Safat B. Wali*[1], Mahammad A. Hannan[1] and Shahrum Abdullah[2], Aini Hussain[1], Salina A. Samad[1]
[1]Dept. of Electrical, Electronic & Systems Engineering, [2]Dept. of Mechanical and Materials Engineering
Universiti Kebangsaan Malaysia, Malaysia.

doi:10.15199/48.2015.01.06

Shape Matching and Color Segmentation Based Traffic Sign Detection System

Abstract. *An automatic traffic sign detection system detects traffic signs from within images captured by an imaging sensor, and assists the driver to properly operate the vehicle. The idea presented here is through pixel value detection for hazard traffic signs containing red color background, computing in range regions and finally shape matching to choose the most appropriate traffic sign candidates to be drawn on the screen. The experimental result showed that, by comparing with the similar color segmentation based techniques, the proposed system has a higher accuracy of traffic sign detection rate with a lower computational time.*

Streszczenie. *W artykule opisano system automatycznego rozpoznawania znaków drogowych na podstawie sygnału czujnika obrazu. System rozpoznaje znaki na czerwonym tle, dopasowuje odpowiedni znak i wyświetla go na ekranie.* ***Automatyczny system rozpoznawania znaków drogowych bazujący na dopasowaniu kształtu i segmentacji koloru****.*

Keyword: Traffic sign detection; segmentation; shape matching; region detection.
Słowa kluczowe: rozpoznawanie znaków drogowych, dopasowanie kształtu, segmentacja koloru

Introduction

As the transportation system develops, the people give more attention to the safety issues of driving. For that reason the topic, automatic Traffic Sign Detection (TSD) system is becoming more popular among the researchers in recent years. It achieves one important application for advance driver assistance systems (ADAS). The traffic signs give us important information about the o way traffic for guiding the vehicle while moving in the street. In an adverse traffic condition, driver may not notice traffic signs may cause accident and that time traffic sign recognition (TSR) system come into action. Thus, the TSR system makes the driving safer and easier.

Developing a TSR system is a tedious job as the traffic sign is keep changing. There are some important issues such as; lighting condition differs according to the time of the day, season, cloudiness and other weather condition, etc. Blurring effect and fading of traffic signs are other challenging factors affecting the traffic sign detection. Multiple traffic sign appearing at a time and similar shape of man-made object also cause problem. Partial occultation and damaged traffic sign is also causing problem during detection. In addition, a fast algorithm is compulsory to run in the real time environment.

According to [1], the first work on automated traffic sign detection was reported in 1984. Since then, a number of different methods have been introduced for traffic sign recognition system. In [2], RGB colour segmentation and Laplacian of Gaussian (LoG) edge detector are used to assemble the red pixels. In [3], RGB colour is converted to HSV colour space to quantize into specific colours. Those colours are then projected in various axes which detects the position of traffic signs. Genetic Algorithm (GA) was used in [4]. To isolate character of a particular shape within an image Hough Transformation method can be used [5]. Space Vector matching and AdaBoost technique is now commonly used for detection and classification of traffic signs [6]. The Nearest Neighbour Classification is a straightforward type of classification process [7]. Most well known and useful method of recognition process is Neural Networks (NN) [8]. Our main vision is to detect the red traffic signs by reducing the processing time and increasing the accuracy using the combination of colour segmentation, shape matching and region detector techniques.

Methods and systems

The main idea is to use colour characteristic of the preferred object to speed up the procedure without employing model-based classifiers which take more processing time [9-11]. After filtering and analyzing the features of detected object, the candidates of traffic sign are selected based on the shape matching. The overall structure of proposed method for TSR is shown in Fig.1.

