Travel Time Measurement in Real-Time using Automatic Number Plate Recognition for Malaysian Environment

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Abstract: Travel time is a basic measure in transportation studies. It is used for performance measures of the developed transportation system. Among many other advanced techniques, Automatic Number Plate Recognition (ANPR) has gained lots of intentions because it is a non-intrusive approach and this system do not required any additional vehicle identification need to be installed to the vehicle. In this paper, a new real-time ANPR system is presented. The proposed ANPR system has been developed to suit with traffic environment in Malaysia. The development of the ANPR system consists of several processing steps such as vehicle detection, number plate localization and extraction, character segmentation and recognition. A number of tests were done in order to measure the performance and capability of the developed ANPR system. Based on the results, the system is reliable and robust and its capability to measure travel time indicated that it have huge potential to be use in traffic and transportation studies.

Key Words: *Travel time, Automatic Number Plate Recognition (ANPR), Optical Character Recognition (OCR)*

1. INTRODUCTION

Travel time can be defined as total time to traverse a given highway segment or road segment. Travel time data are fundamental part for number of performance measure in many transportation studies. Chun-Hsin *et al.* (2003) stated that travel time can be used in the transportation planning, design and operation, and evaluation. Beside that, it can be used for performance measures of the developed transportation system. The travel time data are very useful to drivers in order to make decision or plan schedule. The drivers can add the buffer time or extra time to their average travel time when planning trips in order to ensure on-time arrival.

In recent years, there has been increased in congestion especially on the urban freeway. This situation will give impact to the drivers and road users especially traveler because more journey will be affected by delay. Kwon *et al.* (2000) mentioned that for the travelers that routinely traverse a given route, they won't be affected by the delay problem because they are able to allocate buffer time or extra time to their journey. In some other country, they have a system called route-guidance system which is used to suggest optimal alternative routes or warn of potential congestion to the drivers or road users. Based on this system, the drivers can decide the best departure time or they can estimate their expected arrival time based on the predicted travel times. Bertini *et al.* (2005) stated that the travel time calculation depends on vehicle speed, traffic flow, and occupancy which are highly sensitive to the weather condition and traffic condition. These elements make travel time prediction very difficult to reach optimal accuracy.

From the previous study, it is clearly mentioned the importance of the travel time measurement especially in traffic applications and transportation studies. There are various methods or techniques used to measure the travel time. Coifman (2002) in his research presented a method for estimating link travel time using data from an individual dual loop detector without requiring any new hardware. The estimation technique use basic traffic flow theory to extrapolate local conditions to an extended link. A research done by Nagoaka (1999) measured the travel time based upon data from the detector. The movement of vehicles from starting point to end point is traced on the time distance diagram and the travel time is obtained from the diagram. However these approaches require raw loop detector data as opposed to typical 20s to 30s cumulative data.

Beside that, travel time can also be measured by using the Automatic Number Plate Recognition (ANPR) system. The measurement of travel time using ANPR system is differ from estimation via information from classical stationary detector such as induction loops where this classical devices can only measure volume and local speed and they do not allow to measure travel time for longer distance. There are many researches concerning the development of ANPR system for travel time measurement and the core difference among them is the technique that has been employed in processing algorithm (Bertini *et al.*, 2005; Kanayama *et al.* 1991). The technique is much influenced by various factors such as number plate format as every country has different format, traffic conditions, hardware setup, and climate condition.

The objectives of this research paper are to develop real-time ANPR software and to extend the measurement capability of the developed ANPR software for measuring vehicle travel time which can suit with traffic environment in Malaysia. It is important to perform this study because nowadays, the traffic congestion especially in Malaysia had become more critical. There is a need to take action to solve this problem and to prevent this situation to become worse. To date, there is no ANPR based travel time measurement system was developed or used in Malaysia. Thus, this paper provide the ANPR based technique for travel time measurement and this research can be used to obtain traffic data for the transportation planning, design and operation and as well as for performance measures of the developed transportation system especially by the Malaysian government.

2. AUTOMATIC NUMBER PLATE RECOGNITION SYSTEM

2.1 System Description

Generally, the automatic number plate recognition (ANPR) system consists of two important components which are hardware and software components. The following subsections discuss in detail the development process in each component.

