Research and Postgraduate Studies (RPGS) Unit

UNIVERSITY of RWANDA

TRAFFIC LIGHT CONGESTION MANAGEMENT.

CASE OF KIGALI CITY

By

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A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Information and Communication Technologies (Option: Operational Communications)

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DECLARATION

I, KAGABO Willy Emmason do hereby declare that this thesis is my original work and has not been presented or submitted partially or in full by any other person for a degree in any other university and that all sources of materials used for this thesis have been duly acknowledged.

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CERTIFICATE

This is to certify that the project work entitled "**Traffic Light Congestion Management**" is the record of my original work done by Willy Emmason KAGABO (Reg no:219014967) in partial fulfilment of the requirements for the Degree of Masters of Science in Information and Communication Technology, University of Rwanda during the academic year 2021.

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ABSTRACT

Traffic congestion is the most critical problem particularly in developing cities, and thus traffic control becomes more necessary to minimize traffic congestion, safe driving, and also provides less pollutant environment to the community. This work is designed to develop a density based dynamic traffic signal system. The signal timig changes automatically based on the traffic density at the junction. The traffic system is structured with camera system where the images pre-captured by the camera are processed in order to calculate the traffic flow (vehicles) through the junction. The camera also identifies the siren and reduces time wastage at the intersection, when the green signal is on, with a lane where no traffic (no queuing traffic) is at that road.

In this study, we used edge detection technique to process the image and estimate the vehicle density on the road. This method identifies the region of interest (ROI) where the vehicles are detected in the image and avoids unwanted objects. The Matlab as the simulation tool is used to control the time signals of the traffic light based on the traffic density on the road, and this is done by capturing images of the road, and which are processed to determine traffic density.

Thereafter, based on the images processed through the Matlab, the microcontroller (Arduino) built with light-emitting diodes (LEDs) is used to direct instructions to the LED to glow, thus giving a priority to the road with high traffic and manages traffic at the junctions, without the need for traffic police officers for manual control of the traffic flow at the intersections.

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LIST OF ACRONYMS

BIA: Bugesera International Airport

CCDs: Coupled Camera Devices

CCTV: Closed-Circuit Television

CoK: City of Kigali

EDPRS: Economic Development and Poverty Reduction Strategy

GDP: Gross Domestic Product

GPS: Global Positioning System

GSM: Global System for Mobile

HMM: Hiden Markov Model

HOV: High Occurency Vehicle

ITS: Intelligent Traffic System

JICA: Japanese International corporation Agency

KTMP: Kigali City Transportation Master Plan

LEDs: Light Emitting Diodes

MINIFRA: Ministry of Infrastructure

NISR: National Institute of Statistics of Rwanda

PC: Personal Computer

RFID: Radio frequency identification

RNP: Rwanda National Police

ROI: Region of interest

RTDA: Rwanda TransportDevelopment Agency

RURA: Rwanda Utility Regulatory Agency

TDE: Traffic Density Estimation

TLC: Traffic Light Controller

TPOs: Traffic Police Officers

USB: Universal Serial Bus

VIP: Video Image Processing

WHO: World Health Organization

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CHAPTER ONE: GENERAL INTRODUCTION

1.1 Introduction

The purpose of a trafficn control system is to control vehicle flow through road or lane and to prevent accidents or a road blockage. For the case of Rwanda, the fixed timing system is used today, where the traffic light system used today is designed as, red, yellow, and green for stop, get ready and go respectively. Each light-emitting diode (LED) works on one after another for a given period. This has resulted in delays and traffic congestion depending on the time, day, season, conditions, and irregular situations such as accidents or constructional actions. Road traffic can also be controlled by the construction of new roads, but the shortcoming of this method is that the environment also becomes congested. Here exists a need to adjust the traffic controller system rather than constructing new infrastructure two times (Vani R., 2018).

This challenge of traffic congestion can similarly be resolved by continuously detecting and changing the traffic lights timings dependent on the real traffic capacity, and this is known as an intelligent traffic control system, which can be done by the approach of image processing (Kurniawan, 2017). The occurrence or absence of traffic (vehicles) within a target part can be detected by the camera system. And the traffic signal is dynamically changing centered on the traffic density. The foremost objectives of developing an intelligent traffic control are to minimize traffic congestion and fuel consumption, to reduce waiting time at the junction, and to improve the performance of traffic light signals, hence make the free flow of the traffic at the junctions (Khan, 2013).

Generally, the objective of this study is to detect traffic lights and density variations by employing appropriate image processing techniques. This project is aimed to design a system that would be dynamic to the current situations at the intersection. This brings reduced changes at the intersection and gives the fastest permission to vehicle or pedestal traffic in all possible ways.

This again delivers an adaptable traffic light system that is dependent on the traffic density, besides reduces the stress of traffic officers and accidents. Thereby controlling traffic flow without the need for traffic police officers and the proposed system saves lives and reduces time delays.

1.2 Background and Motivation

Rwanda is located at the crossing point of “Northern Corridor of East Africa” and “Central Corridor”. Therefore, Rwanda function as a relay station of trade. After year 2010, the growth rate of real Gross Domestic Product (GDP) has sustained high ratio of 6.9% - 8.8% according to the Statistical Year Book 2016, National Institute of Statistics of Rwanda (NISR). With regard to population, it is predicted that there will be a population growth in Kigali city that will range from 1.06 million in 2010 to 4.3 million in 2040 as mentioned in Kigali City Master Plan 2013.

Currently, several intersections of the Kigali city road and roads connected to it are congested due to lack of traffic capacity. Population growth and increase of vehicle ownership are projected in the near future, leading to traffic congestion and it is considered that traffic congestion will even be worse than it is currently (JICA N. K., 2019).

The government of Rwanda formulated the economical strategic plan and urban transportation plan, which are named the “Second Ecomic Development and Poverty Reduction Strategy for 2013-2018 (EDPRS2)” and “Strategic Transport Master Plan for Rwanda”, respectively. From these two plans, the Rwanda government aims to develop public transportation network and improve the congested intersections (MINIFRA, 2018).

Furthermore, Kigali City also intends to alleviate traffic congestion and improve urban transport system through formulating “Kigali City Transportation Master Plan”. Additionally, the feasibility study for expressway between Nyarugenge and New Bugesera International Airport (BIA) and the study of improving seven congested intersection have been conducted. However, further detailed study is needed for project implementation since the traffic congestion area has a high population density coupled geological restriction (RTDA, 2012).

The existing public transport services in developing countries are unable to cope adequately with demands due to numerous factors, including inadequate road infrastructure, uncontrolled expansion of cities, high population growth and low level income and poor traffic management (Iles, 2005).

In response to the aforementioned challenge of traffic congestion, the traffic lights at the intersection have been a contributing factor due to its operations that are based on fixed signal timings. It is therefore necessary to have intelligent traffic control system and makes decision based on traffic density, thus managing traffic and also improving the performance of transport system in Kigali city.

The motivation to develop traffic light control system, is to reduce traffic congestion more especially at the junctions, reducing minimal amount of time wastage at the intersections, but also a flexible system that controls the traffic flow, without need of traffic police officers (TPOs) to manually control the traffic flow at the junctions.

1.3 Problem Statement

The existing traffic light management systems are based on microcontrollers. And these traffic light systems have some weaknesses that resulted from the growing number of transportation means, low-quality infrastructure of the roads, and poor traffic light control systems such as fixed timing system that relies on the microcontrollers and microprocessors. Today, the traffic light controllers in Kigali city have limitations because it uses the pre-defined hardware, which is operating based on the program that is not adaptively to the real case situations.

Because of the fixed intervals of the green, orange, and red signals, thus increasing waiting, traffic congestion, and also more fuel consumption at the junctions. Thereafter, we used image processing techniques to detect vehicles, at the intersection, and also improve the present traffic light system to make it more dynamic. This is done by a camera system to capture images of interest, where these images are processed through Matlab tool that is installed within a computer system, thereafter the Arduino microcontroller gets instructions from Matlab to control traffic depending on the density, at the intersections. Thus the performance of the traffic light systems minimizes traffic congestion by reducing waiting time, and also allows free flow of the traffic at the junction.

1.4. Study Objectives

1.4.1. General Objective

The general objective of this study is to manage the traffic lights at the junction, and also density variations by applying image processing techniques such as edge detection. The designed system is adaptable to the current situation at the traffic junction. This involved toy cars simulated as realtime situations at the intersection and the traffic lights provide traffic flow in all possible directions. And this in turn provides a dynamic system that is based on traffic density, reduces the manual control, and the stress of the traffic police officers (TPOs), improves traffic flow at the junction, and also avoids collisions at the junctions. Thus, reducing traffic congestion and the time wastage at the junctions.

1.4.2. Specific Objectives

- To monitor traffic lights and density variations, by the image processing to manage traffic congestion based on the current situations, at the junctions.
- To provide dynamic traffic control and optimizing traffic light signals, to control traffic flow and reduces waiting time accordingly, and also reduces the stress of the traffic officers from manual control of traffic at the junctions.

1.5. Research Questions

The study raises the following questions in order to achieve the above objectives:

- What causes traffic congestion at the junctions, or how does traffic lights contributes traffic jam at the intersections?
- What extent does the existing traffic management system have addressed the problem of traffic congestion, in line with the current traffic situations?
- In order to address the problem of traffic jams, what are the approaches and techniques?

1.6 Scope of the study

This study mainly focuses on the traffic jam at the junctions located in three districts of urban areas, Kicukiro, Gasabo, and Nyarugenge. But we designed a system that is at the small scale, and also effective during daylight clear weather condition where the isolated intersection is considered, and the proposed system used, is to employ image processing, computer system installed with simulation tool (Matlab) to control traffic lights through the microcontroller (Arduino controller), thus managing traffic congestion and also reduces waiting time at the road junctions.

1.7. Significance of the Study

When traffic congestion is minimized, it will reduce jam, waiting time, time wastage, air pollution, ease mobility and transport services in general. It also provides great importance to the Rwandan society in general and law enforcers in particular, through free movement, reduces accidents, road safety and improves the performance of transport systems.

Adaptive traffic control system will help Rwanda National Police (RNP) to avoid manual control of the traffic flow at the road intersections, and also helps relevant Government agencies (MININFRA, RTDA and RURA) to plan for the improvement of infrastructures in the transport system.

This project will also help revevant Government agencies such as RNP to monitor and allocate the resources. The project will be used by other researchers as a reference for the future projects.

