Evolution in Electrical and Electronic Engineering Vol. 1 No. 1 (2020) 199 -209

EEEE

Homepage: http://penerbit.uthm.edu.my/proceeding/index.php/eeee
e-ISSN : 2756-8458

Vision-based Smart Traffic System

W. L. Lim[1]*, K. N. Ramli[1], S. A. Hamzah[1], L. Audah[1]

[1]Faculty of Electrical and Electronic Engineering,
Univesiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Batu Pahat, MALAYSIA

DOI: https://doi.org/10.30880/eeee.2020.01.01.024
Received 01 August 2020; Accepted 06 September 2020; Available online 30 October 2020

Abstract: Traffic congestion has been the most critical issues in many countries all over the world, especially those highly developed countries, however most of the existing traffic system in Malaysia are conventional system, which is not efficient enough to cope up with the increase of traffic congestion on the road. This project implements an algorithm to detect the traffic density and emergency vehicles using image processing on a prototype model of a road junction as well as a mobile application to show the traffic condition. The system uses Raspberry Pi 4 Model B as the microcontroller and webcams to capture images of the road condition. This system uses image processing to detect the number of vehicles and the presence of emergency vehicles, then assigns the traffic signal duration dynamically, while the mobile application will show the traffic light state, congestion level and the existence of emergency vehicles. The system successfully achieves the objectives of the project, nonetheless there are limitations such as the processing power of microcontroller and the usage of only one detection method, thus future improvement can be done by replacing a microcontroller with higher processing power and adding more detection methods.

Keywords: Traffic Congestion, Smart Traffic System, Vision, Image Processing

1. Introduction

In this modernisation era, the increasing economy development results in the fast-growing population in all over the world especially the urban areas, which lead to the number of vehicles increased at the same time [1]. In consequence, the increasing number of vehicles indicates there are more traffic users, thus the traffic congestion in the cities will be further worsen [2]. It is a waste of time to be stuck in the traffic, especially for those with urgencies. The traffic congestion will both directly and indirectly affect the living quality and cause inconvenience in daily life of individuals since the time taken to reach the destination will be longer. Apart from individuals, traffic congestion will affect the productivity of company as well. One might be late for an important meeting due to the traffic jam, resulting a huge loss for the company. The companies where their works are relying on the traffic condition, for instance the logistic companies, will be affected the most. Bad traffic condition will lead to more time consuming for the couriers to deliver parcels, contributing bad performance to the company.

The slow-moving traffic and the long waiting time in the traffic will lead to negative emotion of the drivers. For example, they may feel sleepy, fatigue or anxiety while facing a traffic jam, causing their focus on driving to be decreased. Some of them may start to play their phones because they would

*Corresponding author: limwl7596@gmail.com

feel bored, as a result the probability for them to engage in road accidents increases [3]. To be worse, this issue may lead to a life loss in some cases [4]. If an ambulance with a patient in critical condition was stuck in a traffic, the patient may not be able to reach the hospital and receive treatment in time. Traffic congestion is currently known as one of the most critical issues in the urban areas, and this phenomenon will remain if the number of transportations keep increasing whereas the development of road infrastructure is neglected [5]. Therefore, in order to overcome traffic congestion, the traffic light system ought to be smart so as to confront with various road condition. The crucial issue for the developer is to design a higher intelligence traffic light system which is able to respond to different condition happen on the road.

Most of the current traffic light systems are using the traditional traffic light system which evenly distribute the duration of green light among the traffic light at each junction [6]-[7]. However, the number of vehicles in each lane is different and imbalance at different time, thus the lane with the least vehicles will be left empty when all of them passed through the junction and the remaining time of the green light will be wasted. In contrast, the lane occupied with the most vehicles will accumulate more and more vehicles because they are not able to pass through the junction in the green light duration. Such traffic light system can be said to have low efficiency as it does not help to soothe the traffic condition but leaving the density of vehicles on the road remain the same or even increase gradually. In fact, there are some traffic light systems had been improved in the past [8]-[12] to be able to differentiate the duration of green lights at a junction depending on the number of vehicles on each lane using sensor. Nonetheless, there are still chances where the number of vehicles detected is inaccurate, or even no vehicles are detected due to certain factors.