2.2 Hardware

The selection of suitable hardware is crucial for success real-time implementation. The hardware component can be divided into several parts which are camera, lens, Illuminator and computer. The camera is used to capture the image of vehicle and continuously send the images to the computer for further process. In this research, the high speed on-board digital camera is used in order to avoid blurring image and transmission latency. Correct illumination is critical to an image system and improper illumination can cause a variety of image problems. Blooming or hot spots, for example, can hide important image information, as can shadowing. In order to solve the problem, the infra-red illuminator is installed together with the camera. The infra-red is used for the night vision propose. Figure 1 shows the schematic diagram of the hardware configuration. For the hardware configuration, the high speed on-board digital camera is mounted beside the roadway and the infra-red illuminator is attached to the camera. The camera and infra-red illuminator are connected to the control wireless device. The obtained data are transferred to the central server through wireless connection.

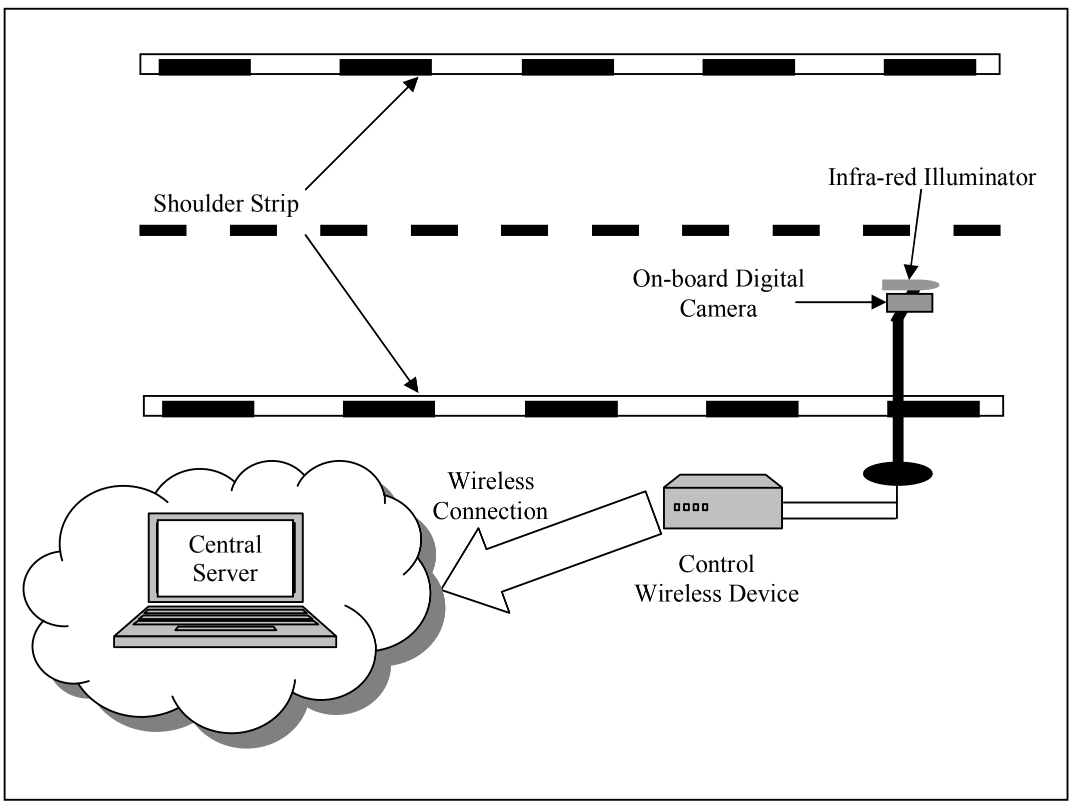

Figure 1 Schematic diagram of the hardware configuration

2.3 Software

Basically, the algorithm component consists of several processing steps; vehicle detection, localization, number plate extraction, character segmentation and character recognition as shown in Figure 2.