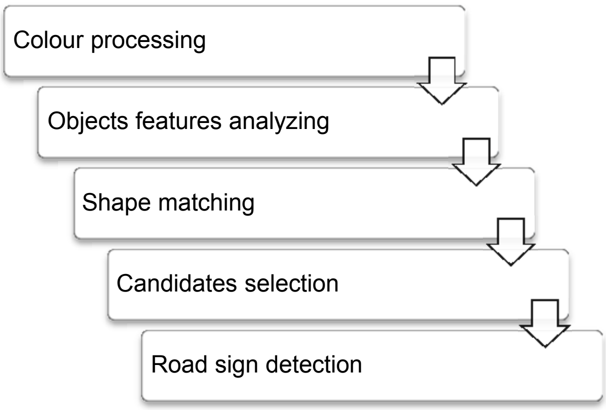


Fig.1. Structure of the proposed traffic sign detection method

In the proposed system, the input image is divided into three different channels R, G and B. A particular threshold level is applied to the test image and it is segmented in three different types, red colour segmentation, green colour segmentation and blue colour segmentation. The logical sum of these three channels can extract the desired region of interest (ROI). A Median filter is applied to smooth the image and to fill up the unexpected area. By defining a particular pixel value and above this value all the pixels of the test image are being filled up. After smoothing, based on longest width, centre and area the particular ROI is selected and marked. After applying this shape matching technique the desired traffic sign is detected. The overall block diagram of the system is shown in Fig. 2.

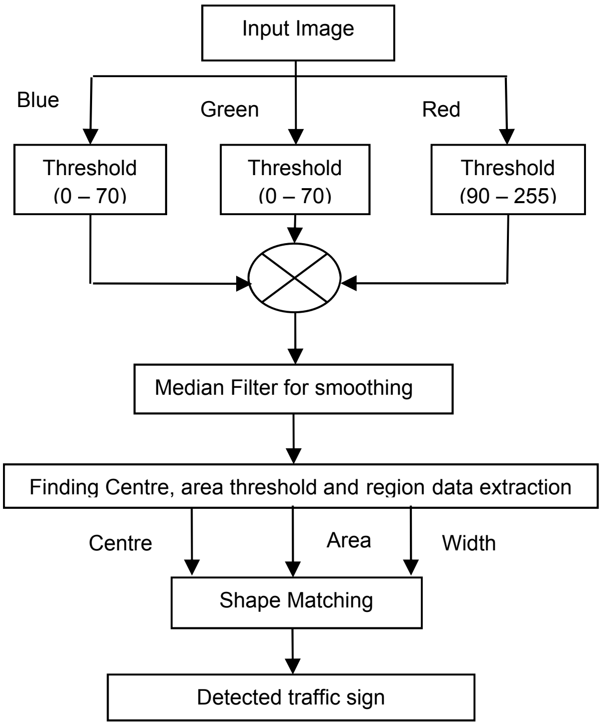


Fig.2. The overall block diagram of the system

RGB Colour Segmentation

The input image is in RGB, therefore it is divided into three channels R, G and B separately. RGB space is asymmetrical to colour perception. The variation of perception between two particular points of colour is unequal to the variation between them. Correlating particular colour in R, G and B honestly is the main difficulty.

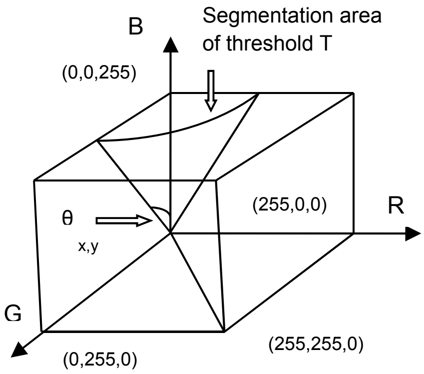


Fig.3. RGB colour space Segmentation

RGB colour space is considered as a vector field of R, G and B components where every point is resembles as a colour eigenvector of three-dimensional space. If P_1= (R_1, G_1, B_1) and P_2= (R_2, G_2, B_2) are two random non-zero colour eigenvectors and the angle between them is δ, then dot product of these two is:

(1) $$P_1.P_2 = \|P_1\| \|P_2\| \cos\delta$$

Coordinate equation is:

(2) $$P_1.P_2 = R_1R_2 + G_1G_2 + B_1B_2$$

Coordinate equation for vector modules are:

(3) $$\|P_1\| = \sqrt{R_1^2 + G_1^2 + B_1^2}$$

(4) $$\|P_2\| = \sqrt{R_2^2 + G_2^2 + B_2^2}$$

Bringing equation (2), (3) and (4) into (1) and transform,

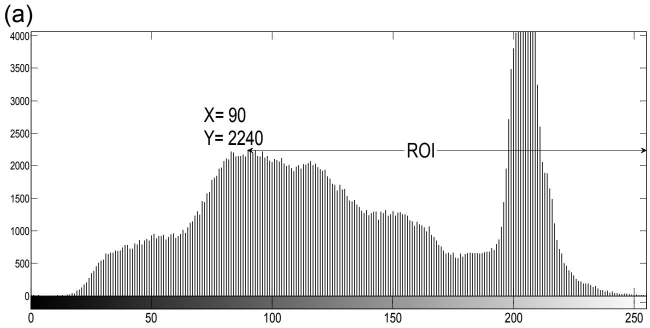
(5) $$\cos(\delta) = \frac{R_1R_2 + G_1G_2 + B_1B_2}{\sqrt{R_1^2 + G_1^2 + B_1^2}\sqrt{R_2^2 + G_2^2 + B_2^2}}$$

From the RGB colour space feature, we come to know that, the greater the angle δ of any two eigenvector means the greater in chroma difference causes less colour similarity between the two images. In our approach, on each channel threshold filters are applied to select just those regions of the image where values of the pixels are in the range of our target object. For example for traffic signs with red background (such as stop sign), the threshold for channel R is pixels with values in the range of 90-255 and for channels G and B is 0-70. The region of interest (ROI) is actually the logical sum of the three filtered channels of R, G and B is shown in Fig.4.

Fig.4. Colour processing for traffic sign detection: (a) Input image, (b) R channel after threshold, (c) G channel after threshold, (d) B channel after threshold and (e) Logical sum of three channels.

The image histogram of three channels R, G and B are given below:

(a)



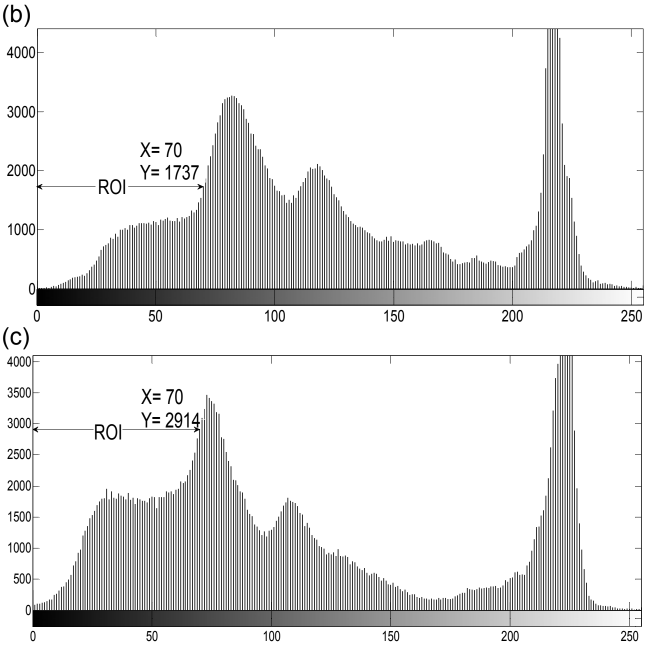


Fig.5. Image Histogram after thresholding of (a) R channel, (b) G channel and (c) B channel.

In Fig.5, for particular threshold value, the image segmentation is applied and these are the image histogram. Here in (a), for particular range threshold level started from X= 90 to X= 255 the Red channel defined and within the range for the red colour of traffic sign, the highest value in Y axis was found. So, somewhere within this ROI, the traffic sign is situated. Similarly in (b) and (c) for a defined range which is X= 0 to X= 70, we got a desired ROI.

Objects Features Analysing

One of the important steps is to eliminate noise from image therefore it would be easier to deal with ROI. Appropriate filters have an enormous effect on accuracy and speed of the procedure without deleting any useful information. In the proposed system Median filter was used to make the image smoother and according to the expected area of traffic signs, any smaller regions would be filled. The amount area range for road sign determines the distance which system could detect the traffic sign. Out of this area range, objects with the same range of pixels value cannot be traffic signs. In this level some crucial information which are centre, area and longest width of each region are calculated. This information is used to decide whether or not each region is traffic sign. In Fig.6, the output of this level is shown.

Fig.6. ROI after filtering and smoothing

Shape Matching and Candidate Selection

As almost all traffic signs are round or square, the proposed method used from this fact to detect hypothetical shapes which are close enough to traffic signs. Those regions with k in the range of 0.7-1.3 are accepted as candidates for traffic signs.

$$k = \frac{a}{\pi \times w^2}$$

Where a is the area of the region, w is the longest width.