The sensors used to detect vehicles are usually buried under the ground, they are quite vulnerable when the vehicles driving through the roads, causing the sensors to be malfunction or broken time easily. Moreover, it will be a tough job to fix the sensors as some road construction must be needed to get to the sensor buried, and the road must be blocked while the maintenance is undergoing, this will be another factor contribute to traffic jam. In addition, the conventional traffic light system will not take account of special cases such as road accidents, vehicle breakdowns or roadworks that may affect the traffic flow. Moreover, the congested traffic will affect the mobility of emergency vehicles like ambulances, police cars and fire trucks on the road, which may lead to serious consequences including life loss. This is one of the crucial issues that should be considered while designing an intelligent traffic light system, where the emergency vehicles should be given high priority to cross the junction. Apart from that, there are some present traffic light systems are not applied with green wave system. This will cause the traffic lights on the same direction of two continuous junction will turn green at different time. The vehicles passing through a junction will have to stop at the next junction, resulting in no difference in the density of vehicles on the road, thus causing traffic congestion.

In this work, an algorithm is designed to detect the number of vehicles on the road using background subtraction. The algorithm is also developed to detect emergency vehicles on the road using colour detection. A mobile application is integrated with the traffic light system to help the users to be aware of the condition at the junction remotely. A prototype model of a road junction with traffic lights is constructed to illustrate the smart traffic system. The algorithm will be able to calculate the traffic signal duration based on the number of vehicles and the presence of emergency vehicles detected using images.

2. Materials and Methods

2.1 Materials

The proposed idea in this project is to design and construct a prototype model of a Vision-based Smart Traffic System. The main materials used to build the prototype will be Raspberry Pi 4 Model B with 4 GB RAM, webcams and traffic light model, where the Raspberry Pi 4 act as the microcontroller of the system while the webcams are used to capture images at a road junction for image processing purpose whereas the traffic light model represent the traffic light at the road junction. The data collected will be send to a database via IoT. A mobile application integrated with the system is implemented to indicate the traffic condition at the junction. The block diagram of the system is shown in Figure 1. This

system uses the number of vehicles at the junction to determine the traffic light duration to be distributed to each lane. To obtain the number of vehicles on the road, an image processing technique is used, which is background subtraction. The method compares two image and the differences will be the result of subtraction. In this project the empty road will be the background and the real time image captured will be used to subtract the background image, the remaining part will be the vehicles on the road. The working principle of background subtraction is shown in Figure 2.