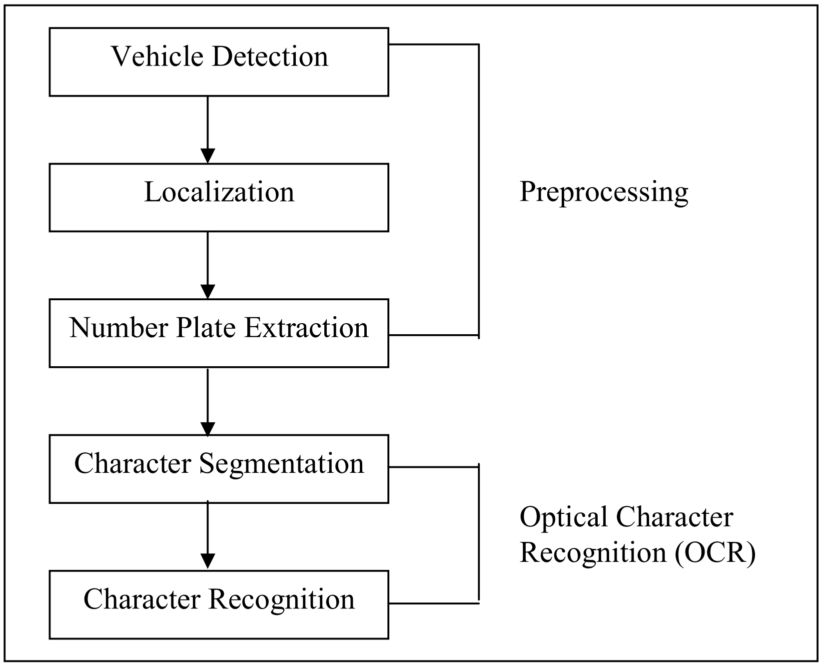

Figure 2 Steps in algorithm

2.3.1 Vehicle Detection

Vehicle detection is the first step for ANPR algorithm. The vehicle presence can be software triggered such as analyzing changes in the images which was done by Eikvil and Huseby (2001) or hardware triggered such as inductive loops, magnetic loops and infrared sensors as mentioned by Broumandnia and Fathy (2005). However, the used of mechanical devices are less cost effective since it need extra instruments for installation purpose. Therefore in this research, the vehicle detection is performed software triggered by utilizing the image subtraction technique. By subtracting the image with the object from the background would therefore only yield the object in the image. The extracted image has to be converted to a binary form. It is performed by thresholding technique and the extracted image is enhanced using the particle filters. The mean average pixel value in the Region of Interest (ROI) is compared by the algorithm.

2.3.2 Localization

Number plate localization is the most important step in developing ANPR system. If the system fail to detect the location of number plate, means that the ANPR system will not able to recognize the number plate. Until now, there have been many algorithms on number plate localization. The techniques based on combinations of edge statistics and mathematical morphology produced very good result as used by Leonardo and Colin (2005). However, the used of edge-based method alone is not suitable to be applied to complex image since they are too sensitive to unwanted edges which may also show high edge magnitude or variance especially at the radiator region in the front view of vehicle. Beside that, other method proposed in previous research is color or gray-scale based processing method used by Wei *et al.* (2001) and Lee *et al.* (1994). The successful of this method is based on color (or gray level) segmentation stage. However, it does not provide high degree of accuracy in natural scene since color is not stable when the lighting conditions change.

Anagnostopoulus *et al.* (2005) in their research used a method called Sliding Concentric Window (SCW) to find the number plate area. This method is developed to describe the "local" irregularity in the image using image statistics such as standard deviation and or mean value. In this method, two concentric windows A and B are created for the first pixel of the image (upper left corner). Then the statistical measurements in A and B are calculated. If the ratio of the statistical measurements in the two windows exceeds the threshold value set by the user, so the central pixel of windows is considered to belong to the Region of Interest (ROI). However, this method will obtain high percentage accuracy only if the parameters are set with the right value based on trial and error method.

In this research, a new method has been developed which can scan the vehicle image with several row distances and count the existent edges. If the number of detected edges is greater than the threshold value, this indicates the presence of a plate. However, if the first scanning process is not found the number plate, the algorithm is repeated and the threshold value for counting edges is reduced. The threshold value is set to reduce automatically. After several tests, this method obtained fast execution times as it scans some row of the image. For this reason, this algorithm is suitable for real-time ANPR system.

2.3.3 Number Plate extraction

The crucial and complicated step in ANPR system is to extract the characters of number plate from the vehicle image background. The procedure for extracting is done in several stages. The number plate extraction is started with the horizontal and vertical edge detection techniques that are based on the characteristics of the edge displayed by the edges of the character on the vehicle's number plate. In order to enable a good number plate extraction process, the thresholding technique was implemented. Noise is eliminated and the small particles are filtered out according to the measurements such as the area, bounding height and bounding width. As far as it is concerned, in real life, the light condition will always change with the time and weather. So, adaptive thresholding is introduced in this research. The threshold value will be specified according to the average grayscale value of the image which we have to determine before thresholding process. In order to determine the relation between grayscale value and threshold value at lane location, a suitable test is performed. In this test, the optimum threshold value is determined based on the grayscale value. The process is repeated for 50 samples and the graph grayscale value against optimum threshold value has been plotted and the relationships are given as follows:

$$V\,(t) \quad \begin{cases} V\,(g) + a, \text{ for } V\,(g) < 55 \\ V\,(g) + b, \text{ for } V\,(g) \geq 55 \end{cases} \qquad (1)$$

Where *V (g)* is grayscale value and *V (t)* is threshold value. *a* and *b* are constant value. In this case, *a* equal to 10 and *b* equal to 25.