1.8. Organization of the Study

Further, the remaining chapters are organized as follows. Chapter 2 presents the literature review of the current traffic systems. In chapter 3, we discuss research methods. Chapter 4, discusses the system design and analysis. Chapter 5 presents results and discussion, while Chapter 6 presents the conclusion and recommendations.

CHAPTER TWO: LITERATURE REVIEW 2.1. Introduction

This chapter presents literature review on what different scholars have discussed in relation to traffic congestion, optimizing traffic light signals, estimation of traffic density and minimizing traffic delays at the road intersection. It also review and summarizes related work read about this research project.

2.2 Traffic Congestion

In Rwanda, particularly Kigali city as any other developing city is facing challenges, especially during morning and evening hours when employees are rushing for work or going back home and this leads to traffic congestion in different roads of Kigali city (Chen, 2001). This is resulting from the increased number of causes; motor vehicle increase, narrow roads and insufficient road infrastructures are the most important causes of the traffic congestion. In addition, traffic rules violations, poor traffic management systems or fixed traffic light control that are not dynamic according to the traffic situations have contributed more traffic congestion. However, the improper planning of the city, inadequate road space management, lack of appropriate street parking are the other causes of traffic jam in the city of Kigali.

Traffic congestion on the roads has been increasing rapidly over the years. Traffic congestion is defined as a condition on the road networks that occurs when the vehicle capacity of the road is nearing saturation. When vehicles are crowded on the road, traffic slows down resulting in traffic jams with vehicles stopped for varying periods. Now, the road is oversaturated with vehicles. Slower speed increases travel time and lead to vehicular queueing. The report of WHO that globally about 1.6 million deaths occur due to traffic accidents and 62% of these are due to technologies not available for efficient traffic management (Sivaraman, 2017).

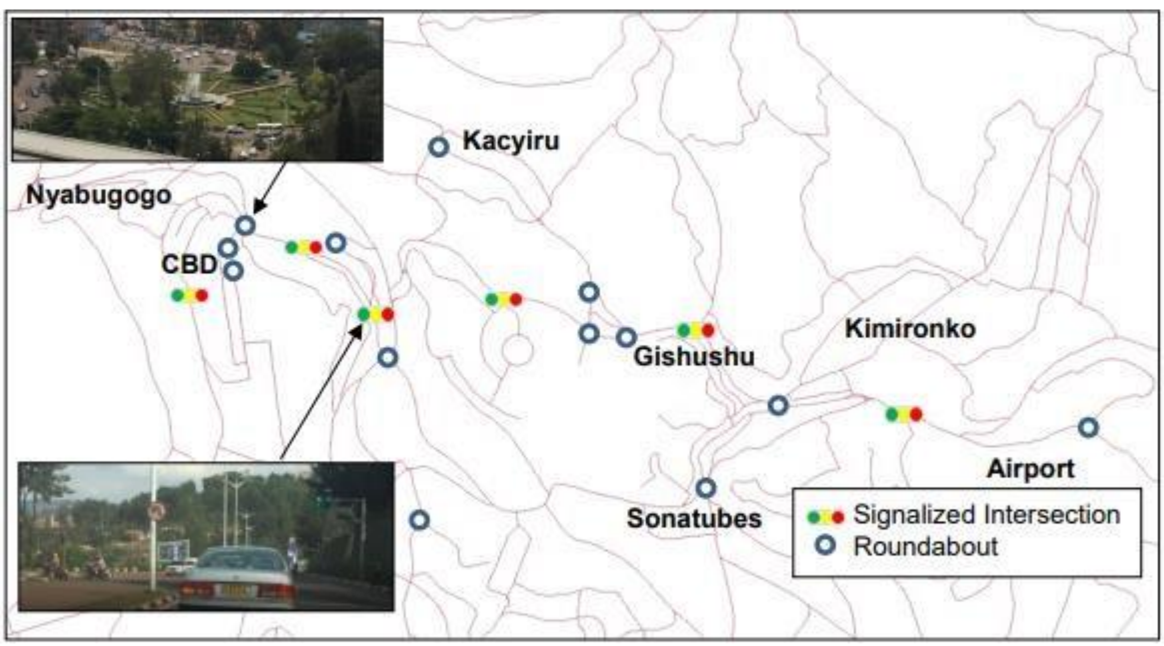
The increasing population, an increasing number of vehicles, and poor traffic management systems are given as the causes of such heavy traffic congestions in these and other cities (Korosec, 2018).

Countries like Denmark, Norway, Japan, Sweden, and Finland, which have heavily promoted cycling, have very less traffic congestion problems. These reports show that the only way to manage traffic and reduce congestion is to implement intelligent traffic control systems adaptable to the current traffic situation, supplemented with policies and strategies to use alternate means of transport and adjusting the working hours of different sectors appropriately (Ahmed, 2018). However, no single strategy will be completely effective to reduce traffic congestion. A combination of different strategies is required to address the issue.

2.3 Existing traffic management systems in Kigali city

Some traffic management systems such as traffic signals and roundabouts can be found in Kigali urban areas. These locations of traffic signals and roundabouts are shown in Figure 2.1.

Currently, most of the intersections in the Kigali city have not been signalized but instead were replaced by roundabouts. But still, the traffic system is insufficient during peak hours in some of the roundabouts and it becomes a cause of traffic congestion (JICA, 2019).



Source: JICA Survey Team, 2019

Figure 2.1: Locations of Signalized Intersection and Roundabout

2.4 Signalized Intersection

There is a number of signalized intersections in the city of Kigali such as Giporoso, Gishushu, Kimihurura (Kabindi), Sopetrad, Rwandex, Muhima (Yamaha), Peage and Gakinjiro etc. But all these operates on fixed timing system where the light signals do not change based on the traffic condition. Each signal is static which is working on a pre-defined system. During night time from 22:00 to 6:00 a.m, the system is switched into a flashing mode. In this case, traffic police officers control the traffic flow using hand signals at congested intersections especially during peak hours. In Figure 2.2 as shown, the system involves components such as a signal controller, pole, light, and cables. Here, the system is based on the microcontroller, this controller is a device that controls almost all the traffic light system in Kigali city, and this system is not adaptable, meaning that is not based on the traffic flow crossing through the junction and however there is a fixed period for red, green and orange lights.

Source: JICA Survey Team, March 2019

Figure 2.2: signal controller and cables

Another traffic management system is the manual controlling, here the Rwanda National Police (RNP) from its department of road traffic and safety, where the traffic police officers are deployed to the congested intersections and roundabouts, and control traffic flow using hand signals, especially during peak hours.

2.5 The drawbacks of the Existing traffic system

2.5.1 Heavy traffic congestion

Due to the increasing number of vehicles on the road network, heavy traffic congestion may largely appear on the major roads, and this happens mainly at the junctions especially in the morning, before office hours, and in the evening hours, after office hours. And the negative effect of this is the increased time of the road users on the road, and also increases fuel consumption.

2.5.2 Waiting at the junction, when there is no traffic

Sometimes even if there is no traffic, road users have to wait because the traffic lights remain red for the preset time, then the road users have to wait until the light turns green. Thus, causing traffic congestion, and also increases waiting time at the junction. In addition to that, it leads to the manual control of the traffic flow by traffic police.

However, the methods above have been outdated by the current traffic situations due to their longstanding techniques that are not relevant to the growing traffic in the developing world. It is for this reason why we suggested to design system of the traffic light congestion management.

2.6 Traffic Management Systems in developing cities

Many cities in developing countries such as Kigali city do not have modern traffic detection and management systems (ITSs) like those deployed in developed countries because of the differences in financial and traffic conditions (Li Li L. C., 2008). Most of the cities in developed countries have nice roads with clear lanes, relatively simple and orderly traffic flow patterns, homogeneous mix of vehicles, cars installed with special devices to work with ITS and are financially well to purchase and deploy such expensive systems (V Kastrinaki, 2003).

Contrary, cities in developing countries like Kigali have poor roads which are bumpy, potholed and sometimes no lanes with disorderly and chaotic complex traffic conditions characterized by a lot of braking and sometimes honking (Raman, 2011).

Most of these roads are narrow, poor plan constructed, and non-laned or with only two lanes. Traffic congestion on these roads is caused by a heterogeneous mix of objects ranging from large carriers, small vehicles, small vehicles, motor bikes, pedestrians, hawkers and sometimes animals. Worse enough, they have high rate of non-recurrent factors such as car break downs, traffic accidents, construction activities which proliferate traffic congestion. There is also little and sometimes no adherence to the right of way protocols and other road safety regulations.

Another big problem is the presence of heterogeneous mix of vehicles and other road users which among others include buses, trucks, cars and vans, motorcycles, auto rickshaws, bicycles, carts, pedestrians, hawkers and sometimes animals. With such big differences in traffic conditions, it is difficult for the intelligent traffic system (ITS) deployed in developed countries to work effectively in developing regions like Rwanda. Also ITSs are very expensive for developing countries to purchase in large number and deploy them on cities' roads and highways; and also require a lot of technical expertise which is not adequately available in developing cities (Mohan, 2008).

It is stated that solutions for generation and dissemination of information on flows and levels of traffic congestion for developing cities are urgently needed not only because their patterns are fundamentally different from those in developed world (Sen, 2011) .

2.6.1 Acoustic array based research

(Sharma, 2010) proposed a low cost monitoring and management system for cities in developing countries. The system comprises of a pair of road side acoustic sensors which capture vehicles' honks as an input data. The captured data (vehicles' honk) is then sent to a centralized server for processing in order to detect vehicles' speed and classify the traffic state as either congested or free flowing.

Although the system is inexpensive and was meant for city roads and highways of developing countries, it has some shortcomings. First, it makes an assumption that honking is a drivers' common practice in all developing countries as it is in India, which is not true. In many cities of developing countries like Rwanda, drivers only honk in certain international conference, convey of diplomats and public figures, sports (e.g Tour de Rwanda) and other chaotic events such as "walk to work" or when two big teams (APR FC vs Rayon Sports) plays against each other in the city of Kigali, it cause chaotic traffic congestion.

Secondary, the system's sensors will only capture vehicle's honks when the vehicles are close enough to the sensors. Thirdly, the system will only be able to help road users who are at that particular moment driving on the roads equipped with sensors and can honk. It cannot help those who are at home or any other places with no sensors but would want to get the state of the traffic congestion on certain roads in the city they want to use.

Lastly, the system is not able to sense noise from opposite direction lanes of wide road network.