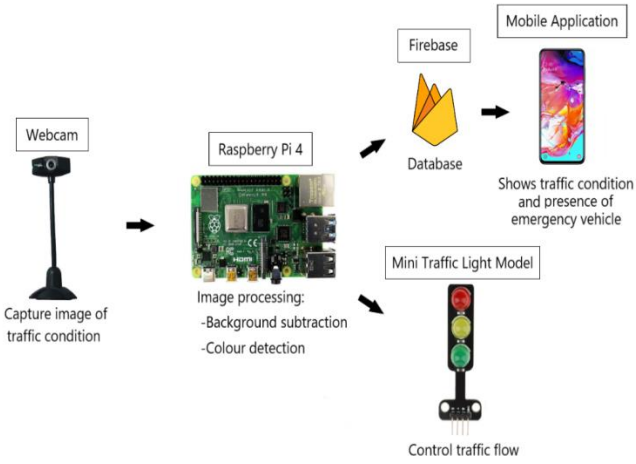


Figure 1: Block diagram of vision-based smart traffic system

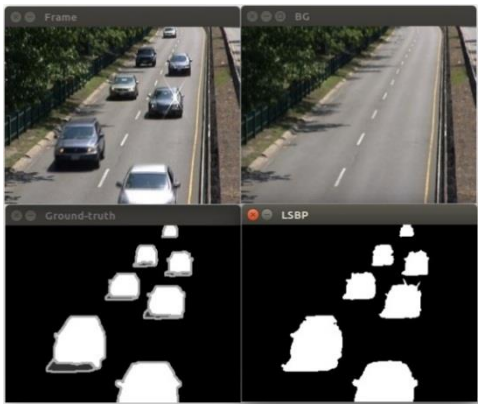


Figure 2: Working principle of background subtraction

There is another image processing technique used in this system, which is known as Colour Detection by OpenCV, where it will detect objects with the colour selected presented in the image. The detection of colour in this method uses HSV colour, where H stands for hue, S represents Saturation and V is the value. Hue is the colour portion expressed in number from 0 to 179 degrees, it is mainly divided into 3 colour regions which are red, green and blue in the ascending order of the degrees. Saturation is the intensity of a colour, expressed from 0 to 255 where the higher the number the higher the saturation of the colour. Value represents the brightness of the colour, it is expressed from 0 to 255 as well, where the higher the number the brighter the colour. In this project, red vehicle is used to represent emergency vehicle, therefore Colour Detection is used to detect red colour representing the detection of emergency vehicle. A mobile application is designed and implemented to integrate with the smart traffic system proposed in this project. It will show the current traffic signals at the road junction and the existence of emergency vehicle on the road beside indicating the current congestion level on the road, thus the users will be aware of the current traffic condition. The method used to create the mobile application is the MIT App Inventor2 as it has a simple interface to ease the application design. Prior knowledge of any programming languages is not necessary because it uses block terminology to build the algorithm, a functioning app can be completed within a short period. The data needed will be provided by the Firebase, the database where the data collected in this project will be sent to. To construct the prototype model of the smart traffic system, some hardware components are used, including Raspberry Pi 4 Model B, webcams, and traffic light models. The system in this project uses image processing technique to analyse the image captured to obtain the traffic information at the junction, thus a microcontroller with high processing power is not an option but a must in order to ensure the performance of the system. The operating system used in Raspberry Pi 4 Model B is Linux, the most used open source operating system. Webcams are used in the prototype model of this project to capture the images of road condition at the junction for image processing purpose so as to determine the number of vehicles at each lane and thus calculate the traffic light duration to be distributed to each lane. In reality, the camera should be installed on top of traffic light to have a wide vision from a high angle in order to capture all required information. However, it is impossible to construct a road junction model with original scale, the prototype model in this project will be using a small scale and the webcams will be respectively large to be installed with the traffic light models, so the webcams will be placed at beside the traffic light model on the prototype model board. The smart traffic system is designed to control the traffic light duration based on the number of vehicles at the junction, thus there

must be traffic light models which are able to function well in the prototype model so as to demonstrate the traffic condition at a junction. The traffic light model used in this project has 4 pins which correspond to red light, yellow light, green light and ground respectively, it required simple connection and it easy to be controlled through the microcontroller.

2.2 Methods

The algorithm of the system proposed is to detect the number of vehicles on road and the data collected will be used to determine the duration of traffic light to be assigned to each lane at a junction.