The next stage for number plate extraction is image enhancement process. The main purpose of enhancement process is to remove all the noise in number plate image. After the noises are removed it is ready for the next process.

2.3.4 Character Segmentation

Segmentation process is used to find the individual characters on the number plate. In this research, segmentation of characters is performed using the thresholding technique. It is segmented by finding the characters inside the image and bounded each character with the rectangle to separate them as shown in Figure 3.

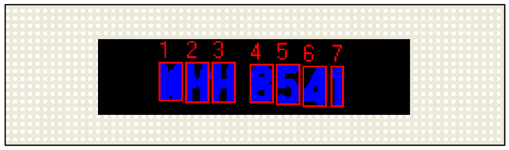

Figure 3 Segmented Characters

2.3.5 Character Recognition

The Optical Character Recognition (OCR) software is used in order to convert the character of number plate to the ASCII code. Before the conversion process is started, the OCR software is trained in order to enhance its ability to recognize the characters. Many samples with various angles are collected and trained to make the OCR software intelligent enough to recognize all the characters from A to Z and from 0 to 9. All the characteristic of characters are analyzed and stored into the database. All the characters that sent to the OCR software are matched with the characters in database. The one with the highest score is chosen and it will be converted into the ASCII code. Figure 4 shows the converted characters into the ASCII code.

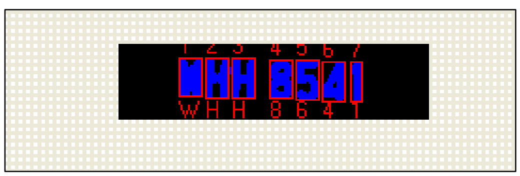

Figure 4 Converted Characters

3. TRAVEL TIME MEASUREMENT

Measurement of travel time with the classical methods is insufficient and only feasible with high cost. The stationary detectors used to measure velocity allow only the estimation of travel time. A possible way to obtain more accurate measurement of travel time is by tracking vehicles on the whole route where the travel time is to be measured. By accessing the floating car data, only a small portion of vehicle is observed.

The travel times of all travelling through vehicles can be measured with high accuracy by setting up ANPR systems at a minimum of two positions of one route. In this research, the travel times are measured using the developed real-time ANPR system. The schematic diagram of the travel time system is shown in Figure 5. Based on Figure 5, the travel time system consists of two ANPR systems located beside the roadway at two different locations in University of Malaya. The distance between first ANPR system and second ANPR system is

180m (short segment). The vehicles are traversed through first ANPR system then through the second ANPR system. The system read the number plate each time the vehicle pass each location. The number plate strings and time-stamped tags are sent via wireless Local Area Network (WLAN) connection to the central server. The server matches the number plate strings and time-stamped tags collected at different checkpoint in order to measure the travel time.