The final selected candidates that have in range pixel value, area and shape are drawn on the image by using extracted data (centre and area) of each of them. Fig.7. are showed the detection steps and the detected traffic sign.

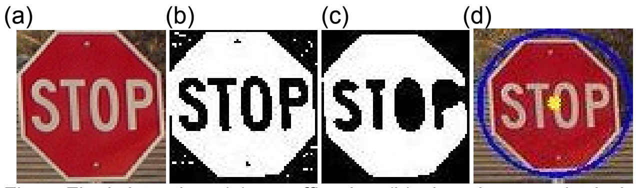


Fig.7. Final detection: (a) a traffic sign (b) closed curve obtain by colour thresholding (c) after filtering and smoothing the candidate (d) detected ROI after shape matching and candidate selection.

Result and discussions

To perform the proposed system on the image, Windows XP with Intel (R) Core (TM) 2 CPU 2.13 GHz and 1.97 GB of RAM was used. The system was developed by image processing toolbox of MATLAB R2007a using three methods, the colour segmentation, shape matching and region detection. In the Figure 1 the red colour of the traffic sign has been identified and segmented to white. In Figure 2 the probable place of finding the traffic sign has been identified after filtering and smoothing and in Figure 4 the resultant image of detected traffic sign was found.

We classify our result in 4 sections.

- False Positive Rate (FPR: The sign is not detected correctly.
- False Negative Rate (FNR): The sign is detected as a non-sign region.
- True Positive Rate (TPR): The sign is correctly detected.
- True Negative Rate (TNR): A non-sign region is correctly recognized as a non-sign region.

The detection performance of matching step is given in contingency matrix in Table 1.

Table 1. Contingency matrix of our sign detection method.

		Total
TP=105	FP=0	105
FN=18	TN=227	245
123	227	350

According to this data, the calculated sensitivity and specifity values are as follows:

- Sensitivity: $\frac{\mathrm{TP}}{(\mathrm{TP+FN})}$ = % 83.4
- Specificity: $\frac{\mathrm{TN}}{(\mathrm{TN+FP})}$ = % 100
- Accuracy: $\frac{(\mathrm{TP+TN})}{(\mathrm{TP+TN+FP+FN})}$= % 94.85

The results of our detected traffic sign in various lighting condition is given below in Fig.8.

(a) (b) (c)

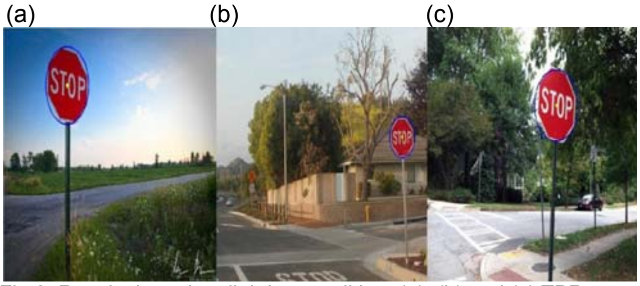


Fig.8. Results in variant lighting condition: (a), (b) and (c) TPR.

The image histograms of R, G and B of image (b) are given below:

(a)