Further, (Schreiber, 2008) proposed an inexpensive and energy efficient ITS called Nericell tailored for developing cities which uses sensors namely accelerometer, GPS, Microphone and GSM radio available on smart phones. These sensors are used to detect potholes, humps and vehicles' braking or honking and send the data to centralized server for aggregation. Processed data (information) may then be sent to various road users to help them search for roads with little or no traffic congestion.Though there is inexpensive and uses mobile phone which of the road users have, its major weakness is that the system's data sources (bumps, potholes and honking) are not evenly distributed on city roads and highways. Some sections have many potholes and bumps than others and the honking is not common practice by drivers in all driving situations. This has a potential of generating inaccurate information for drivers.

2.6.2 Image processing based research

Image Processing (R. C. Gonzalez, 2012) is a technique to enhance raw images received from cameras/sensors placed on space probes, aircrafts and satellites or picture taken in normal day today life for various applications. An image is rectangular graphical object that involves issues related to the image representation, compression techniques and various complex operations, which can be carried out on the image data. The operations that come under image processing are image image inhancement operations such as sharpening, blurring, brightening, edge enhancement etc. image processing is any form of signal processing for which the input is an image, such as photographs or frames of video; the output of image processing can be either an image or a set of characteristics or parameters related to the image. Most image processing techniques involve treating the image as a two dimensional signal and applying standard signal-processing techniques to it. Image processing usually refers to digital image processing, but optical and analogy image processing are also possible.

The field of digital image processing comprises of methods involving processing digital images using a computer. A digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are called picture elements or pixels. Image processing resolves issues related to image representation, their compression, and various other complex operations, which can be carried out on the image data. The operations that come under image processing are image enhancement operations such as sharpening, blurring, and brightening, and edge enhancement (Nagaraj J. R., 2013).

In (Mimbela, 2003), a video image processing (VIP) based traffic management system is proposed. The system assumes that individual vehicles can be tracked and therefore requiring segmentation of vehicles in each image frame. Such an approach has serious disadvantages as it may cause shadow detection and requires sophisticated algorithms to remove occlusion. It also assumes that vehicles are the only moving objects being monitored and are constrained within specific lanes and roads.

Moreover, traffic congestion caused by different objects such as vehicles, pedestrians and cyclists was conducted by (Maurin, 2005). Like others, the research was based on segmentation and tracking of individual objects and does not provide classification of the types of objects being tracked.

(Chen E. T., 2007)researched on traffic congestion without segmentation of vehicle and object detection using hidden Markov Model (HMM). Though the work provides classification of objects, it assumes that road conditions are not clustered, which is not the case with the roads in the developing cities.

Another work on traffic congestion estimation is detailed in (Li, 2004); aiming at using a VIP based urban traffic management techniques to determine the real-time traffic congestion estimation without vehicle classification. The proposed solution aims at determining two parameters in order to estimate the traffic congestion. These parameters are occupation rate and movement status of the vehicles. Though the solution is proposed to have high performance on a wide range of traffic conditions like light traffic, congestion and varying speeds, in a wide variety of lighting conditions like sunny, overcast, twilight, night and rainy, and operate in real-time, it has two major weaknesses. Firstly, it relies on expensive surveillance CCD cameras, and secondly it assumes that vehicles are the only moving objects being monitored and are constrained within specific lanes and roads.

(Zhu, 2009) suggested a video based traffic monitoring that uses adaptive background subtraction method to predict the occurrence of traffic congestion. According to (Huang J. , 2008) video solutions based on background subtraction method are not effective in heavy traffic congestion and abrupt change of light as they fail to produce satisfying background model.

(Holger, 2008) proposed a traffic monitoring system based on embedded computer vision system to predict the occurrence of traffic congestion. Despite its strengths, the solution has serious weakness. It relies on expensive CCTV cameras and attains fairly low accuracy of about 74% of traffic prediction caused by factors such as resource constraint (memory and processing power) of the embedded computer system, occlusion and bounding box inaccuracies generated by the detection algorithms. Also the solution is based on object detection and tracking, and assumes that road conditions are not cluttered.

(Huang X. , 2008) Proposed a video based system that uses charge coupled devices cameras (CCDs) installed on poles or buildings close to city roads and highways. The system which is based on background substraction, frame differencing and time spatial image detects the movement of vehicles and then uses this information to produce real time traffic congestion estimation for various road users. This system has several weaknesses. First, it has no concerns about traffic congestion conditions of cities of developing countries. The system is well built for city roads and highways of the developed countries. Secondly, it lacks a mechanism for disseminating information on traffic congestion flows and levels to road users.

Automated traffic detection system is therefore required to run the civilization smooth and safe which will eventually lead us towards proper analysis of traffic, proper adjustment of control management, and distribution of controlling signals (Nagaraj J. R., 2013).

There are many techniques proposed to design an intelligent traffic system, forexample, fuzzy based controller and morphological edge detection technique are proposed. Then, this technique is based on the measurement of the traffic density by correlating the live traffic images with reference image. The higher the difference is, the higher traffic density is detected. Therefore, the system based on four lanes and time is allocated to the number of vehicles on the lane (Naeem Abbas, 2013).

Automated traffic monitoring and surveillance are important for road usage and management. Traffic parameter estimation has been an active research area for the development of intelligent transportation systems (ITS). For ITS applications traffic-information needs to be collected and distributed. Various sensors have been employed to estimate traffic parameters for updating traffic information (CHOUDEKAR, 2012).

2.6.3 Research Gap

Concerning the facts gathered from the literature review, it is clear that ITSs deployed in the developed cities cannot have equal performance and effectiveness like when it is deployed in developing cities or underdeveloped cities (Siriah, 2011).

This is due to differences in traffic situations such as urban texture, high price, and technical expertise of the system as discussed in the above sections. Because of these limitations, many cities underdeveloped countries have not deployed such systems, but instead, they are still using old methods of controlling and managing traffic congestion. And these methods still operate on fixed signal control system or not adaptive, and does not measure the density of the traffic flow, thus ends up not being effective to prevent and minimize traffic congestion, especially at the road intersections.

This study suggested and designed a traffic managing system that relies on image processing and computer system techniques which is suitable for traffic conditions of developing cities like Kigali city. The system is composed of Arduino Uno (ATMEGA328P) coupled with a computer. The computer installed with MATLAB tools, which are used in image processing, and edge detection for traffic density estimation, to control traffic and the microcontroller (Arduino) changes light signals accordingly.

CHAPTER THREE: RESEARCH METHODOLOGY 3.1 Introduction

This chapter presents the methods, techniques, and tools that were used to achieve the specified objectives of this project. The system model is made of three main components, which describe the system structure as shown below. And the components involved are Traffic Control System, Microcontroller system, and image acquisition or camera system.

In the proposed system, the traffic (vehicles) are detected and processed by the techniques of image processing through Matlab tool. Instead of using electronic sensors, the camera system at the traffic lights are used to capture road images and these images are processed to detect traffic density at the junction. After that, the objective of the proposed system is to reduce traffic congestion, to minimize time wastage, and also to optimize traffic light signals in order to allow free flow, and avoid collisions at the junctions.

The proposed system is illustrated in the Figure 3.1 below; that shows the main components of the traffic control system;

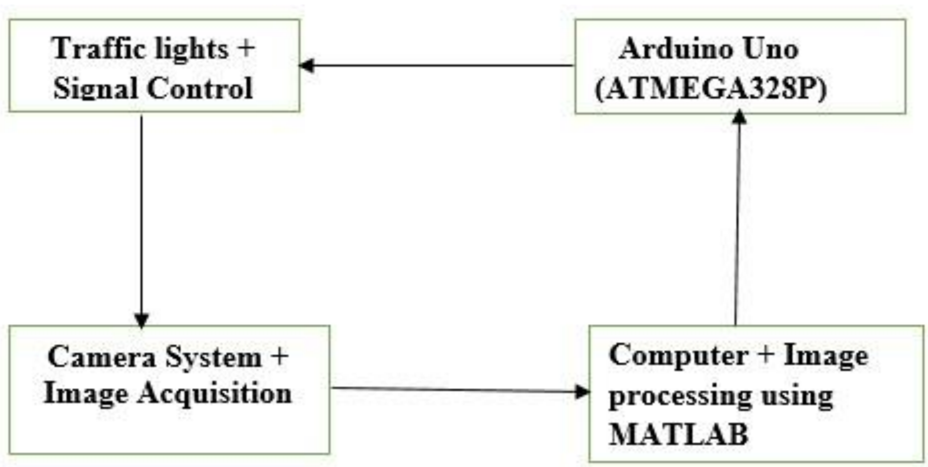


Figure 3.1: The overview of the proposed traffic control system

The technique used for detecting traffic congestion here, is the image processing where the images captured by the camera system are taken as inputs, and these images are processed to determine traffic density by using edge detection, where the images of traffic detected are considered as the traffic estimated. Here, these are the images of the crowd density among all the four directions (at the intersection), the targeted area is cropped, images are converted to grayscale, processed, and then the traffic density of each road at the junction is determined by comparing each with other images of road traffic (image comparision) of road or lane, and find the road with traffic than others, so as to give it a priority to allow the traffic flow to cross the junction.

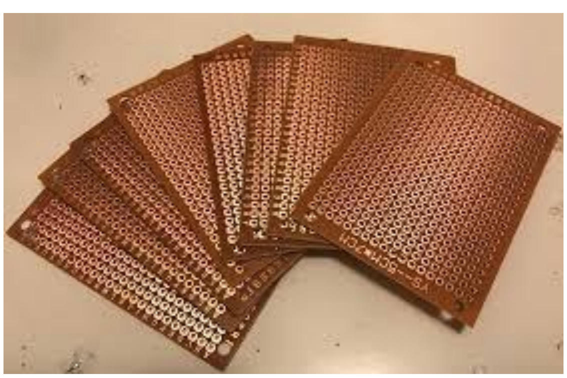


Figure 3.2: The Components of the current proposed system (source: www.TheEngineeringProjects.com)

In this subsection, we briefly discuss about each and every requirement that builds up the signal system;

3.2 Hardware Module

Here, the traffic light control system consists of the several parts. The architecture of the traffic light system is divided into three main parts as shown in the figure 3.1 above. The first is the camera system, which has a role to capture video images of the traffic conditions at a particular junction on each road crossing through it, and the decision is made by the computer system based on the traffic density in which the situation is identified from the processed images.

The second part is the main component, which is the computer system that is used as the brain of decisions to be made. After receiving the input data from the precious components, the data in form of traffic images, and the role of this component is to process these traffic images in order to determine the density (number of vehicles) on the road at the junction. The traffic density is determined by the image processing through the Matlab simulation tool.

