TRAFFIC-SIGNAGE DETECTION AND RECOGNITION BASED ON K-MEANS CLUSTERING AND SUPPORT VECTOR MACHINE CLASSIFICATION

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I would like to dedicate my thesis to my beloved parents, wife, and sister.

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ABSTRACT

Traffic signage detection and recognition are essential components in the intelligent vision based transportation system by which in-vehicle is able to recognize the traffic signage in various shapes and interpret the contents such as speed limit, stop, and yield. The main challenge of traffic signage detection and recognition is to find a way to extract specific information from an image and classify it to the right category. Since the traffic signage images may contain shading and noise, the quality of the images can be varied from one to another. Besides, machine learning kernel for signage recognition is compute-intensive and requires extremely long precessing time to classify an image. In this project, an intelligent traffic signage detection and recognition system which uses k-means as signage detection and support vector machine (SVM) as classification model is proposed. The objective of this project is to develop a color segmentation algorithm which is invariant to different illumination levels and to optimized the performance of recognition algorithm in term of speedup. The new model has successfully implemented in the software environment to compared its performance with existing works. Experimental results show an overall detection rate of 97.6% is achieved. The linear kernel outperforms the RBF kernel by 3% with 92% of correct classification rate. Combining all the modules, the single frame processing time is successfully speedup by 333× and the memory utilization is reduced by 99.8%. The proposed method has excelled the previous works and is preferable for future hardware implementation.

ABSTRAK

Pengesanan isyarat lalu lintas dan pengiktirafan adalah komponen-komponen penting dalam sistem pengangkutan pintar dimana kenderaan dapat mengenali tanda-tanda lalu lintas dalam pelbagai corak dan mentafsir isi kandunganya seperti had kelajuan, berhenti, dan beri laluan. Cabaran terutama dalam pengesanan isyarat lalu lintas adalah memperolehan maklumat tertentu dari imej dan mengelaskan kepada kategori yang betul. Imej isyarat lalu lintas mungkin mengandungi bayang and kekacauan signal, kualiti imej akan terjejas. Selain itu, *support vector machine* (SVM) kernel adalah amat intensif dalam pengiraan dan mempunyai masa precessing sangat panjang untuk mengelas imej. Dalam projek ini, pengesanan isyarat lalu lintas dan pengiktirafan sistem pintar yang menggunakan *k-means* sebagai sistem pengesanan isyarat lalu lintas dan SVM sebagai model klasifikasi telah dicadangkan. Objektif projek ini adalah untuk membangunkan satu algoritma segmentasi warna yang tak berubah ke tahap pencahayaan yang berbeza dan meningkatkan prestasi algoritma pengiktirafan dari segi kelajuan. Model yang baru init telah berjaya dilaksanakan dalam perisian dan dibandingkan dengan kerja-kerja lain yang sedia ada. Hasil uji kaji menunjukkan kadar pengesanan sebanyak 97.6% telah dicapai. Selain itu, kadar ketepatan klasifikasi linear kernel adalah sebanyak 92%, ini telah melebihi RBF kernel sebanyak 3%. Menggabungkan semua modul, kadar pemprosesan yang diambil telah berjaya meningkat sebanyak 333$\times$ dan penggunaan memori telah berjaya dikurangkan sebanyak 99.8%. Kaedah yang dicadangkan telah cemerlang kerja-kerja sebelum ini dan adalah lebih baik untuk pelaksanaan perkakasan pada masa depan.

