Performance analysis of robust road sign identification

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Abstract. This study describes performance analysis of a robust system for road sign identification that incorporated two stages of different algorithms. The proposed algorithms consist of HSV color filtering and PCA techniques respectively in detection and recognition stages. The proposed algorithms are able to detect the three standard types of colored images namely Red, Yellow and Blue. The hypothesis of the study is that road sign images can be used to detect and identify signs that are involved with the existence of occlusions and rotational changes. PCA is known as feature extraction technique that reduces dimensional size. The sign image can be easily recognized and identified by the PCA method as is has been used in many application areas. Based on the experimental result, it shows that the HSV is robust in road sign detection with minimum of 88\% and 77\% successful rate for non-partial and partial occlusions images. For successful recognition rates using PCA can be achieved in the range of 94-98\%. The occurrences of all classes are recognized successfully is between 5\% and 10\% level of occlusions.

1. Introduction

In recent years, road sign identification system has attracted numerous research works with the possibility of using in autonomous or driver assistance system (ADAS). Research in road sign identification with occlusion, however, is still lacking. Many existing techniques that have been developed produce inaccuracy when dealing with occlusions. Even though the occurrences of road signs with the presence of occlusions are small, yet it is a problem that needs to be addressed.

Road sign gives vital information about the situation and conditions of the road. There are varieties of road signs utilized on the road and they are different in color and shape to represent road sign such as restrictions, prohibitions, warnings and obligations. The study aims to evaluate a system performance of the road sign identification system that able to detect and identify road signs in order to increase its accuracy and robustness. The identification of road signs can be divided into two main processes which are addressed as detection and recognition stages [1-3]. In detection stage, the candidates of possible road sign are extracted. Then, in the recognition stage, the specific type of road sign of the extracted candidates is recognized.
2. Literature review
According to Pazhoumand Dar and Yaghobi [4], road signs information can be illustrated using three features; shapes, color and pictogram. Khan et al. [5] stated that road sign detection becomes an important task for intelligent and autonomous vehicles in order to make the traffic regulation and guiding work smoothly. Road sign is normally detected based on their color or shape. Color model is the most popular approach in color segmentation technique. Amongst the existing techniques, the popular technique that has been widely used is Red, Green and Blue (RGB) color space. Hue, Saturation and Intensity (HSI) or Hue Saturation Luminance (HSL) has been used to segment the sign images and also has been recommended by other researchers [4].

The initial research on recognition of road sign has started in 1984. Basically PCA is widely used in face recognition. PCA is introduced in 1991. The principal component actually generates eigenfaces resulting from eigenvectors of the face image. Besides that, PCA also has been used in handling road sign of the partial occlusion situation. Implementing a robust road sign recognition system is not easy. A lot of conditions should be considered such as illumination conditions, orientation and condition of the road sign as well as occlusions on the road signs. Several important and the most dominant methods are artificial neural network (ANN), principal component analysis (PCA) and hidden Markov models (HMM).

3. Overview of the system
In this study, the focus is on road signs used in Malaysia. Sign identification is based on color and shape. A total of 12 types of road signs were used to form 403 images for detection and 600 images for recognition. These images were taken at night and daytime involving illumination and rotational changes as well as partial occlusions. The road sign was detected when the algorithm conducts the searching for the pixel data in the image based on its colors. Only colors of red, blue and yellow road signs are considered in the research. The algorithm is also able to detect more than one road sign in the frame.

3.1 Methodology
The dataset images consisted of 12 road sign classes. They are Uneven Road, No Entry, No-U-Turn, Right Junction, Give Way, Keep Both Side, Stop Sign, Keep Left, Left Junction, Speed Limit 30km/hr, Speed Limit 50km/hr and Speed Limit 60km/hr signs. These signs are chosen because they are the most common traffic signs in Malaysia. The images size used in the study are with a resolution of 500 x 667 pixels. The color space conversion is used where the images segmentation of the detection process is implemented using HSV color algorithm. A pixel is marked based on the hue, saturation and value ranges.

The recognition process using PCA is divided into two steps; training and testing processes. Based on the flow process of road signs recognition using PCA, the system starts with creating a training dataset folder. In order to make use the dataset that have been created, several pre-processing techniques are required so that the dataset can be easily performed in recognition stage.