Lastly, the third component is the traffic light. The traffic light is integrated with the Arduino microcontroller which will give signals according to the images that have been processed. For this case, we made microcontroller (Arduino) with ATMega328p. Here, the role of microcontroller is to translate instructions from the computer system installed with the Matlab, and these instructions are changed into digital signals which are represented by the miniature of traffic light consist of LEDs coloured red, yellow, and green.

3.3 Software Module

Here, the MATLAB tool is used for simulations, testing the purpose of each module, and also the entire algorithm for image processing is implemented in this software.

In addition to that, this tool (MATLAB) is used to write codes and upload them to the microcontroller board, thus controlling the LED lights.

3.4 Interfacing

The computer system and Arduino microcontroller are interconnected over the Usb cable. Here, the computer is the central component used for various image processing activities. The microcontroller that is composed of a set of ATMega microcontroller with differen elements of resistors, capacitor, LED (indicator), the transistor crystal, etc. The Arduino is used to receive the codes implemented from the Matlab, and received through Usb cable to control Light Emitting Diodes (LEDs) based on traffic density.

Light Emitting Diodes (LEDs) acts as the prototype of the real world traffic light control system, and also is used to represent the traffic signal system and displays light signals to allow traffic flow.

In this proposed method, the system for controlling the traffic light by image processing. The system detects vehicles through images instead of using electronic sensors (Choudekar, 2012). The camera system installed alongside the traffic light, the image sequences of the road traffic are captured from the camera. Then these images are processed through Matlab for the traffic detection, and based on the traffic situations at the road junction. Thus, the traffic lights are controlled.

The activities that were carried out under the image processing are illustrated in the Figure 3.3;

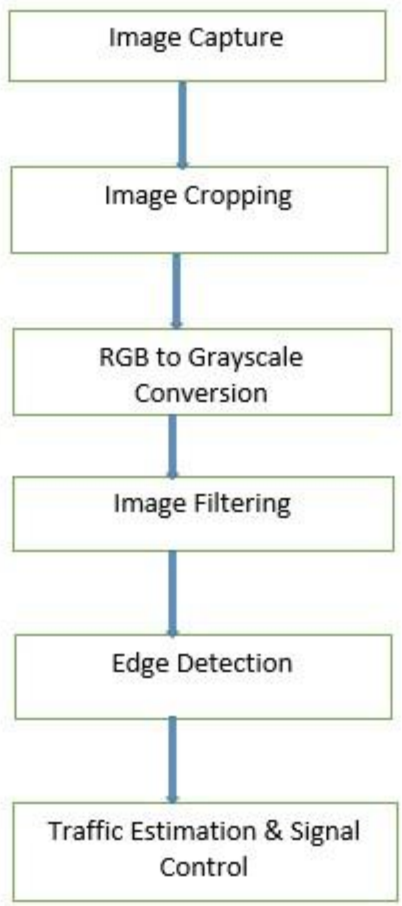


Figure 3.3: Block diagram of the image processing

The steps involved in the proposed method of image capturing are described as follows;

The traffic light control and congestion management is designed by Matlab simulations,that is aimed to reduce traffic congestion. And this is done by image processing in order to determine traffic density at the junctions, through vehicle detection. For implementing this project the following as shown in the figure 3.3 have been considered; image acquision, RGB to grayscale conversation, edge detection, and traffic density dermination.

At first, the images of the traffic are captured by the camera system, at the intersection. The images of the road was at the area of the interest or at the junction to avoid unwanted objects. Then these images are processed to determine the traffic density. Thus, according to the processed images through the Matlab, thereafter, the vehicles detected in the road images , at the junction. Then, the traffic density is determined, and the MATLAB program instructs the the Arduino controller controller and controls traffic light signals to manage traffic congestion accordingly.

CHAPTER FOUR: SYSTEM ANALYSIS AND DESIGN 4.1 Introduction

This chapter involves the analysis and design of this project. Where the traffic simulator was employed, and developed in the MATLAB environment. That is, the simulations are designed by the Matlab tool, and the images of the traffic (vehicles) are processed. Then, the vehicles are detected through images in the road, and also traffic congestion is controlled at the junction.

4.2 System Structure

The Traffic Control system manages the intersection by displaying the green light signal for the road that should have right or a priority to cross the intersection, the red light signal for the road that should wait, and also yellow for the road that is about to get a priority or a warning. In this system, the traffic light system is integrated with a microcontroller (Arduino board) which controls the intersection and the traffic crossing through the intersection from four different directions. Although the traffic light system is built with a microcontroller, the order of displaying the light signals is controlled by the MATLAB tool for improving performance.

Image acquisition or camera system, here the system of the image processing was used for controlling traffic lights, where the traffic is detected through images instead of using electron sensors. But due to the lack of accessibility of real-time streaming images of the traffic flow, from the surveillance cameras installed on the public high ways. In this project, we used the pre-captured images of the toy cars as the inputs for the image processing and simulations. And this helps to determine the traffic density for controlling traffic congestion and reducing time at the junction based on the actual situation.

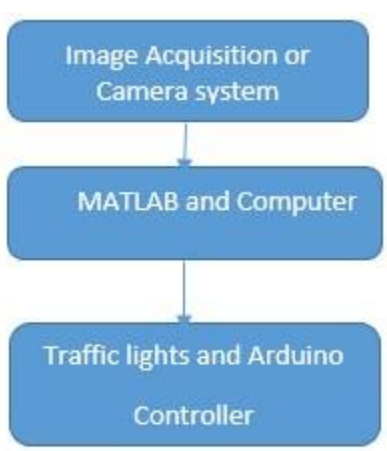


Figure 4.1: System structure

In Figure 4.1, the image processing is applied to control the traffic light signals, in which we select the region of interest at the junction, and captured road images of the traffic. Those images are processed and the vehicles are detected through edges. Then road traffic is compared with each other to find the difference among them. Thus, managing traffic congestion.

4.3 Image Acquisition

The first step of image processing is image acquisition, which is defined as the action of retrieving an image from the source (camera system), usually a hardware-based source so that it can be passed through whatever processes need to occur afterward. The image that is acquired is completely unprocessed and is the result of whatever hardware was used to get it. And this process acquires real time image through MATLAB, since, this image is essentially a paused video of a moving vehicle, the quality of this image is extremely weak and would be inappropriate to compare the image without further enhancement (Hasan M. &., 2014).

Figure 4.2: The road images captured for image processing

Figure 4.2, shows the image of the wooden board that is designed with toy cars (Road is designed on this board), and these toy cars are alternated to represent traffic different situations, as the real case scenarios, which are used for image processing and vehicle detection.

4.4 Image Cropping

Cropping of the original image helps to reduce processing time as well as to analyze the region of interest more easily. It also increases the accuracy of calculation. Since the position of the camera is fixed, it can be easily to remove unwanted objects like trees, footpaths, shops, buildings by cropping the road picture, these objects create obstacle in our estimation and make some unwanted errors. So we used the cropping image to elimate the rrors.

4.5 RGB to Greyscale conversion

A greyscales image is an image in which the value of each pixel is a single sample, that is, it carries only intensity information. Images of this sort are also called black and white images. This conversion is required because greyscale images are easy to process as less image data is concerned. The intensity of a pixel is expressed within a given range between a minimum and maximum, inclusive.

4.6 Image filtering and filling

Median filtering is a nonlinear operation and is more effective than convolution when the goal is to reduce noise and preserve edges at the same time. Since the captured images are still raw, uprocessed image and contain noises, Canny edge detector utilizes a Gaussian filter to remove noise. The filtered image is a little hazier (reduced visibility) than the original image, liberated from noises. In the canny edge operation, the image is first smoothed by circular two-dimension Gaussian function, computing the gradient of result and then using the gradient magnitude and direction to approximate edge strength and direction at every point.

4.7 Edge detection

To build a flexible traffic light controller based on density of traffic, edge detection techniques must be used. The criteria and techniques for edge detection is discussed below:

Images containing varying shades of reyscale images. These images are crucial for detection of edges and segmentation of images. There are three discontinuities that can be observed in a grayscale image: points, lines and edges. Using spatial marks we can detect these discontinuities. The most crucial factor for a traffic signal is to detect edges. An edge is defined as a set of connected pixels that form a boundary between two disjoint regions. Discontinuity of scene features like brightness gives rise to edges. An edge is based on strength, edge direction and edge position. Different types of edges are step edge, ramp edge, roof edge, ridge edge (Brinda, 2015).

4.8 Edge Detection using Canny Edge Dectector

The canny edge detection algorithm (Qian Xu, 2014) is an edge detector with good performance. However, image smoothing by Gaussian filtering may lead to higher edge location error and corner roudness in application. The first and most obvious is low error rate. It is important that edges occurring in images should not be lost, so that there would be no responses to non-edges. The second condition is that the edge points are well localized. The canny edge detection algorithm operates on the image and has a latency that is proportional to the size of the image. While performing the canny algorithm at the block-level would speed up the operations. It would result images consist of a mix of smooth regions, texture regions and high-detailed regions and such a mix of regions may not be available locally in every block of the entire image.

Canny edge detection method (Canny, 1986), for detecting edge of the images. The Canny operator is widely used in image processing for edge detection. It has some advantages over the other methods, which are as follows (Sons, 2005):

- It maximizes the signal-to-noise ratio
- It minimizes multiple responses to a single edge.
- It ensures that the edge points are well localized.

Canny edge detection method has the following steps (Ray, 2005):

- Noise is removed with the Gaussian filter.
- Gradient's module as well as direction is computed.
- Non-maximum suppression ensures that local maxima are marked as edges.
- Adaptive hysteresis thresholding is used for edge linking.

The canny edge detector consists of the following steps;

4.8.1 Removal of the noise

Since raw, and unprocessed image data contain unwanted objects (noises), the Canny edge detector utilizes a Gaussian filter to remove noise. The filtered image is a little hazier than the original images but is free from noises.

4.8.2 The Intensity Gradient Calculation

An edge that occurs in an image may be in any orientation or direction. So the canny algorithm uses four filter masks to identify vertical, horizontal, and two diagonal edges in the filtered image. The Sobel operator for edge detection returns values for the first order differentials in the horizontal and vertical direction. From these derivatives, the horizontal and vertical gradients along with direction could be computed. The gradient direction angle is approximated to any one of the four angles which correspond to horizontal, vertical, and two diagonals (which are 0, 90, 45, and 135 respectively). The magnitude, or edge strength, of the gradient, is then approximated using the formula below (Narayanan, 2018).