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LIST OF ABBREVIATIONS

ADAC	-	Allgemeiner Deutscher Automobil-Club
AI	-	Artificial Intelligent
ANN	-	Artificial Neural Network
DtB	-	Distance to Blob
GPS	-	Global Positioning System
HSV	-	Hue, Saturation, and Value
Lab	-	Luminosity, Chromaticity-layer a, and Chromaticity-layer b
PCA	-	Principle Component Analysis
RBF	-	Radial Basis Function
RGB	-	Red, Green, and Blue
ROI	-	Region of Interest
SVM	-	Support Vector Machine
TSDR	-	traffic signage Detection and Recognition

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

Intelligent traffic signage detection and recognition (TSDR) is an essential component in modern vehicles, providing drivers with safety and precaution information. The visibility of traffic signage is important for driver's safety to indicate the state of the road, guiding and warning drivers. The first TSDR system was appeared in late 2008 on the redesigned BMW 7-Series, and the following year on the Mercedes-Benz S-Class (Figure 1.1). At that time, these systems were only able to detect the round speed limit signage found all across Europe [1] using a combination of cameras and maps. Objects detected by the cameras are matched with navigation-system maps for confirmation. Second generation systems are improved to detect no overtaking signage. The system is available on the 2011 Volkswagen Phaeton and 2012 Volvo, as a technology called traffic signage information.

Figure 1.1: TSDR system on BMW heads-up display and Mercedes-Benz [2].

The study of traffic signage recognition system has been of great interests for recent researches primarily on traffic signage classification. According to the

US Census Bureau in 2009 alone, 10.8 million motor vehicle accidents occurred resulting in almost 36 thousand fatalities. Hence, research on different types of TSDR solutions is very important in developing an accurate, reliable and cost effective traffic signage recognition system. Due to the complex outdoor environment, variations in weather, lighting conditions, and partial occlusions remain as the greatest challenge in vision based traffic signage recognition system. A test has been carried out by Allgemeiner Deutscher Automobil-Club (ADAC) on several existing TSDR systems. Results show that all systems are having problems with variable speed-limit signage that are increasingly used on major highways [2].

TSDR system can varies in two different ways based on the technology applies:

1. Distributed computing. A software based system that can be located on a network communication system by passing messages. The components interact with each other to obtain the traffic signage information.
2. Artificial intelligent (AI) and image processing. A hardware system that uses digital camera to detect physical signage and transforms the image to a recognizable feature via image processing.

Table 1.1 shows the characteristics of TSDR based on different technologies.

Table 1.1: Characteristics of TSDR.

Properties	**AI and image processing**	**Distributed computing**
Data Type	Physical signage and digital image	Digital data
Data Receiver	Digital camera	Network services
Environment	Hard environment	Soft environment
Technologies	AI and image processing	Distributed and pervasive application
Accuracy	Coarse classification	Refined classification
Feasibility	Feasible	Immature

This project is to implement a TSDR based on AI and image processing techniques. Despite distributed computing method can provide a refined recognition of traffic signage, the implementation requires related facilities and services, such as network services and global positioning system (GPS). In contrast, AI and image processing technology uses in-vehicle digital camera to capture live images. The focus of this project is mainly on the detection and recognition of signage. traffic signage classification uses SVM [3] for new instances and k-means clustering on L*a*b color space [4] for traffic signage detection are proposed.

Both detection and recognition algorithms are computationally expensive. Traffic signage detection usually needs to deal with very large and complex data sets (gigabytes or terabytes). This requires data mining algorithm that can cluster large amount of numeric and categorical values. To address this problem, k-means clustering algorithm is proposed [5]. On the other hand, Support Vector Machines work by translating non-linearly classifiable feature data into a higher-dimensional hyperplane where it is possible to classify the data in a simple, linear manner. The SVM classification suffers from linear dependencies on the number of support vectors and the problem's dimensionality. For large-scale problem like traffic signage image, the classification task can become very time consuming and have real-time constraints. Therefore, feature extraction or dimension reduction is essential to reduce the classification time while maintaining good accuracy.

1.2 State-of-the-Arts

From a high level perspective, the vision based TSDR system which uses AI and image processing technologies consists of 2 main blocks (detection module and classification module) as shown in Figure 1.2. The front camera on the interior mirror keeps track of traffic signage. Information recorded by the camera is sent to the detection module in the form of RGB image. Color segmentation is used for traffic signage detection to extract the object from background. If a traffic signage is detected in an image, only the traffic signage object is preserved and send to the classification module for recognition.