To recognize road signs using the PCA technique, we have to produce a matrix for training and testing images. After we find the mean from training database image, we then calculate the covariance matrix. Then, we calculate the eigenvector and eigenvalue of the images respectively. Based on the eigenvector value of covariance matrix, we produce eigensign value which is then projected to sign space. Before we extract the feature vector, the input of training images are resized in two dimensional pixels and reshape to one dimensional vector. Then, the difference of values between the feature vector and the mean are computed. Finally, based on the minimum value of Euclidean distance that is produced from the difference of value of projected space, the system will be able to recognize the road signs. The flow chart of road sign recognition is illustrated in Figure 1.

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3.1.1 Pre-processing process of road sign image data set

Once the dataset is ready to be used, they will be converted from grayscale to binary image so that the processing step in feature extraction technique would be faster and easier. Figure 2 illustrates the technique of the image of no-u-turn sign is cropped, resized and converted to grayscale color using IrfanView program. Similarly, the process to resize the detected sign and convert to grayscale color using Matlab is shown in Figure 3. Once the image is resized in resolution size of 40 by 40 and converted to grayscale color, it is subsequently put in a testing folder. We did the similar process for training folder. The images in these folders consequently are used for training and testing process.

The database consists of road sign images in gray scale color with each image consists of resolution of 40 by 40 dimensions. Training data is set to 30 for each class and 20 signs for each class is set for testing data. Hence, 360 images are employed for training, while 240 images are for testing of the trained recognition system.

**Figure 1.** The workflow of road sign recognition using PCA

**Figure 2.** Image is manually cropped using IrfanView program.

**Figure 3.** Examples of partially occluded sign image is automatically resize and convert to gray scale color in detection stage.

3.1.2 Partial occlusion and rotational changes signs
In order to evaluate the performance of the system in partial occlusions, testing dataset comprised partial occlusion as well as rotational changes are utilized. The different percentage of occlusion in dataset is important as it will be used to see how robust the system is towards the severity of occlusions. Therefore, the percentage of partial occlusion \( O_p \) is calculated as follows:

\[
O_p = \frac{a_{op}}{t_{dm}} \times 100\%
\]

where \( a_{op} \) is the number of partial occlusion coverage on the candidate signs and \( t_{dm} \) is the total dimension of the pixels that represented as the whole of the candidate signs. The partial occlusion on each sign is set to maximum range of 44% coverage. The rotational changes on each signs are simply determined by setting it manually using IrfanView program. Figure 4 shows 20 test images for the No-Entry sign with their respective rotational degrees and partial occlusion values. The signs dataset will be subsequently used in recognizing road sign using PCA techniques.

![Figure 4](image-url)

\( \theta \) = degree of rotation, \( \Delta \) = percentage of occlusion

4. Result

4.1 Evaluation of Accuracy of Detection Stage

Table 1 shows the percentage of detection performance based on HSV color segmentations. Images are split into two parts; 131 images with occluded signs and 272 images are non-occluded signs. The detection accuracy is computed using the following equation:

\[
a_d = \frac{b_{sd}}{b_{td}} \times 100\%
\]

where \( b_{sd} \) is number of successful detected and \( b_{td} \) is the total number of detected images.

Based on Table 1, HSV produced minimum of 77% successful detection for occluded images. It shows very high detection accuracy with minimum rates of 88% on non-occluded images. This is due to the fact that HSV color ratio is invariant to illumination changes.
Table 1. Accuracy performance of HSV color space

| Sign          | Partial occlusion sign (131) | Non-occluded signs with rotational changes (272) | Detected sign | Percentage (%) |
|---------------|------------------------------|-----------------------------------------------|---------------|----------------|
|               | Partial occlusion sign       | Non-occluded sign                           |               |                |
| Red           |                              |                                               |               |                |
| Blue          |                              |                                               |               |                |
| Yellow        |                              |                                               |               |                |

4.2 Evaluation of accuracy of recognition stage

The result of the experiment carried out in the research is computed based on the percentage of accurately recognized road sign. The correctly recognized road sign is calculated by dividing the overall number of testing road sign database images and times by 100. Hence, the percentage of correctly recognized, \( s_r (%) \) is computed as below:

\[
s_r = \frac{y_r}{y_r} \times 100\%
\]

where \( y_r \) is number of correctly recognized sign and \( y_r \) is the total number of testing signs.