The gradient magnitude |G| and gradient angle Θ are calculated as;

$|G| = \sqrt{Gx2 + Gy2}$ and $\Theta = \arctan Gy/Gx$

Where $Gx = \delta f / \delta x$; $Gy = \delta f / \delta y$

Gx and Gy represents the horizontal and vertical gradients respectively, and f=f (x, y) represents the image pixel. The gradient magnitude can be obtained by convolving the image with the horizontal and vertical gradient mask. The equations above show the convolution mask using the sobel operator to find the gradient magnitude.

-1	**0**	**1**
-2	**0**	**2**
-1	**0**	**1**

Gx

-1	**-2**	**-1**
0	**0**	**0**
1	**2**	**1**

Gy

Figure 4.2: Convolution Kernels in X and Y direction

The Figure 4.2 represents Sobel's operator 3 * 3 matrix, which is used for the first derivative operator to find the edges and is operated by changing the center coefficient to '2', the Sobel operator only considers the two orientations which are 0 and 90 degrees convolution kernels.

4.8.3 Non-maximal suppression

After the gradients of the image are found, the following step is to study whether the gradient magnitude reaches the local maximum along the direction of the gradient. If the estimated gradient angle is zero degrees (0º), the pixel can be preserved as an edge pixel in the horizontal axis, if its gradient magnitude falls above the magnitudes of pixels in the north-south directions (since the gradient angle is normal to the edge) (Gonzalez, 2006). Similarly, if the approximated gradient angle is 90 degrees, the pixel will be treated as an edge pixel if its gradient magnitude falls above the magnitudes of a pixel in the east-west directions. If the approximated gradient angle is 135 degrees, the pixel will be treated as an edge pixel its gradient magnitude falls above the magnitudes of pixels in the southwest and northeast directions. If the approximated gradient angle is 45 degrees, the pixel will be treated as an edge pixel if its gradient magnitude falls above the magnitudes of pixels in the northwest and southeast directions. At this stage, a set of binary edge points called thin edges are obtained.

4.8.4 Thresholds calculation

Larger intensity gradients have a greater probability to correspond to an edge than a smaller intensity gradient. Generally, it is not possible to fix a threshold value at which a given intensity gradient change from one that corresponds to an edge to that of a nonedge. Therefore, the Canny edge detector uses thresholding with hysteresis which needs two thresholds (low=0.75 and high=0.075). These thresholds are calculated based on the histogram of the gradient magnitude of the whole image. The higher threshold is computed such that a percentage P1 of the total pixels in the image would be categorized as strong edges, which can be added directly to the final edge image. A high threshold is a point at which the value of the gradient magnitude cumulative distribution function (CDF) equals (1-P1). A low threshold is calculated as the percentage P2 of the high threshold. P1 and P2 are set as 0.75 and 0.075 respectively.

4.8.5 Location of edges through hysteresis thresholding

A pixel is categorized as a strong edge pixel if its gradient magnitude is larger than the upper threshold. A pixel is labeled as a weak edge if the value of gradient magnitude of the pixels falls between the lower and higher threshold. Strong edges are the ones that can be included immediately as edges in the final edge image. Weak edges can be marked only if they are linked to the strong edges. The block diagram in Figure 4.3 shows the processes of the Canny edge detection.

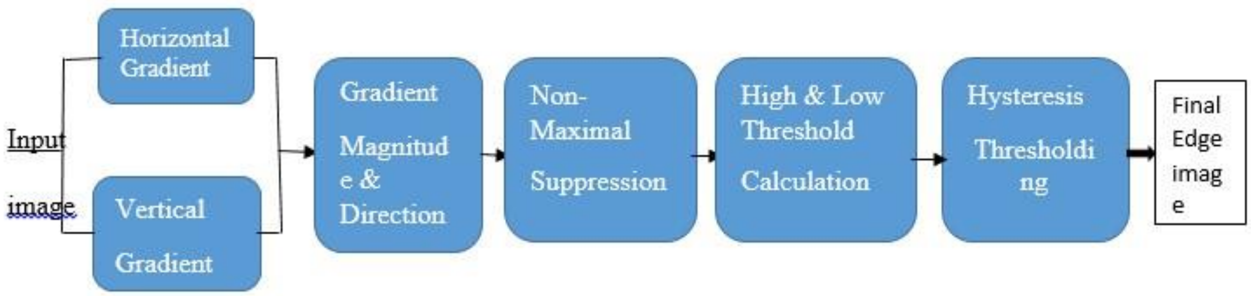


Figure 4.3 shows the processes of the canny edge detection.

4.9 Decision making

The vehicles are detected through these edges, we compared each road traffic with the remaining three roads to determine the difference in the number of vehicles (density). Thus, the program implemented in the MATLAB simulation decides which road should be given a priority first based on the number of vehicles or density. Then, the traffic congestion is controlled or managed. The steps involved in Figure 4.4 below show the comparison of each road and every road traffic in all four directions, at the intersection.

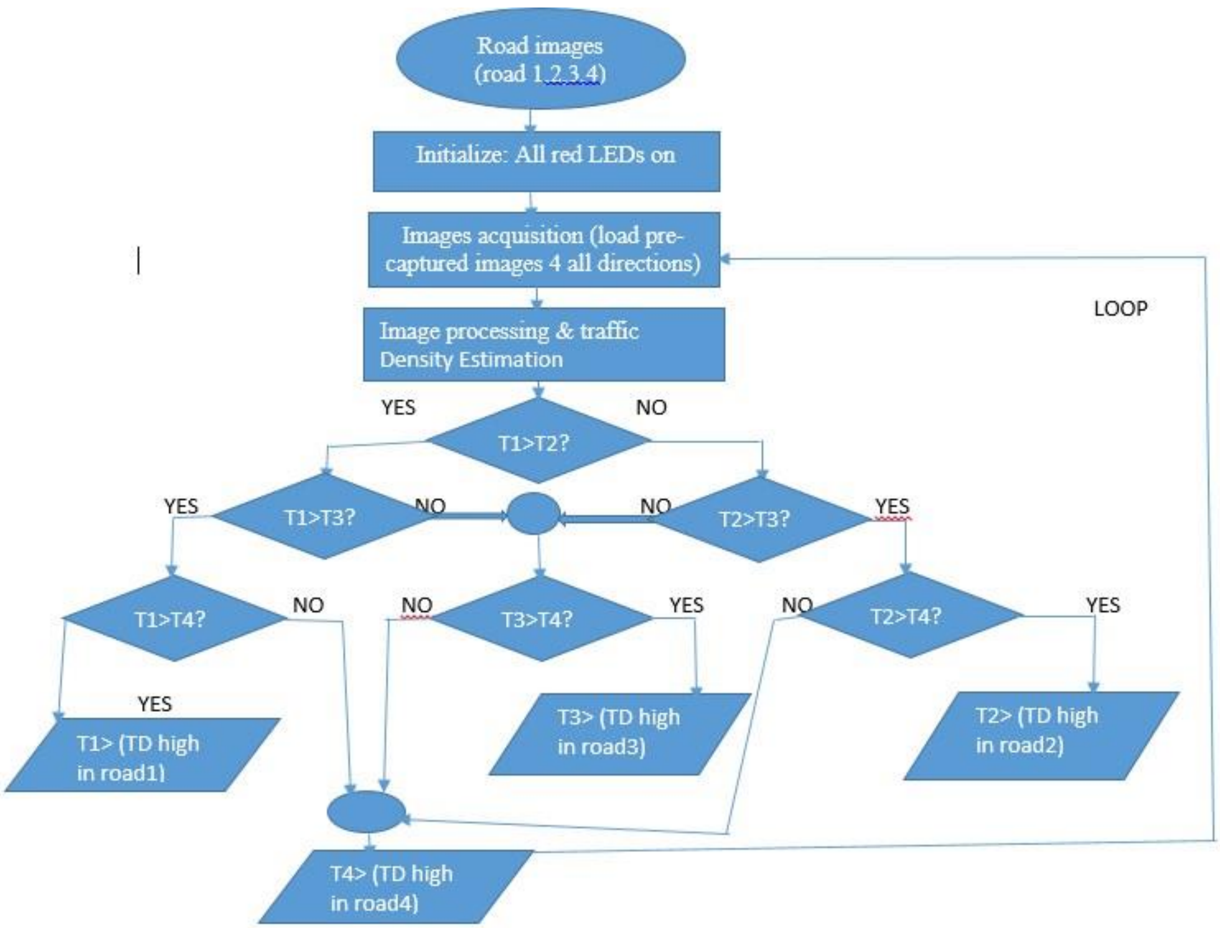


Figure 4.4: The flow chart of the traffic density estimation process

Once all the steps involved in the image processing are completed by MATLAB simulations as described in Figure 4.3 above, the vehicles were detected by the edges of the road traffic. And also traffic density is determined by the difference in the road traffic, after comparing each road among each other.

The flowchart for the determination of the traffic density where T is traffic and TD stands for traffic density, and also other symbols such as T1 is traffic in road 1, T2 is traffic in road 2, T3 is traffic in road 3, and also T4 is traffic in road 4. And this indicates the vehicles detected for all four directions of the road at the junction. After, finding the road with higher traffic. Thus, allowing traffic flow and manages congestion.

The codes below summarizes all steps involved in the image process, and vehicles are detected in the traffic images to make a decision.

4.10 Pseudocode of the image processing and decision making

```
1. Start

2. Image of the traffic captured

3. RGB to grayscale conversion

4. For {

      Vehicle detected in the road images;

5. If {number of vehicles> threshold}

    Output traffic density (TD) is high;

 Else

     Choose the number of vehicles in the image;

  End

        End

6. Go back to step 4

End
```

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1 Introduction

This chapter illustrates the results and discussion with the different images captured, and these images represents road traffic at the intersections.

The images of the road traffic are captured by the camera system, but these images still have unwanted objects (noise). As such, the images are converted to grayscale, and enhanced to remove distortions, then these images are compared each other to find the difference. The difference is compared to a threshold value and this is done on MATLAB. Here, edge detection locates the pixels in the image of the traffic and these detected edges corresponds to the edges of vehicles obtained from the road image through image processing by MATLAB. Once these images are compared, and the road with high density than others, is determined. Then traffic lights at the intersection can optimized to reduce congestion and traffic flow.

5.2 Input image

Traffic congestion is considered to be one of the big problems in urban environments. It depends on the increase in transportation means and also due to low-quality roads. The captured image is considered as the input, and it is processed with the help of image processing techniques.