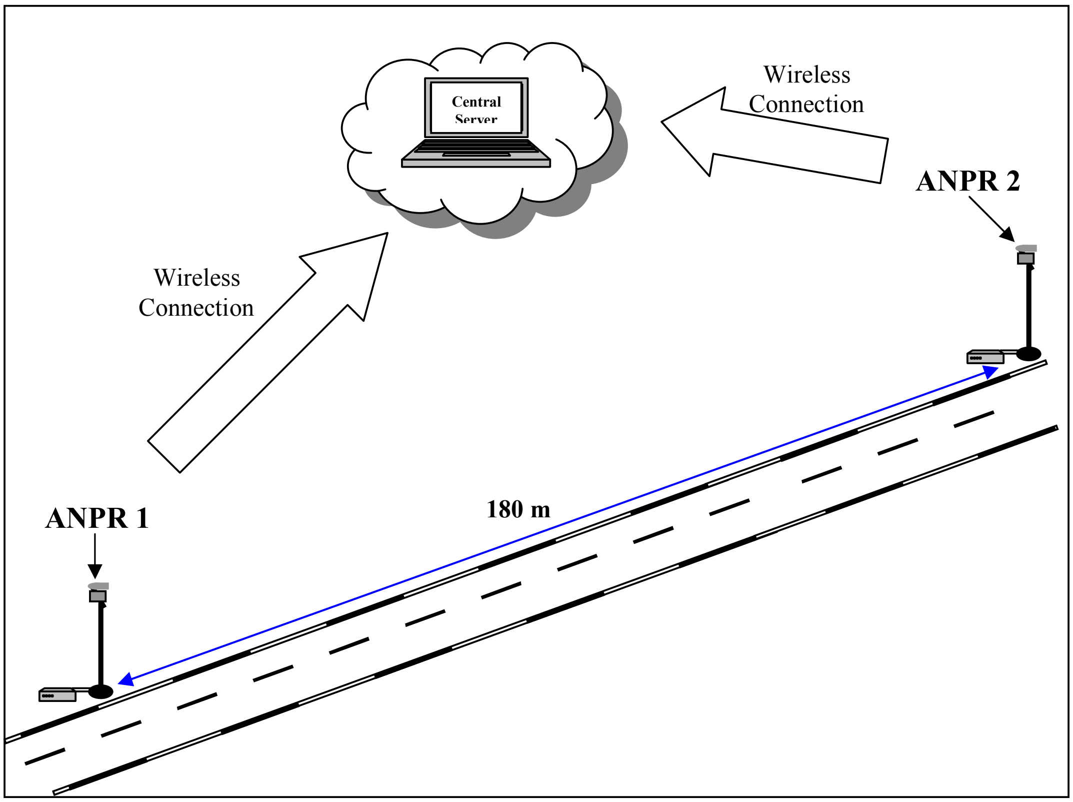

Figure 5 Observation route with two ANPR systems

4. DATA COLLECTION

4.1 Performance Test

In this research, performance test is divided into two tests which are angle test and accuracy test.

4.1.1 Angle Test

This test was conducted using the recorded mode where the pan angle (vertical angle) is fixed to 5 degree and the tilt angle (horizontal angle) is changing. The selected tilt angles (horizontal angles) to be tested are 5 degree, 7.5 degree, 10 degree, 12.5 degree and 15 degree. Each selected angle is tested with 25 samples. Figure 6 and Figure 7 show the typical configuration for angle test.

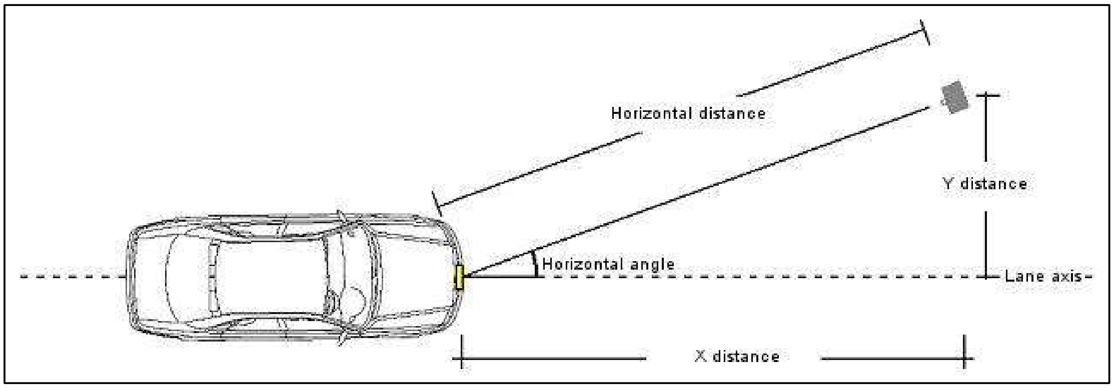

Figure 6 Horizontal Angle

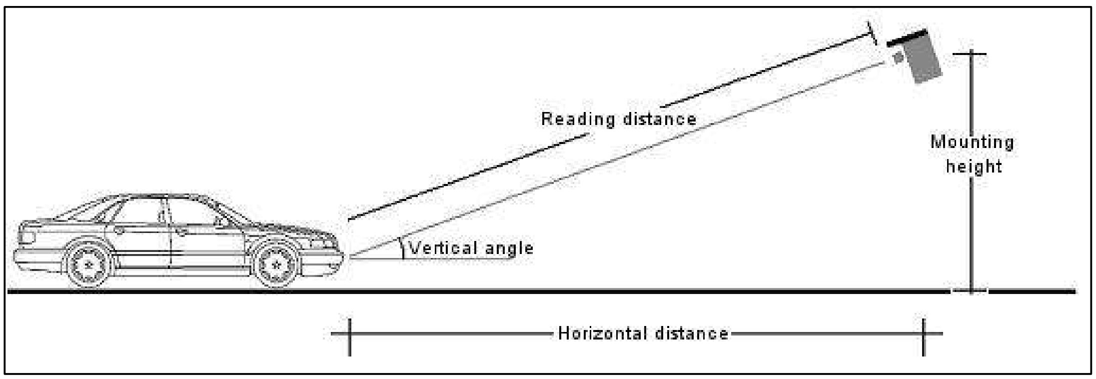

Figure 7 Vertical Angle

4.1.2 Accuracy Test

The accuracy test was conducted in real-time mode during the day time with 50 samples. The purpose of this test is to measure the capability of the developed ANPR system during the real-time test. The result from this test will be given in Section 5.