From the experiment conducted in this study, the percentage of road sign identification is described in Table 2. The result in the Table 2 indicates that PCA produces a better detection rate on every type of road signs tested. With a very low false rate, we can also say that PCA based recognition system is more robust towards occlusion. It shows that the technique using PCA has a high accuracy with a minimum of 94% classification rate of road signs.

4.3 Robustness to partial occlusion

The percentage of occlusion coverage on each sign are indicated into six ranges namely; 5%, 10%, 20%, 30%, 40% and more than 50% occlusions. Graph in Figure 5 illustrated the overall occurrences performance based on PCA techniques in recognizing occlusion signs.

As can be seen from the summary of recognition rates (%) in figure 5, 12 classes are successfully recognized with 5% and 10% occlusion. It is also produced strong recognition rates with at least 6 classes of signs can be recognized when the percentage of occlusion increased gradually. However the system falsely recognized road signs with mostly more than 50% occlusions mark and more than 16 degrees rotation.

Table 2. Accuracy performance of PCA technique

| Shape                  | Partially occluded road sign | Success | False |
|------------------------|------------------------------|---------|-------|
| No-entry               | 95                           | 5       |       |
| No-u-turn              | 96                           | 4       |       |
| Keep both side         | 97                           | 3       |       |
| Keep left              | 97                           | 3       |       |
| Speed limit 30km/hr    | 95                           | 5       |       |
| Speed limit 50km/hr    | 94                           | 6       |       |
| Speed limit 60km/hr    | 94                           | 6       |       |
Inverted triangular

| Shape         | Recognition Rate (%) |
|---------------|----------------------|
| Yield/Give away | 97                   |
| Uneven road    | 98                   |
| Right junction | 95                   |
| Left junction  | 96                   |
| Stop           | 97                   |

Diamond

| Shape | Recognition Rate (%) |
|-------|----------------------|
|       | 3                    |

Figure 5. Summary of recognition rates using the PCA technique

4.4 Recognition processing time

PCA is faster in the recognition process and widely used in other applications. Therefore, processing speed using PCA is suitable to be used in offline and real time basis. Real time implementation needs at least 30 frames per second of processing time. In this work, it is observed that the recognition processing time per frame using PCA is 0.0238s. Hence, the average processing time for 30 frames is only 0.714s which is comfortably less than 1s.

5. Conclusion

To sum up, a technique towards road sign detection and recognition using both HSV and PCA was presented in this paper. It shows that these algorithms able to identify the 12 road sign classes successfully. From the experiments conducted with dataset consisting of partial occlusions and rotations variants, we verified the performance of the proposed approach. It can be concluded that the percentage of accuracy using HSV robust and invariant to lighting conditions and PCA approachable to identify occluded images.

6. References

[1] Y. Y. K. Nguwi, A. Z., "A Study on Automatic Recognition of Road Signs," in Cybernetics and Intelligent Systems, 2006 IEEE Conference on, 2006, pp. 1-6.
[2] M. Sajjad Hosain, Mahmudul Hasan, M., Ameer Ali, M., Humayun Kabir, Md, & Shawkat Ali, A. B. M., "Automatic detection and recognition of traffic signs," in IEEE Conference on Robotics Automation and Mechatronics (RAM), 2010, pp. 286-291.
[3] K. Wen-Jia and L. Chien-Chung, "Two-Stage Road Sign Detection and Recognition," in Multimedia and Expo, 2007 IEEE International Conference on, 2007, pp. 1427-1430.
[4] H. Pazhoumand-Dar and M. Yaghobi, "DTBSVMs: A new approach for road sign recognition," in Proceedings - 2nd International Conference on Computational Intelligence, Communication Systems and Networks, CICSyN 2010, 2010, pp. 314-319.
[5] J. F. Khan, Bhuivan, S. M. A., & Adhami, R. R., "Distortion invariant road sign detection," in Proceedings - International Conference on Image Processing, ICIP 2009, pp. 841-844.