.setCursor(0, 1);
lcd.print(F("deleted"));
delay(1000);
```

```
}
else if (digitalRead(button1) == LOW && digitalRead(button2) == HIGH &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW)
{
lcd.setCursor(0, 0);
lcd.print(F("Fingerprint"));
lcd.setCursor(12, 0);
lcd.print(i);
lcd.setCursor(0, 1);
lcd.print(F("not deleted"));
delay(1000);
}
}
else
{
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Memory is"));
lcd.setCursor(0, 1);
lcd.print(F(" empty"));
delay(1000);
}
}
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Returning to"));
lcd.setCursor(0, 1);
lcd.print(F(" Main Menu"));
delay(1000);
loop();
}
}
/////////////////////////////////////////////////////////MEMORY
CHECK/////////////////////////////////////////////////////////////////
void MemoryCheck()
{
int check = fps.GetEnrollCount();
lcd.setCursor(0, 0);
lcd.print(F(" Welcome to"));
lcd.setCursor(0, 1);
lcd.print(F(" MEMORY CHECK"));
delay(1000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print(F("Number enrolled:"));
lcd.setCursor(0,1);
lcd.print(check);
delay(2000);
lcd.clear();
lcd.setCursor(0,0);
```

```
lcd.print(F("O:"));
bool usedid;
for (int i = 0; i <= 20; i++)
{
usedid = fps.CheckEnrolled(i);
if (usedid == true)
{
lcd.print(i);
}
}
delay(1000);
lcd.setCursor(0,1);
lcd.print(F("V:"));
for (int i = 0; i <= 20; i++)
{
usedid = fps.CheckEnrolled(i);
if (usedid == false)
{
lcd.print(i);
}
}
delay(5000);
lcd.clear();
lcd.setCursor(0,0);
lcd.print(F(" Returning to"));
lcd.setCursor(0,1);
lcd.print(F(" Main Menu"));
delay(2000);
loop();
}
//ENROLLMENT
void Enroll()
{
// Enroll test
lcd.setCursor(0, 0);
lcd.print(F(" WELCOME TO"));
lcd.setCursor(0, 1);
lcd.print(F(" ENROLLMENT"));
delay(1000);
lcd.clear();
// find open enroll id
int enrollid = 0;
bool usedid = true;
while (usedid == true)
{
usedid = fps.CheckEnrolled(enrollid);
if (usedid==true) enrollid++;
}
fps.EnrollStart(enrollid);
// enroll
```

```
lcd.setCursor(0, 0);
lcd.print(F("Saving to memory"));
lcd.setCursor(0, 1);
lcd.print(enrollid);
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Press"));
lcd.setCursor(0, 1);
lcd.print(F(" finger"));
while(fps.IsPressFinger() == false) delay(100);
bool bret = fps.CaptureFinger(true);
int iret = 0;
if (bret != false)
{
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Remove"));
lcd.setCursor(0, 1);
lcd.print(F(" finger"));
fps.Enroll1();
while(fps.IsPressFinger() == true) delay(100);
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Press same"));
lcd.setCursor(0, 1);
lcd.print(F(" finger again"));
while(fps.IsPressFinger() == false) delay(100);
bret = fps.CaptureFinger(true);
if (bret != false)
{
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Remove"));
lcd.setCursor(0, 1);
lcd.print(F(" finger"));
fps.Enroll2();
while(fps.IsPressFinger() == true) delay(100);
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Press same"));
lcd.setCursor(0, 1);
lcd.print(F("yet finger again"));
while(fps.IsPressFinger() == false) delay(100);
bret = fps.CaptureFinger(true);
if (bret != false)
```