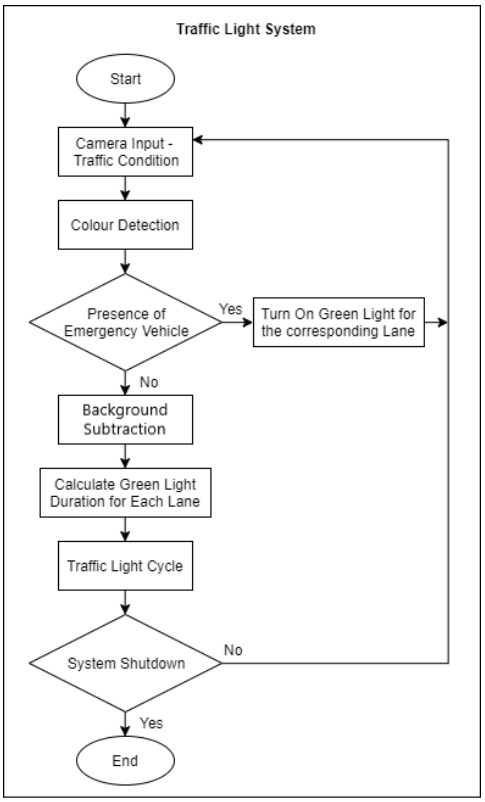


Figure 3: Flowchart of vision-based smart traffic system

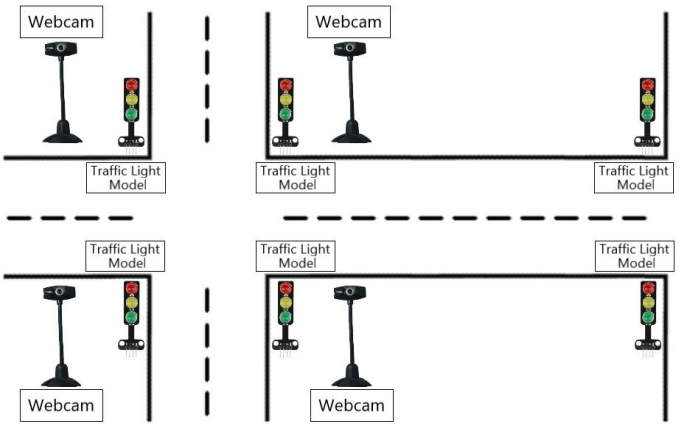
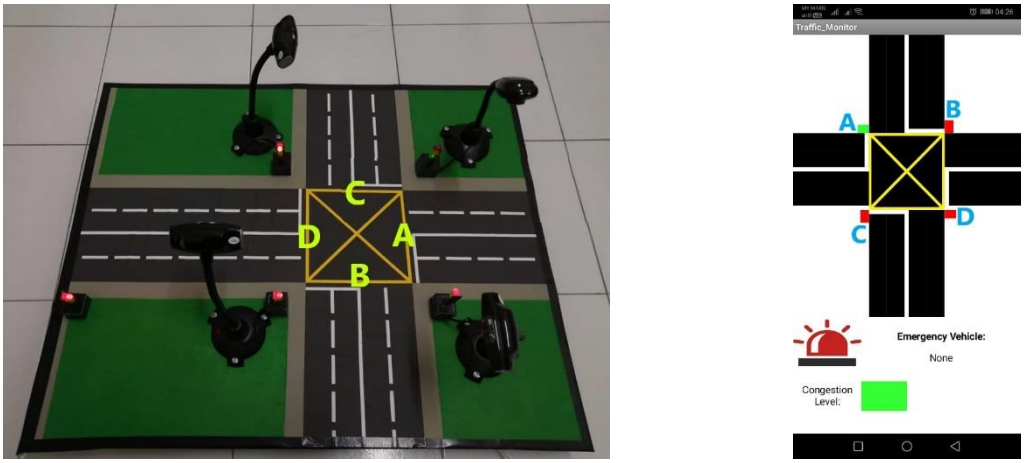


Figure 4: Design of vision-based prototype model

The presence of emergency vehicles will be detected and the lane will be given higher priority to have green phase so as to allow the emergency vehicles to cross the junction without hesitation. The flowchart of the system is shown in Figure 3. A prototype model of a road junction with traffic light will be constructed to integrate with the smart traffic system proposed in this project. The design and the completed prototype model are shown in Figure 4.