4.2 Reliability Test

Two tests were conducted for the reliability test. This test was performed in two different environments which are during day time and night time with 50 samples for each test. The purpose of this test is to measure the reliability and the robustness of the developed system.

4.3 Travel Time Measurement Test

A test for travel time measurement was performed during the day time. The ANPR systems were placed at the selected route for 30 minutes. The travel time is measured by the developed ANPR system and the collected data is validated by actual travel time survey data along selected routes. In this research, the validation process is run by running "test car" through the section and making observations on intermediate travel times at the selected route. In order to assure some uniformity of data, the driver of test vehicles is instructed to use "Average Car Technique" of driving strategy. In this procedure, the driver is asked to approximate the average conditions in the traffic stream, using her/his judgment only. The purpose of this test is to measure the travel time as well as space mean speed and then to validate the measured travel time. The space mean speed is calculated based on the estimated travel time and the selected route distance. From the calculated space mean speed data, the frequency diagram was plotted and this data diagram is used to study the speed frequency of vehicles that traversed at the selected route.

5. RESULT AND DISCUSSION

5.1 Performance Test

5.1.1 Angle Test

Based on Table 1, the percentage of localization for all tested angles are same and not vary since the number plate localization algorithm is not depending on the angle of number plate. However, the percentage for number plate recognition and percentage of single character reading seems to decrease when the horizontal angle is increase or become wider. This is happened due to perspective error where the perspective error normally occurred when the camera axis is not perpendicular to the inspected object image. Perspective error is most troublesome in imaging applications involving objects with depth or objects moving relative to the lens. In this case, the angle of 5^o is near to perpendicular condition. As the angle of number plate is increase so the perspective error becomes more critical. In this situation, when there is perspective error, it gave problem for the ANPR system because the system will have difficulty to recognize the characters of number plate in the image.

Table 1 Percentage of recognition rates

Angles (Degree)	Localization (%)	Single Character Reading (%)	Number Plate Recognition (%)
5.00	96.00	95.21	95.65
7.50	96.00	91.10	91.30
10.00	96.00	86.30	86.95
12.50	96.00	81.51	82.61
15.00	96.00	76.71	78.26

5.1.2 Accuracy Test

As shown in Figure 8, the developed ANPR system has successfully read the number plate. However, from the accuracy test, there are some images that cannot give the 100% perfect reading. One of the example which the system fail to read for certain characters is shown in Figure 9. Actually, there are few things that have to be considered. Based on observation through several tests, the algorithm sometimes confuse with characters “0” and “D”, “Q” and “8” and “B”, “H” and “M” and “W”. These problems occurred due to the shapes of those characters are very similar in binary form. Back to the problem as occurred in Figure 9, the fault happened on character “D” where the system read as character “0”. In order to avoid this problem to repeat, more training has to be done on the OCR software to make it intelligent enough to differentiate the characters mentioned above. There are situation where the system is failed to find the location of number plate. This problem is shown in Figure 10. Problem like this occurred due to poor of quality images since the localization process is depending on the quality of the captured image.