The Figures 5.1 and figure 5.2 show examples of the traffic lights giving yellow signal as the warning to north direction and other direction remains red to stop traffic flow and avoid collisions at those directions.

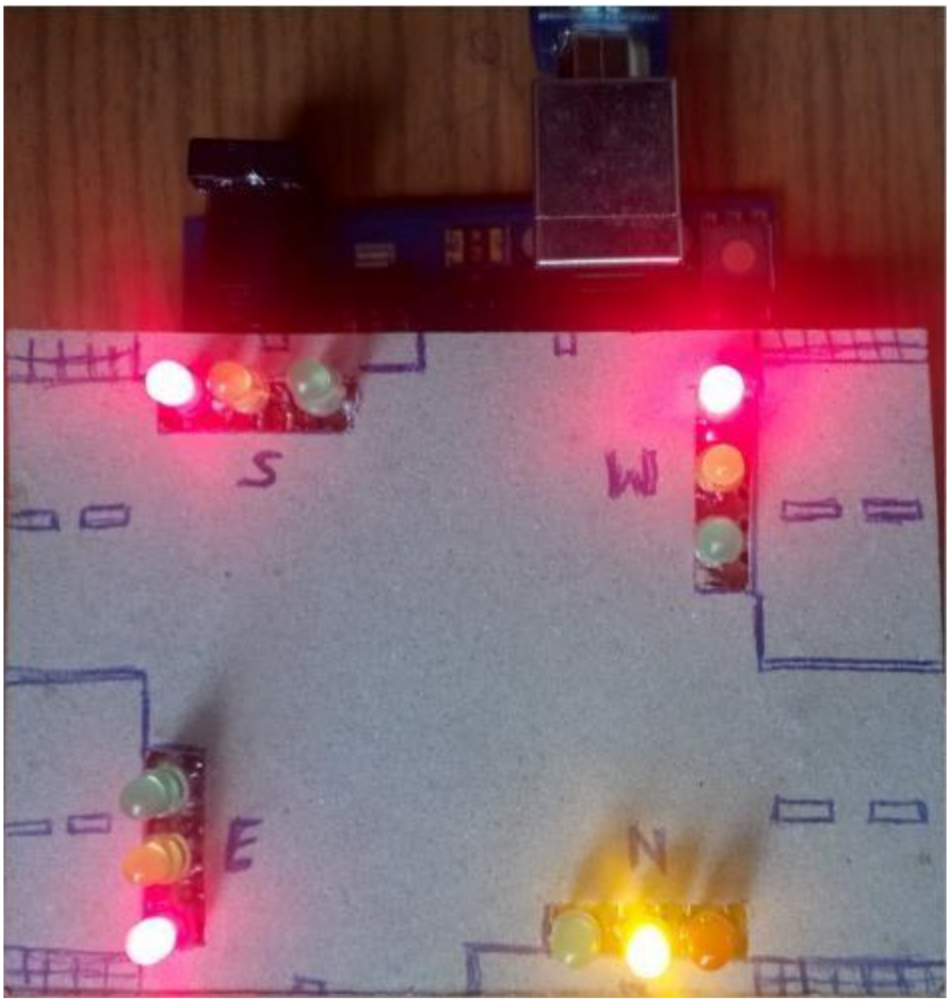


Figure 5.1: The traffic light glows yellow at the north side, others remain red

The example shown in Figure 5.1 indicates a yellow signal in the north direction as the warning to that direction to alert the traffic flow, that is about to give a green light to allow the traffic to cross or go through the junction.

The yellow signal means warning before the traffic light switches green to that direction, hence allowing traffic flow to that side based on the density.

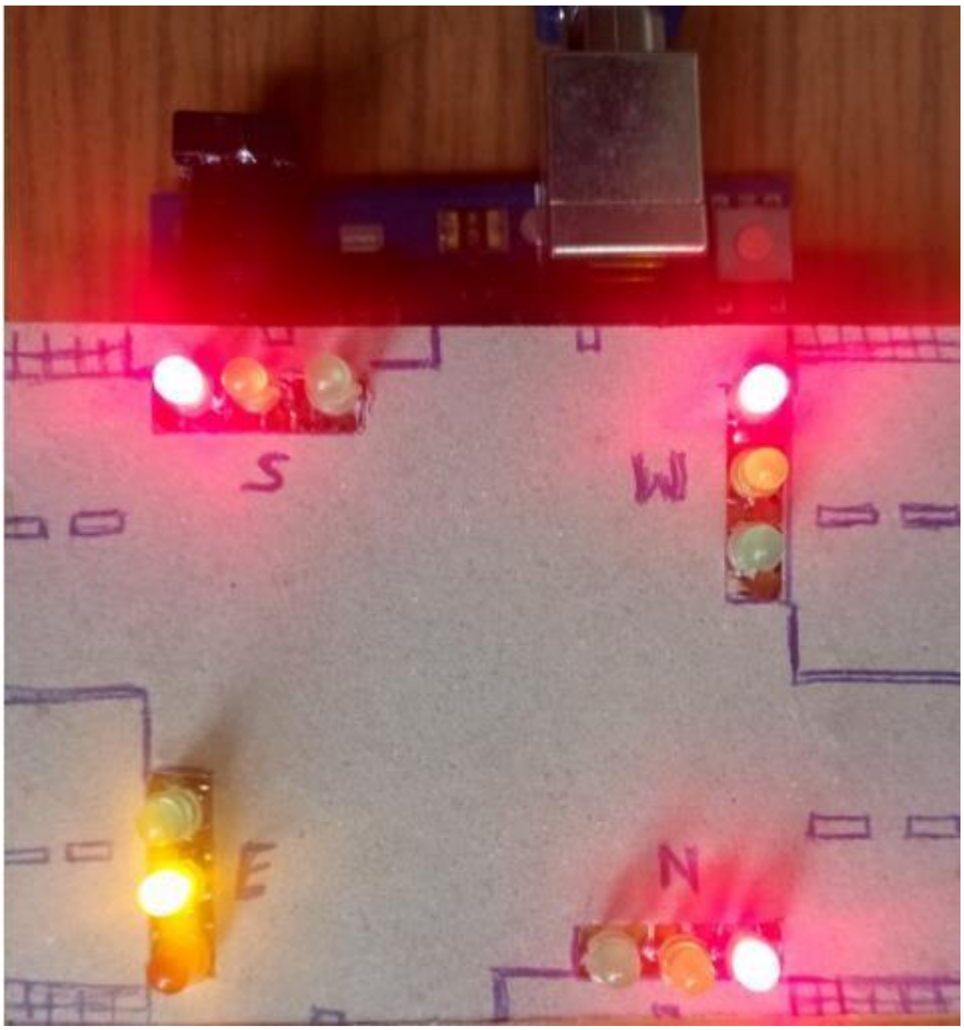


Figure 5.2: The traffic light glows yellow at the east side, others remain red

Figure 5.2 indicates that the yellow signal in the east direction, so as preparing to give them a priority to that direction hence allowing traffic flow through the junction.

5.3 Processing of the image

Here, edge based comparision is used, wherein this process images of different road traffics are compared against each other. Any edge on one image is compared against all the edges on the other image. Edge detection of road images is done by using the canny operator. Once these edges of traffic images are detected and compared. The traffic congestion is managed and traffic lights are optimized accordingly.

Edge detection is a well developed field on its own within image processing. Edge is the important characteristic of image. Edges characterize boundaries and are therefore a problem of fundamental importance in image processing. Edges typically occur on the boundary between two different regions in an image. Edge detection allows user to observe those features of an image where there is a more or less abrupt change in gray level or texture indicating the end of one region in the image and the beginning of another. Therefore, Edges are detected from the filled image of road.

The images of the road traffic below showing different situations through the processed images of the traffic to determine the traffic density by counting the number of edges detected.

The figures (fig 5.3, fig 5.4, fig 5.5, and 5.6) below show each road separately with different traffic situations, and this traffic is determined through edges of the images detected.

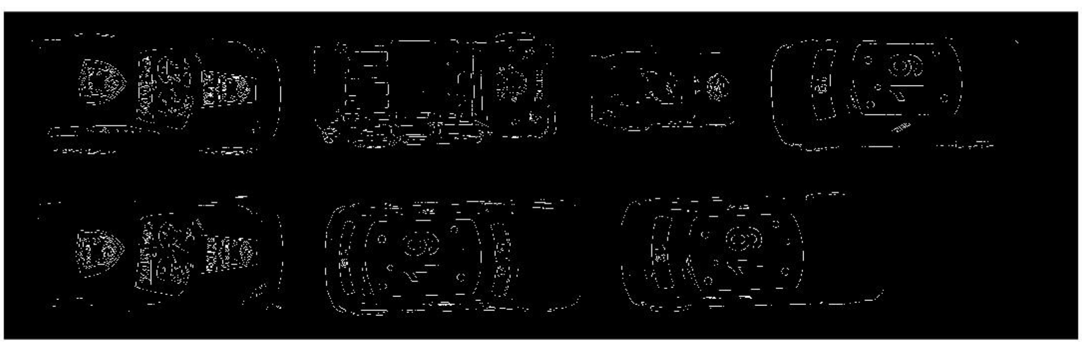


Figure 5.3: the seven (7) vehicles are detected in this image

Figure 5.3 shows the first case scenario of road traffic that is indicated by the edges of the vehicles appearing at the one direction of the junction, and the situation in Figure 5.3 is showing seven vehicles in the image.

Figure 5.4: The five (5) vehicles are detected in this image

The second situation Figure 5.4 is showing five vehicles that were detected by the edges of the road traffic, and this case is considered to be a low priority compared to the previous case of seven vehicles detected in the road traffic.

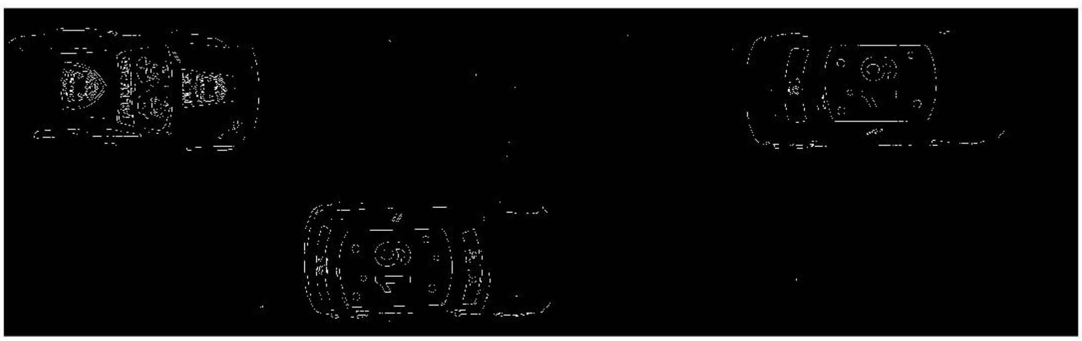


Figure 5.5: The three (3) vehicles are detected in this image

Another case above that is showing three vehicles detected in the road traffic is considered to be a high priority compared to the last case that is indicating one vehicle in the road traffic.