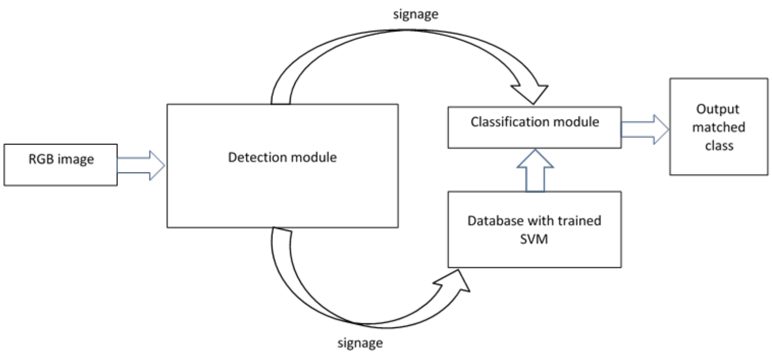

Figure 1.2: High level overview of proposed TSDR.

1.3 Problem Statement

Traffic signage present in unique colors and shapes to attract driver's attention and both characteristics determine the meaning of each traffic signage. Practically, traffic signage normally appears at the side of or above the roads as shown in Figure 1.3.

Figure 1.3: Speed limit traffic signage.

Traffic signage detection and recognition involves classification phase to identify the content of the extracted traffic signage using various data mining techniques. The captured images for recognition may contains shading, occlusion, under-illumination, over-illumination, noise, and undesired background that can result in failure of traffic signage recognition if the detection algorithm is not robust. Thus, taking advanced method to precisely pre-process the traffic signage information is essential to be able to extract the region of interest (ROI) and preserve the information for recognition in the later stage.

Color segmentation by shadow and highlight invariant algorithm is a widely used approach in TSDR [6] in which RGB image is converted to HSV color space . On the other hand, a method based on color information using fuzzy detection of the relevant hue and saturation components is proposed [7]. These algorithms work well on normal illumination conditions but deteriorate in low lighting conditions such as images obtained from night driving.

Apart from segmentation, classification is another major challenge in TSDR systems. The major issue of classification lies in learning of finding an optimal separation between classes and nearest neighbor approach to seek for similar training samples on huge number of attributes. Increasing of data size per training set and testing set requires expensive computation cost where it stretches the computational time significantly. On a limited processing capacity system, accuracy and efficiency have becoming a major problem in real-time application. Fixed size block of 28×28 pixels in gray-scale is used for candidate image [8]. This means the amount of attributes per training set and testing set is as many as 961. There is a need to reduce the feature vector dimension in order to improve the processing time. Motivated by both problems and advantages, this leads to develop a strategy to optimize the detection and recognition process.

1.4 Objective and Scope

1. To design a TSDR system that is able to detect and identify different signage over a considerable database. The system is expected to be able to accept a 640×480 RGB image and transform it into a form of data that is usable for classification.
2. To study and optimize the processing time of the proposed TSDR system. One of the main objective is to explore the total processing time of classification,

in millisecond, for gray scale representation. The test time is compared with simplified data set known as eigen vector representation. The results are analyzed to identify the compute-intensive component.

3. To analyze the overall accuracy and compare the proposed TSDR system with relevant published researches in term of accuracy. The traffic signage images generated from the detection model is tested on various SVM recognition model to compare the performance difference from various aspects. Besides, the overall detection rate of the k-means clustering is studied to understand the invariance properties of the proposed color space.