3. Results and Discussion



(a) (b)

Figure 5: (a) Completed prototype model of vision-based smart traffic system, (b) interface of mobile application

Table 1: Background subtraction and colour detection

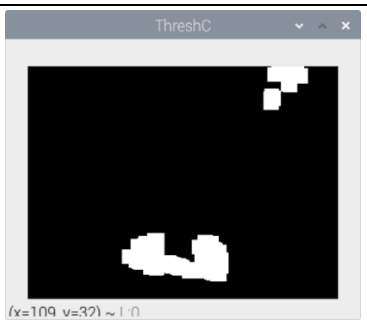
Process	Captured Image	Threshold Image
Background Subtraction		
Colour Detection		

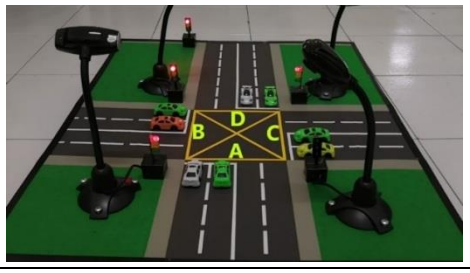
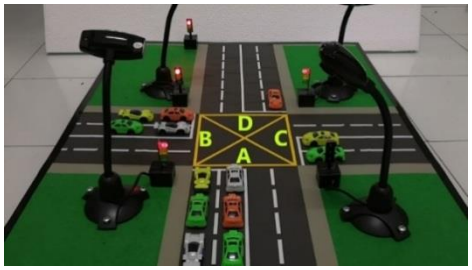
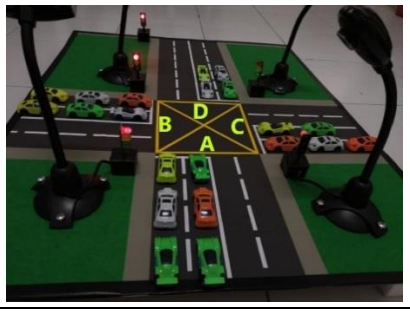
Figure 5(a) shows the completed prototype model of the smart traffic system. Apart from the prototype model, a mobile application is created to integrate with the smart traffic system proposed to show the traffic condition on the road. The interface of the mobile application is shown in Figure 5(b). The webcams act as the data acquisition part of the smart traffic system proposed. Since the junction chosen to be the scenario in the prototype model is the cross junction containing four lanes, there are four webcams used in the system to capture the image of road condition at each direction. The image captured will then be used for image processing to analyse the traffic congestion level and to detect the existence of emergency vehicles on the road as well as to calculate the traffic signal time. The Raspberry

Pi 4 Model B plays the most important role in the prototype model of the smart traffic system proposed, that is the microcontroller which can be said as the brain of the whole system. It will collect data obtained from the data acquisition part, which is the image captured by the webcams and use them to carry out image processing. In this process, background subtraction is used to detect the presence of vehicles on the road while colour detection is used to detect the presence of emergency vehicles represented by red cars on the road. Besides, it will calculate the traffic light duration to be distributed at each lane based on the number of vehicles detected on each lane, and if there is emergency vehicle on the road, the lane will be given green phase until the emergency vehicle cross the junction. Table 1 shows the process of background subtraction and colour detection done by the Raspberry Pi 4. The traffic light models are placed at the road junction on the prototype model to illustrate a traffic junction scenario in reality. The models are connected to the Raspberry Pi 4 Model B thus the duration of traffic signals can be controlled accordingly.

3.1 Adaptive traffic control

The smart traffic system proposed in this project can control the traffic flow at the junction according to the traffic condition at each lane in order to help to reduce traffic congestion.

Table 2: Traffic light duration distribution in different situation

Situation	Description
	The duration of traffic signals is distributed evenly to every lane.
	The descending order of the duration of traffic signals is lane A, lane B, lane C and lane D.
	Lane A and lane B are distributed the same duration of traffic signals which is the longest, followed by lane C, and lane D is distributed the shortest duration.