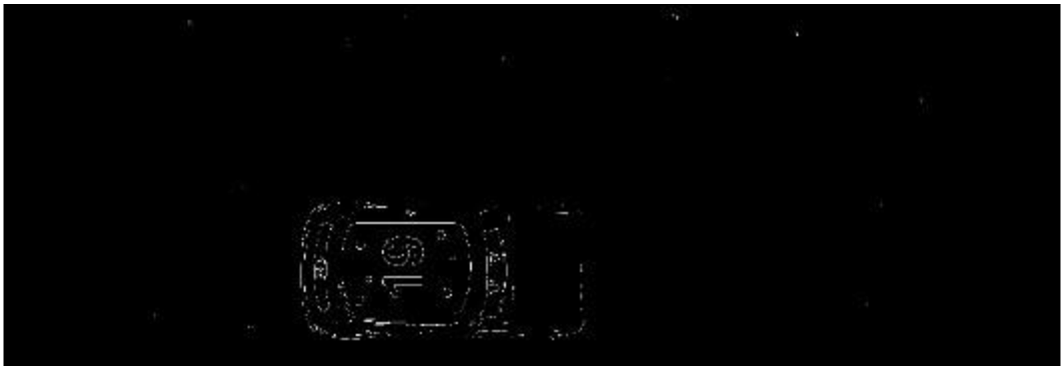


Figure 5.6: the one vehicle is detected in this image

Lastly, the situation in figure 5.6 above indicating one vehicle will be considered last based on the traffic density, and after completing the process, then there is a free flow of the traffic there will iteration of the process.

5.4 Out image

From the edge detected images, the number of objects (vehicles) are estimated for all the roads by counting the number of edges as the vehicles detected, and these edges of the image on each road are compared with the next road images to determine the one with high traffic. After that, the figures below shows the number of vehicles (traffic) on each road. For instance, the roads at a particular junction are named as; North, East, West, and South. For example, North road counts seven (7) which indicates the number of vehicle is seven. Each road is given a green light depending on the number of vehicles detected in the image. Then, the first priority will be assigned to that road based on the greater number of vehicles to that direction.

Below are the vehicles estimated on each road, then LEDs outputs based on the traffic density:

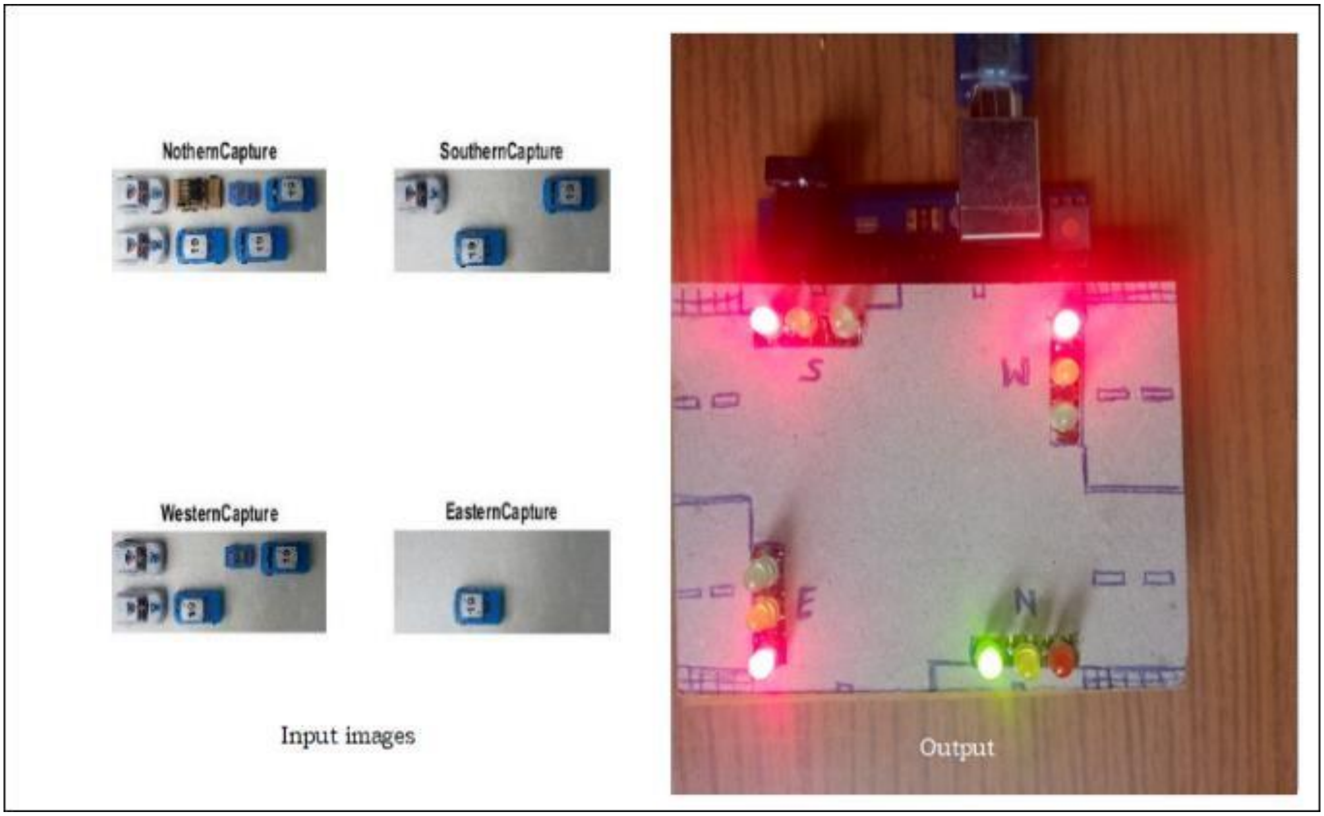


Figure 5.7: High traffic to the North direction

In Figures 5.6 and 5.7, where each figure shows small frames of the road traffic on the left side and the microcontroller board (Arduino) integrated with the traffic lights. For instance, after processing the images of the road traffic and determine that the south direction has high density than other directions. Hence, we give a priority to that direction by indicating a green light to allow traffic flow.

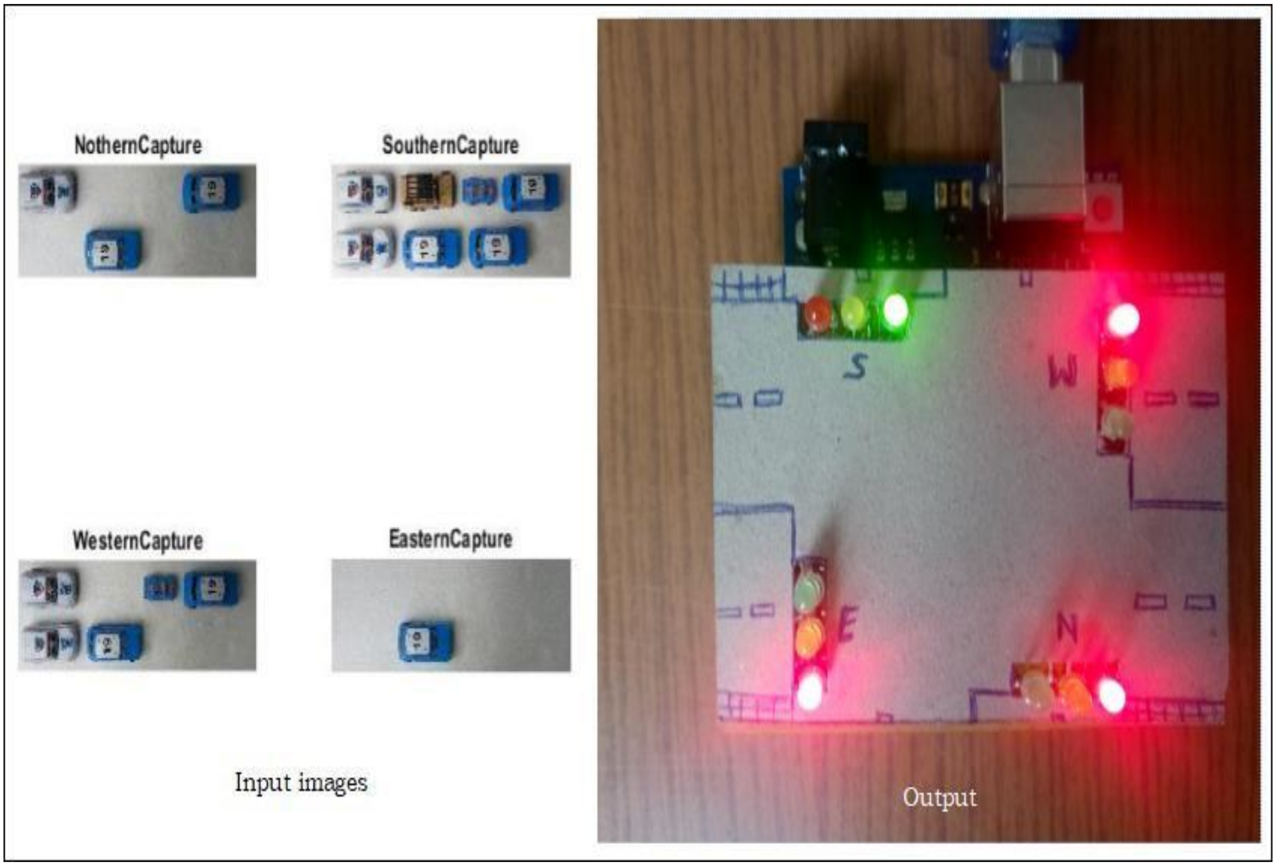


Figure 5.8: High traffic flowing to the South

Figure 5.8 below; shows the left four images of the road traffic captured by the camera and these images are for determining which direction has high traffic so that it gets a priority first.