Figure 8 Perfect reading

Figure 9 Wrong reading for one character

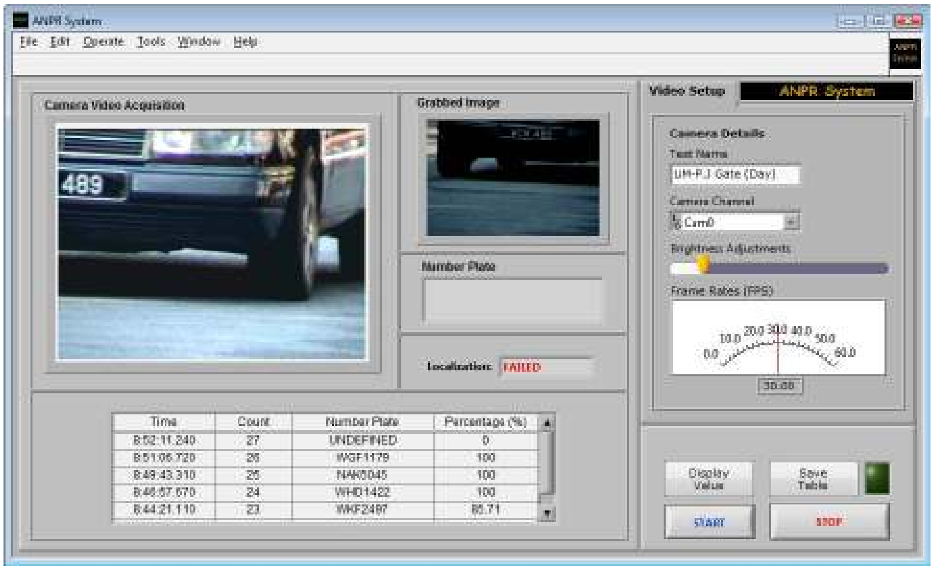

Figure 10 Failed to find number plate area

The analyses of the accuracy test results are based on aspects localization, single character reading and plate number recognition. The result for the accuracy test can be found in Table 2. Based on the accuracy test results, it is clear that percentages of all selected aspects are high. For the localization, only two dislocation of number plate occurred. The two dislocation of number plate is caused by the poor of quality images and the motion blur of images. This problem already discusses in previous test. In order to solve this problem, further research has to be done. Calculation of plate number recognition is based on the localization and single character reading. Only plates which have successfully been located are counted.

Table 2 Overall accuracy test result

Aspects	Number of Correct Reading	Percentage (%)
Localization	48/50	96.00
Single Character Reading	254/306	83.01
Number Plate Recognition	40/48	83.33

5.2 Reliability Test

Table 3 and Figure 11 show the reliability test result during the night time. Based on the results, the percentage of localization is low if compared with results in Table 2 which is during the day time test result. Since the quality of image during the night time is quite low, it caused the system failed to find the location of the number plate for certain captured images. However, the percentage result can be increased by enhancing the lighting and illumination system. Besides, the quality of image also influences the efficiency of character reading. If the image quality is low, so the percentage of character reading also low as can be seen in the Table 3. As mentioned previously, the calculation of plate number recognition is based on the localization and single character reading. In this case, the low percentage of single character reading gave low percentage on the number plate recognition. Based on the result, the obtained percentages are acceptable and developed ANPR system can be considered as reliable and robust.

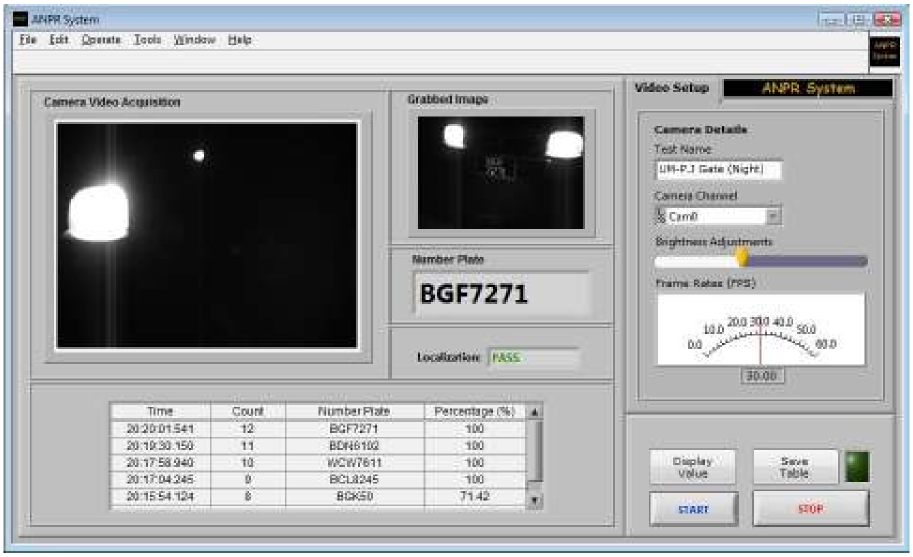

Figure 11 Reliability test during night time

Table 3 Reliability test during night time result

Aspects	Number of Correct Reading	Percentage (%)
Localization	39/50	78.00
Single Character Reading	180/247	72.87
Number Plate Recognition	28/39	71.79

5.3 Travel Time Measurement Test

To validate the measurement accuracy of travel time, a “test car” was running on the selected route where ANPR system is in operation. The “test car” was run for three times where the average measured travel time was 18.92s at average speed 35km/h. By comparing with the reference value measured manually, this value can be considered within the acceptable range. Figure 12 shows some of the result for travel time measurement using developed ANPR system when system is operated for 30 minutes while the Figure 13 shows the frequency diagram for vehicles’ space mean speed. Based on Figure 13, the vehicles traversed at the selected route at regular speed between 31 km/h to 33 km/h.