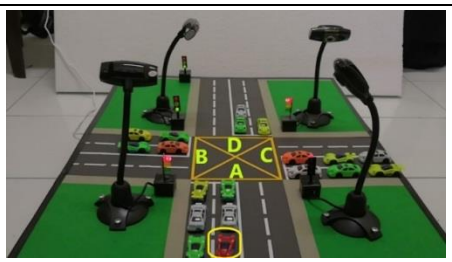
The number of vehicles on the road is determined based on the images captured by the webcams, then the microcontroller will analyse the data collected and calculate the traffic light duration to be assigned to each lane. The traffic signals sequence is set to run in other from lane A to lane D, and the whole sequence is counted as one cycle where the duration of one cycle is set to 20 seconds in this project. The lane occupied with the highest number of vehicles will be given the longest duration of green phase so as to allow more vehicles to pass through the junction, while the lane with the lowest

density of vehicles will be distributed the least time for the vehicles to cross the junction. The green phase duration on the other lanes will be assigned according to the number of vehicles on the road, where the higher the vehicle density, the longer the duration of green phase. Once the traffic signals complete a cycle, the system will use the images captured at that time to carry out a new analysis and calculation to determine a new distribution of traffic light duration which is more suitable for the scenario. Table 2 explains the traffic light duration distributed in different scenarios.

3.2 High priority for emergency vehicle

To illustrate the scenario of emergency cases, red vehicle is used to represent an emergency vehicle in this project as red colour usually stands for alert or caution. Whenever the system detects the presence of red vehicle on the road, the corresponding lane will be given a higher priority for the vehicles to cross the junction. Before assigning green phase to the corresponding lane, the current traffic signal distribution will be stored to the database then the current lane having green phase will be turned into red phase. This can help the emergency vehicle to pass through the junction as quick as possible without being stuck in the traffic. After the emergency vehicle have crossed the junction, the traffic system will assign the traffic signals to return to the previous pattern stored in database, then the system will run as normal condition. Table 3 shows how the system run when there is emergency vehicle detected on the road.

Table 3: System running in emergency mode

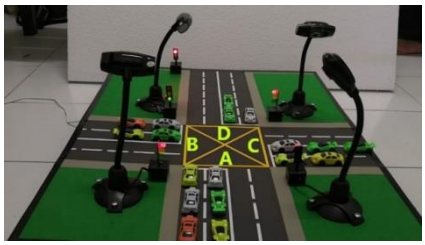
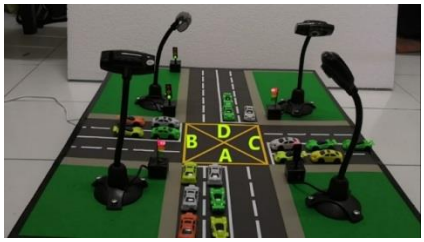
Situation	Description
	The system is running in normal mode where the green phase is assigned to lane C at the time.
	The traffic light at lane A turns green when there is a red vehicle on the road detected by the system.
	When there is no red vehicle detected indicating the emergency vehicle has passed through the junction, the system run the normal mode again with the traffic signal pattern stored, so the traffic light at lane C turns green.

3.3 Green wave

Green wave occurs when the traffic light systems in a series of road junction turns the traffic light in one direction green in a sequential manner, it allows the vehicles to drive smoothly in the direction. This method is especially efficient in cities that the distance between traffic light junctions is short, as the vehicle queue in a junction may interrupt the traffic in another junction if the traffic lights turn green at different time. In this project, there is two traffic light models placed in lane A where one is used in the main traffic system while another is used to represent the traffic light in an adjacent junction. When

the traffic light of the main junction turns green, the traffic light at the second junction will turns green as well after a delay. The delay depends on the distance between the two junctions and the average time taken for the vehicles to reach from one junction to another, in this project the delay time is set to 1 second. Table 4 shows how the green wave principle work in the traffic system.

Table 4: Green wave

Situation	Description
	The traffic light of lane A at the main junction turns green.
	After 1 second, the traffic light of lane A at another junction turns green.

3.4 Mobile application

A mobile application is designed to integrate with the smart traffic system proposed in this project. The data collected from the system will be stored in a database created using Firebase, then the data will be retrieved and shown in the application. The information shown in the application include the current traffic state of each lane and the congestion level at the junction beside indicating the presence of emergency vehicle on the road. Table 5 shows the mobile application screen with different congestion levels and the situation when there is emergency vehicle on the road.