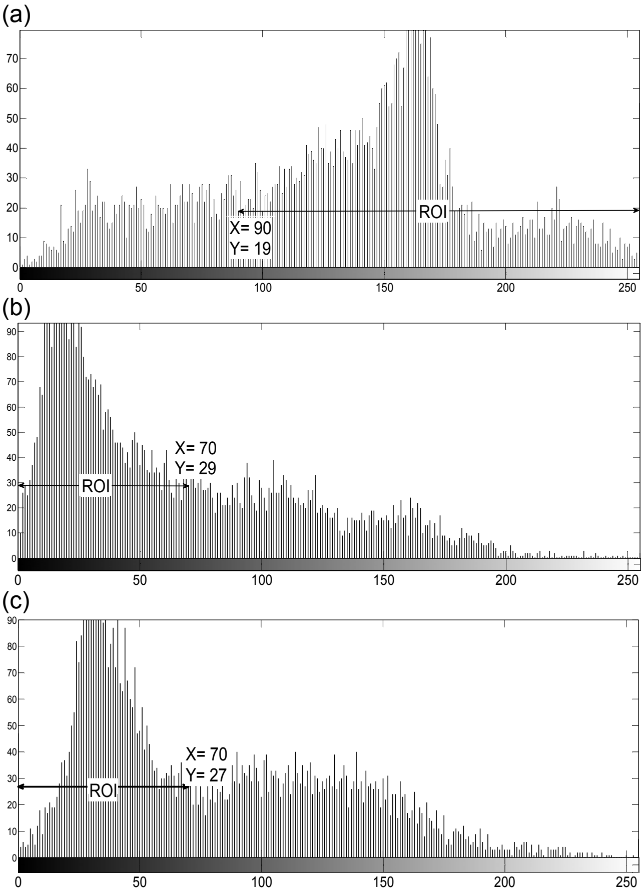


Fig.9. Image Histogram of (b): (a) Red channel (b) Green channel (c) Blue channel.

By comparing the image histogram of Fig.5 and Fig. 9, we can seen that, from the particular threshold level, the probability of finding the traffic sign is highest if the the imge is completely illuminated by those reasons which are explained earlier. Within the range of that threshold value, the highest value of the Y axis was found and this is the desired detected traffic sign.

a) (b) (c)

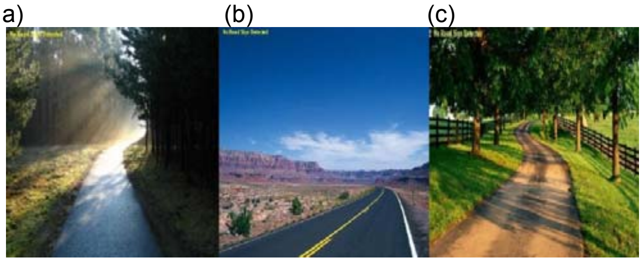


Fig.10. Results in variant lighting condition: (a), (b) and (c) TNR.

The image histogram of (a) is given below:

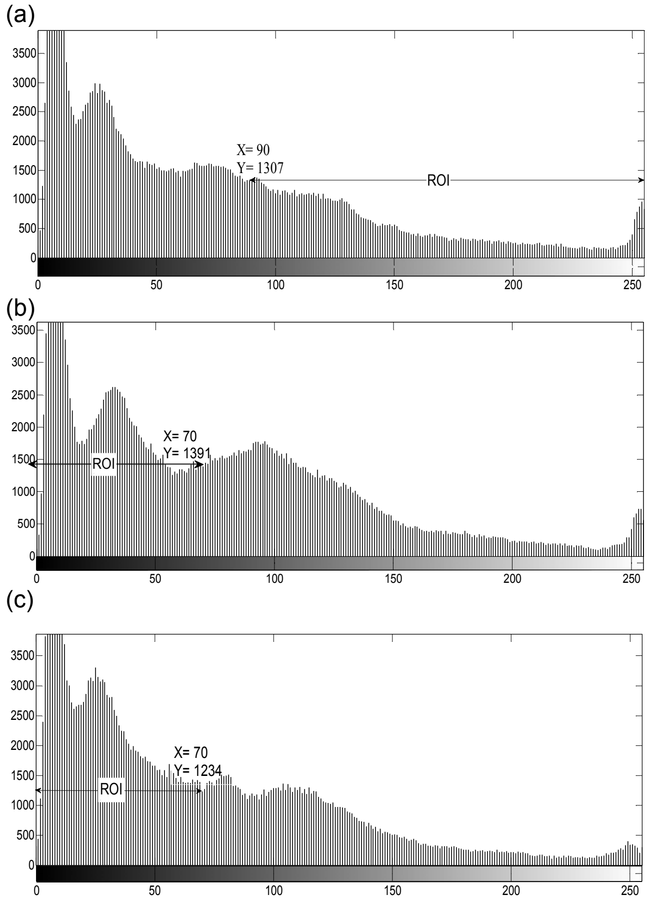


Fig.11. Image Histogram of (a): (a) Red channel, (b) Green channel, (c) Blue channel.

From Fig.11, we can see that, there is no particular region of traffic sign is found in that particular threshold level which is defined earlier. In our tests, several problems affected the detection performance. Variant lighting conditions, occultation and illumination of traffic signs are the main reasons. The false negative rates are shown in Fig.12.