Figure 12 Travel time measurements

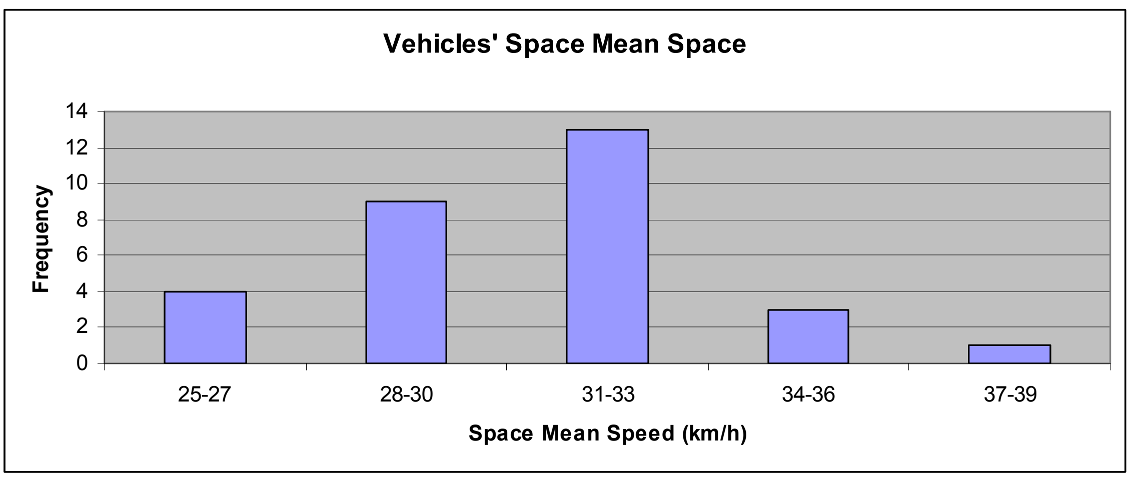

Figure 13 Vehicles' space mean speed

6. CONCLUSION AND FUTURE REMARKS

In this paper, the developed ANPR system obtained high percentage reading especially during day time. Even though the percentage reading during the night time test is lower than day time test, but the obtained results are acceptable and the developed ANPR system can be considered as reliable and robust. Besides, the developed ANPR system has ability to measure the travel time and space mean speed as well. This shows the potential of ANPR system to be used for transport planning, traffic engineering and traffic operation.

REFERENCES

A. Broumandnia, M. Fathy (2005), *Application of Pattern Recognition for Farsi License Plate Recognition*, Journal of Graphics, Vision and Image Processing, vol. 5, Issue 2, Jan. 2005.

Bertini, R.L., Lasky, M., Monsere, C.M. (2005), *Validating Predicted Rural Corridor Travel Times from an Automated License Plate Recognition System: Oregon's frontier project*, Proceedings of the 2005 IEEE Conference on Intelligent Transportation Systems, Sep. 13-15, 2005 pp. 296-301.

Chun-Hsin, W., Jan-Ming H., D. T. Lee (2003), *Travel Time Prediction wit Support Vector Regression*, Proceedings of the 2003 IEEE Conference on Intelligent Transportation Systems, 2003 – Shanghai, China: IEEE.

Coifman, B. (2002), *Estimating Travel Times and Vehicle Trajectories on Freeways Using Dual Loop Detectors,* Transportation Research: Part A, 2002, vol 36, no 4, pp. 351-364.

K. Kanayama, Y. Fujikawa, K. Fujimoto and M. Horino (1991), *Development of Vehicle-License Number Recognition System Using Real-Time Image Processing and Its Application to Travel-Time Management*, Proceedings 41st IEEE Vehicular Technology Conference, pp 798-804, 1991.

Kwon, J., Coifman, B., and Bickel, P. (2002), *Day-to-Day Travel Time Trends and Travel Time Prediction from Loop Detector Data*, Transportation Research Record no. 1717, Transportation Research Board, 2000, pp 120-129.

L. Eikvil, R.B Huseby (2001), *Traffic Surveillance in Real-Time Using Hidden Markov Models*, Proceedings 12th Scandinavian Conference on Image Analysis, Bergen, 2001.

Lee E.R., Kim P.K., Kim H.J. (1994), *Automatic recognition of a car license plate using color image processing,* Proceedings of IEEE International Conference on Image Processing, Austin, Texas., 2:301-305P.

Leonardo G. C. Hamey, Colin Priest (2005), *Automatic Number Plate Recognition for Australian*, Proceedings of the Digital Image Computing on Techniques and Applications, pp 14.

Nagaoka, K. (2000), *Travel Time System by using Vehicle Information and Communication System (VICS),* Proceeding of 1999 IEEE/IEEJ/JSAI International Conference on Intelligent Transportation Systems, 5-8 Oct. 1999 Page(s):816 – 819.

W.Wei, M.Wang (2001), *An automatic method of location for number-plate using color features*, IEEE International Conference on Image Processing, v 1, p 782-785.