Table 5: Mobile application

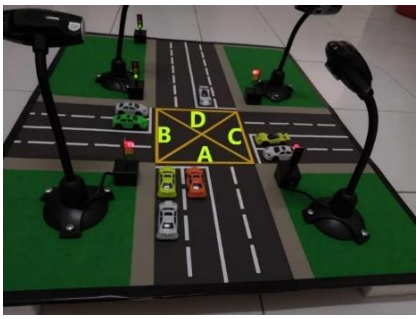
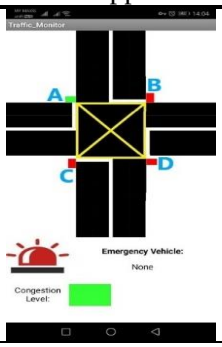
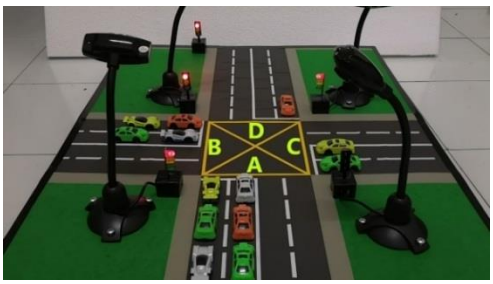
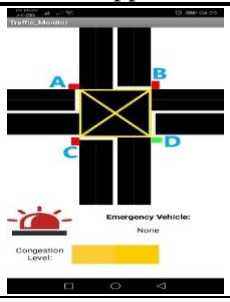
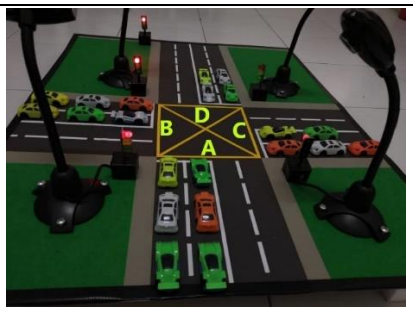
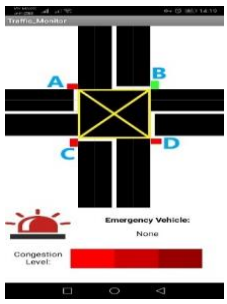
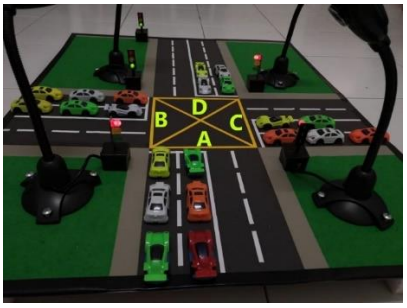
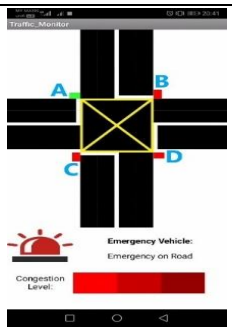
Situation	Prototype Model	Mobile Application
Low Congestion Level		

Table 5: Mobile application (continue)

Situation	Prototype Model	Mobile Application
Medium Congestion Level		
High Congestion Level		
Emergency Case		

4. Discussions

The result obtained is based on the model instead of actual scale due to some limitations. The situation demonstrated in the project is in the normal condition, however there will be environmental factors that may affect the detection using camera such as rains and light intensity. Therefore, if the system is to be applied in actual traffic system, the parameters have to be adjusted accordingly and the surrounding affect have to be considered. The webcams are not having high quality, the image capturing is highly affected by the environment factors such as light intensity. When applied in reality, the camera used will have higher quality and it will be placed statically. They have to be placed above the traffic lights to get a wide vision and avoid the vision to be blocked. Besides, the technique in the system is only image processing, which may not be efficient in detecting the traffic condition. The background subtraction method may be affected when there are other objects appear on the road, which may be counted as a vehicle and the traffic signal calculation may be inaccurate. The emergency vehicle detection using colour detection is a mere sample to illustrate the possibility of the solution, since detecting the emergency vehicles using the colour will have many limitations. Other technology such as machine learning may help to improve the detection more specifically.