```
{
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Remove"));
lcd.setCursor(0, 1);
lcd.print(F(" finger"));
iret = fps.Enroll3();
if (iret == 0)
{
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Enrollment"));
lcd.setCursor(0, 1);
lcd.print(F(" Successful"));
delay(2000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("1 Return to Menu"));
lcd.setCursor(0, 1);
lcd.print(F("2 Enroll again"));
do
{}
while (digitalRead(button1) == LOW && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW);
if(digitalRead(button1) == HIGH && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW)
{
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Returning"));
lcd.setCursor(0, 1);
lcd.print(F(" to Main Menu"));
lcd.clear();
delay(1000);
loop();
}
else if(digitalRead(button1) == LOW && digitalRead(button2) == HIGH &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW)
{
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Returning"));
lcd.setCursor(0, 1);
lcd.print(F(" to Enrollment"));
lcd.clear();
delay(1000);
```

```
Enroll();
}
}
else
{
lcd.clear();
delay(100);
lcd.setCursor(0, 0);
lcd.print(F(" Enrollment"));
lcd.setCursor(0, 1);
lcd.print(F(" Failed"));
lcd.clear();
delay(500);
lcd.setCursor(0, 0);
lcd.print(F(" Restarting"));
lcd.setCursor(0, 1);
lcd.print(F(" process"));
Enroll();
}
}
else {Serial.println(F("Failed to capture third finger"));
lcd.setCursor(0, 0);
lcd.print(F("Failed to enroll"));
lcd.setCursor(0, 1);
lcd.print(F(" third finger"));
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Restarting"));
lcd.setCursor(0, 1);
lcd.print(F(" process"));
Serial.println(iret);
Enroll();}
}
else {Serial.println(F("Failed to capture second finger"));
lcd.setCursor(0, 0);
lcd.print(F("Failed to enroll"));
lcd.setCursor(0, 1);
lcd.print(F(" second finger"));
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Restarting"));
lcd.setCursor(0, 1);
lcd.print(F(" process"));
Serial.println(iret);
Enroll();}
}
else {
Serial.println(F("Failed to capture first finger"));
```

```
lcd.setCursor(0, 0);
lcd.print(F("Failed to enroll"));
lcd.setCursor(0, 1);
lcd.print(F(" first finger"));
delay(1000);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F(" Restarting"));
lcd.setCursor(0, 1);
lcd.print(F(" process"));
Serial.println(iret);
Enroll();
}
}
//Active
void Active()
{
do{
// Identify fingerprint test
if (fps.IsPressFinger()) //When the finger is pressed...
{
fps.CaptureFinger(false); //Stop reading from the FPS
int id = fps.Identify1_N(); //Find a match...assign the address to
the variable 'id'
if (id < 20) //<- change id value depending model you
are using
{
//if the fingerprint matches, provide the matching template ID
lcd.print(F("Pass!"));
delay(1000);
lcd.clear();
digitalWrite(LEDGREEN, HIGH);
digitalWrite(LEDRED, LOW);
lcd.print(F("Opening..."));
delay(1000);
lcd.clear();
for (pos = 0; pos <= 90; pos += 1)
{
myservo.write(pos);
delay(15);
}
digitalWrite(LEDGREEN, LOW);
digitalWrite(LEDRED, HIGH);
delay(500);
lcd.print(F("Closing..."));
delay(1000);
lcd.clear();
for (pos = 90; pos >= 0; pos -= 1)
{
myservo.write(pos);
```

```
delay(15);
}
}
else
{ //if unable to recognize
lcd.clear();
lcd.print(F("Finger not found"));
delay(1000);
Serial.println(F("Finger not found"));
}
}
else
{
digitalWrite(LEDRED, HIGH);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("--PLACE FINGER--"));
lcd.setCursor(0, 1);
lcd.print(F("----------------"));
}
delay(500);
}
while(digitalRead(button1) == LOW && digitalRead(button2) == LOW &&
digitalRead(button3) == LOW && digitalRead(button4) == LOW);
lcd.clear();
lcd.setCursor(0, 0);
lcd.print(F("Returning to "));
lcd.setCursor(0, 1);
lcd.print(F(" Main menu"));
lcd.clear();
delay(1000);
loop();
}
```