Fig.12. Example of False Negative Rate (FNR)

The result shows that it can segment the red colour of the traffic sign which is unswervingly illuminated by the sun. This is happened because of the property of the colour segmentation using RGB model involves comparing the RGB values. In our system, we improve our computational time. And it is around 0.25s which is much less than the other methods. It is found that the traffic sign detection performance efficiency is 94.85%. A comparison of previous studies in detecting the traffic sign is given in Table 2.

Table 2. Results of some previous studies

STUDY	PROCESSING SPEED (sec)	DETECTION PERFORMANCE (%)
Gao et al. (2002)	0.475	89
Miura et al. (2000)	0.500	47
Alefs et al. (2007)	0.420	90
Ruta et al. (2010)	Not mentioned	92.90
Proposed Method	0.250	94.85

In [9], CIECAM97 is used to extract the traffic sign region and edge orientation histogram matching is used in [10]. In [11], color, local and global shape features and learning methods include local invariants statistical descriptors including color variation and wavelets are used for traffic sign detection and recognition. In [12], particular color enhancement technique is used and then specific edge maps are extracted by simple filters to detect the traffic signs. Then color distance transform is used to verify the candidates. The detection performance in [12] is 92.9%, which is quite high. Our proposed method has a higher detection rate and it is around 94.85%.

Conclusion

A robust system for traffic sign detection by combining three methods, color segmentation, region detection and shape matching is presented here. This system identifies traffic signs in different lighting condition and maybe somewhat distorted. Fast processing time is another key feature of this system. The evaluation of the system showed a promising performance. Currently in our proposed system, there are some deficiencies like ignoring other traffic sign except the sign containing red color and partial occlusion of traffic sign with other objects and partially illuminated traffic signs. These complexities for detecting the traffic sign will reduce in the future.

ACKNOWLEDGEMENT

This project was supported by Universiti Kebangsaan Malaysia under the grant number: UKM-AP-2011-13.

REFERENCES

[1] Paclik P., *ITS Intelligent Transport System*, [Online]. Available: http://euler.fd.cvut.cz/research/rs2/files/skoda-rs-survey.html (1999).

[2] Yang H.M., Liu C.L., Huang S.M., Traffic sign recognition in disturbing environments, *Proc. of ISMIS'03,* (2003), 28–31

[3] Hsien J.C., Chen S.Y. & Liuo Y.S., Traffic Sign Detection and Recognition Using Markov Model*, Asian journal of health and Information Sciences*, 1 (2006), 85-100

[4] Escalera A.D.L, Armingol J.M. & Mata M., Traffic Sign Recognition and Analysis for Intelligent Vehicles, *Image and Vision Computing*, (2003), 21

[5] Naguwi Y.-Y., Kouzani A.Z., A Study of Automatic Recognition of Traffic Signs*, IEEE Conference on Cybernetics and Intelligent Systems*, (2006)

[6] Ying L., Pankanti S., Guan, W., Real time traffic sign detection: an evolutionary study, *IEEE International Conference on pattern Recognition*, (2010)

[7] Escalera S., Radeva, P., Fast Grayscale Traffic Sign Model matching and Recognition*, Recent Advances in Artificial Intelligence Research and Development*, J. Vitria *et al.* (Eds.) IOS Press, (2004), 69-76

[8] Fistrek T., Loncaric S., Traffic Sign Detection and Recognition Using Neural Networks and Histogram based Selection of Segmentation Method, *53rd International Symposium ELMAR*, (2011)

[9] Gao X., Shetsova N., Hong K., Batty S., Podladchikova L., Golovan A., Shaposhnikov D., Gusakova V., Vision models based identification of traffic signs, *European conference on color in graphics, imaging, and vision*, (2002)

[10] Miura J., Kanda T. and Shirai Y., An active vision system for real-time traffic sign recognition, *proc of 2000 IEEE Int. Conf. on Intelligent Transportation* Systems, (2000), pp 52–57

[11] Alfes B., Eschemann G., Ramoser H., Beleznai C., Road sign detection from edge orientation histogram, *proc of 2007 IEEE Intelligent Vehicles Symposium*, (2007), pp 993–998

[12] Ruta A., Li Y. & Liu X., Real time traffic sign recognition from video by class-specific discriminative feature, *Pattern Recognition*, 43 (2010), no 1, 416–430

Authors: *The authors are with faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia. The corresponding e-mail: safat.2804@gmail.com*