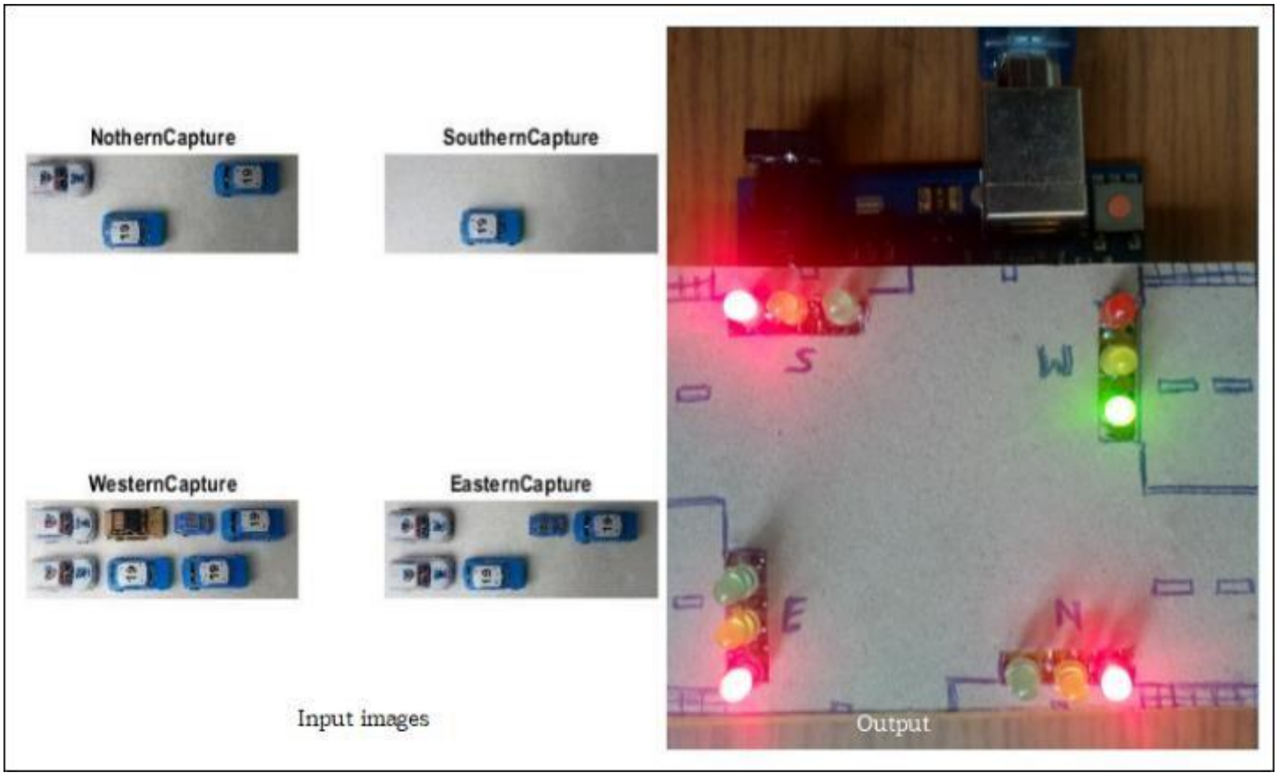


Figure 5.9: High traffic to the west direction

In this situation above, we found that the west direction is found to have high density than others. Hence, green light grows in that direction to allow traffic flow to cross the junction.

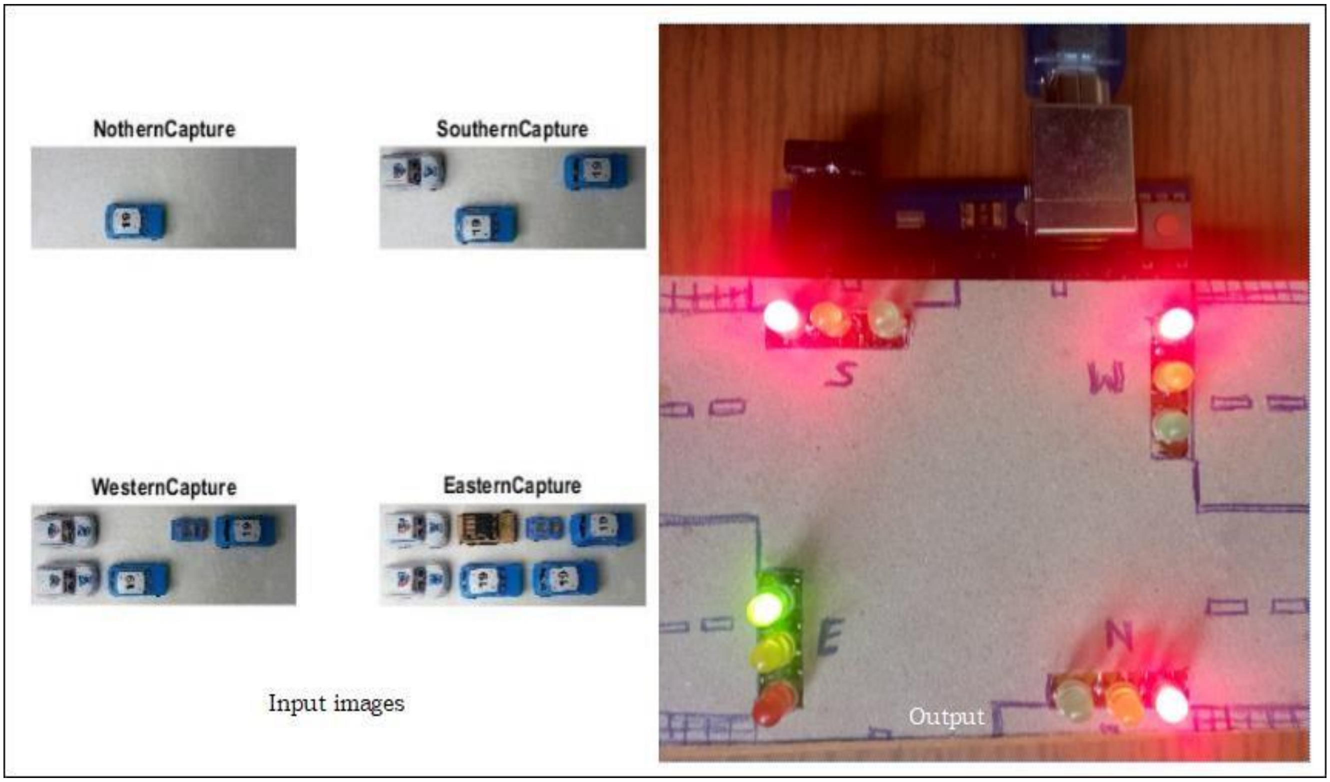


Figure 5.10: High traffic to the East direction

Another situation is shown in figure 5.9 above, where it indicates that the traffic going in the east direction is more than the traffic appearing in other directions. Hence, giving green LED in that direction to allow traffic flow in the direction, and reduces jam at the junction.

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The project presented the method of traffic congestion management through image processing to improve the performance of the traffic lights and reduce congestion based on the density estimation through MATLAB simulations that reduces the production costs and enables to improve performance of the traffic light signals, reduces traffic congestion, and also waiting time at the intersection. The proposed system reduces issues of the traffic congestion and also minimize time delays. Also, the benefits of the image processing method involve not use of sensors or RFID techniques which decrease manual control of the traffic and also reduces the stress of traffic officers.

6.2 Recommendations

Further, the proposed system can identify emergency vehicles as they pass and give them a priority according to their preferences. But also our proposed system can be further developed to achieve a product that can control traffic light signals efficiently, and also accurately work even in extreme weather conditions such as mist or fog. Also, the research direction is that as technologies in hardware are advancing and becoming more sophisticated, image processing algorithms need to be developed to get a traffic management system that is more effective in different traffic situations.

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APPENDIX System Prerequisites

Before installing the congestion system some prerequisites have to be satisfied on the computer system and control board.

A.0 Hardware Requirements

A.1 Computer Components

The preferred choice of the operating system is windows 10 though the same can be done on the Linux family. The windows 10 used, has specifications are; Intel(R) Core i5-2.60GHz, RAM 8.0 GB, 64-bit OS, x64 based processor.

A.2 Microcontroller Board (MCB)

The Microcontroller board is used; Arduino ATmega328P-8bit AVR family, Input Voltage 7-12V, 14 Pins (Out of which 6 pins) provide Pulse Width Modulation (PWM) output.

The 6feet × 4feet wooden board (Road is designed with toy cars on this board).

B.1. Software requirements

MATLAB Version 2018a installed on the computer system with minimum requirements; Any Intel or AMD x86-64 processor, 2GB HDD space for MATLAB only, 4-6 GB for a typical installation, Minimum 4 GB. And also MATLAB installed with the Simulink Support package.

B.2. Some examples of MATLAB Code using Canny Edge Detection in Image Processing.

```
% let's start
% clc,clear,close all,warning off all
clc,clear all
counter=1;
global mcb;
global currentPassing;
currentPassing=0;
mcb = arduino();  %creates a connection to Arduino hardware
%initialize red light on
writeDigitalPin(mcb,'D2',1);    %writes the specified value to the specified
writeDigitalPin(mcb,'D5',1);
writeDigitalPin(mcb,'D8',1);
writeDigitalPin(mcb,'D11',1);
%load images from local drive
a = imread('1.jpg');
b = imread('3.jpg');
c = imread('5.jpg');
d = imread('7.jpg');
while 1%loop through different scenarios we expect to have in real situation
    if counter==1
       north=edges(a);
       show(a,1,'Nothern');% call the function to show the images appearing
       south=edges(b);
       show(b,2,'Southern');
       west=edges(c);
       show(c,3,'Western');
```

```
        east=edges(d);
        show(d,4,'Eastern');
      elseif counter==2
          north=edges(b);show(b,1,'Nothern');
          south=edges(a);show(a,2,'Southern');
          west=edges(d);show(d,3,'Western');
          east=edges(c);show(c,4,'Eastern');
      elseif counter==3
          north=edges(b);show(b,1,'Nothern');
          south=edges(d);show(d,2,'Southern');
          west=edges(c);show(c,3,'Western');
          east=edges(a);show(a,4,'Eastern');
      elseif counter==4
          north=edges(d);show(d,1,'Nothern');
          south=edges(b);show(b,2,'Southern');
          west=edges(c);show(c,3,'Western');
          east=edges(a);show(a,4,'Eastern');
     end
     decide(north,south,east,west);
     if counter<4
         counter=counter+1;
     else
         counter=1;
     end
     pause(30);%the loop is iterating every 30 sec
 end
```