5. Conclusion

A model of a road junction with traffic lights is constructed to implement the algorithm of vehicle number detection and emergency vehicle detection in the smart traffic system. The system is able to analyse the traffic condition using the images captured by the webcams and calculate the traffic signal duration for each lane at the junction based on the number of vehicles on each lane, thus the system is adaptive to the traffic condition. The data collected can be sent to the database for storing and retrieving

by the mobile application. The emergency vehicle detection is represented by colour detection in image processing instead of specific detection, thus the accuracy and reliability of the process is relatively low due to that limitation. Nonetheless, the scenario of the smart traffic system function when there is emergency vehicle on the road is successfully illustrated in the project. Mobile application is used to show the junction traffic condition using the data retrieved from the database. The application can indicate the congestion level at the junction and the current state of the traffic lights. The user can recognise the traffic remotely using the application and decide whether the route should be taken. Besides, when emergency vehicle appears at the junction, a dialogue stating emergency vehicle on the road is shown in the application. The smart traffic system in the project can be said to function well if the limitations are neglected. Further enhancement must be made so as to improve the performance of the system and to deal with more possible situation related to traffic.

Acknowledgement

The authors would like to thank the Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia for the facilities.

References

[1] M. H. Malhi, M. H. Aslam, , F. Saeed, O. Javed, and M. Fraz, "Vision based intelligent traffic management system," IEEE Conference on Frontiers of Information Technology , pp. 137-141, December 2011

[2] V. Jain, A. Sharma, and L. Subramanian, "Road traffic congestion in the developing world," Proceedings of the 2nd ACM Symposium on Computing for Development, no. 11, pp. 1-10 , March 2012

[3] D. A. Hennessy and D. L. Wiesenthal, "Traffic congestion, driver stress, and driver aggression," Aggressive Behavior: Official Journal of the International Society for Research on Aggression, vol. 25, no. 6, pp. 409-423, 1999

[4] K. Athavan, G. Balasubramanian, S. Jagadeeshwaran, and N. Dinesh, "Automatic ambulance rescue system," 2012 IEEE Second International Conference on Advanced Computing and Communication Technologies, pp. 190-195, January 2012

[5] P. Sharma, A. Mishra, and K. Singh, "Density based intelligent traffic control system using IR sensors," International Journal of Scientific Research, vol. 4, no. 5, pp. 2277-2278, 2015

[6] P. Ravikumar and T. V. Mathew, "Vehicle-actuated signal controller for heterogeneous traffic having limited lane discipline," Institute of Transportation Engineers (ITE) Journal, pp. 44-53, May 2011

[7] K. A. R. Jomaa and C. J. Kie, "An integrated model to control traffic lights: Controlling of traffic lights in multiple intersections using fuzzy logic and genetic algorithm," Asian Journal of Business and Management, vol. 5, no. 1, pp. 12-20, February 2017

[8] K. H. Chao and P. Chen, "An intelligent traffic flow control system based on radio frequency identification and wireless sensor networks," International Journal of Distributed Sensor Network, vol. 4, pp. 1-10, May 2014

[9] A. Toshniwal, S. Bhaskar, S. Doshi, K. Vaity, and A. Bandekar," Traffic congestion management and monitoring in IoT," International Journal for Scientific Research and Development, vol. 6, no. 2, pp. 2243-2247, 2018

[10] S. Sukode, and S. Gite, "Vehicle traffic congestion control and monitoring system in IoT," International Journal of Applied Engineering Research, vol. 10, no. 8, pp. 19513-19523, 2015

[11] A. S. Chitta and P. Dinesha, "Priority management of emergency vehicles using IoT approach," International Journal of Advanced Research in Computer and Communication Engineering, vol. 5, no. 9, pp. 465-470, 2016

[12] R. Linganagouda, P. Raju and A. Patil, "Automatic intelligent traffic control system," International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 5, no. 7, pp. 5902-5906, 2016