1.5 Scope of Work

In this project, a traffic signage detection and recognition system is developed. The system consists of 3 stages as shown in Figure 1.4

1. Traffic regulatory signage detection by color segmentation using k-means clustering to extract the targeted color of the specific traffic signage. Color is a distinct property of traffic signage making them easily distinguish from other objects, thus color information is used for signage detection.
2. SVM is a compute-intensive algorithm, instead of testing and training a full scaled image, feature extraction by Principle Component Analysis (PCA) is applied to reduce the size of the data for SVM classifier in order to achieve higher throughput in shorter time.
3. At this final stage, the extracted signage is classified in a supervised learning machine to categorize the traffic signage according to their shapes and inner contents. Support Vector Machine (SVM) learning machine [3] is chosen due to its advantages comparing to neural network [1].

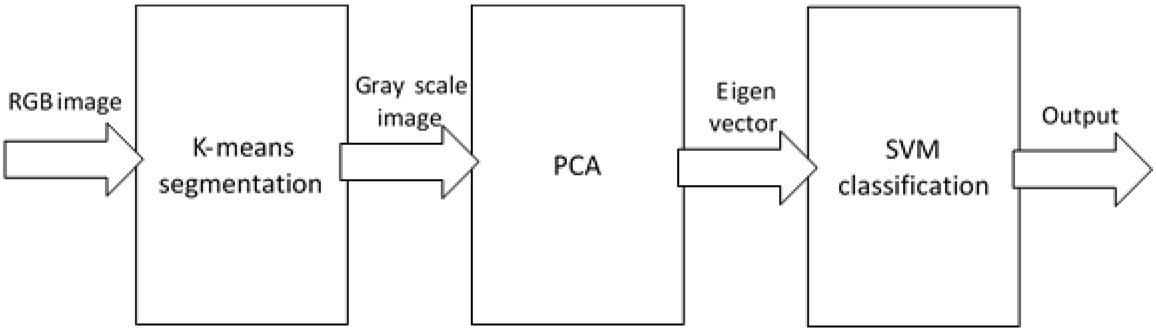

Figure 1.4: Sequence of TSDR system.

The experiments is conducted on European traffic signage in the form of triangle, octagon, and circle. The traffic signage in each image is extracted by exploiting color segmentation algorithm. Next, the extracted signage are sent for classification and the output is analyzed the to assess the overall accuracy. As for the performance analysis, reduced dimension method is used to train and test the SVM recognition model. The output of the SVM decision function is analyzed and compared with the existing designs. Figure 1.5 and Figure 1.6 shows the some example of Swedish road traffic regulatory signage.

Figure 1.5: Swedish road traffic signage - warning signage [9].

Figure 1.6: Swedish road traffic signage - prohibitory signage [9].

1.6 Organization

This thesis consists of five chapters. The first chapter gives an overview of the project as well as the problem statements and objectives of the project.

Chapter 2 covers the literature review and discuss on the researches of k-means and SVM algorithm.

Chapter 3 covers the system overview of this project. It describes the various modules development and basic operation of each module. All two modules and enhancement will be described briefly in this chapter.

Chapter 4 will discuss on the system architecture and research methodology. Detection and recognition modules development and basic operation of each module will be explained in detail.

Chapter 5 explains the results and analysis of each experiment. The improvement in system performance is also discussed in this chapter.

Chapter 6 summarized the project outcome. Future works are suggested to further enhance the design.

REFERENCES

1. M. L. Eichner and T. P. Breckon, "Integrated Speed Limit Detection and Recognition from Real-Time Video," *IEEE Intelligent Vehicles Symposium*, no. 10220151, pp. 626–631, 2008.
2. "ADAC: Car IT," December 2010.
3. S. Maldonado-Bascon, S. Lafuente-Arroyo, P. Gil-Jimenez, H. Gomez-Moreno, and F. Lopez-Ferreras, "Road-Sign Detection and Recognition Based on Support Vector Machines," *IEEE Intelligent Transportation Systems*, no. 9490284, pp. 264–278, 2007.
4. G. Siogkas and E. Dermatas, "Detection, Tracking and Classification of Road Signs in Adverse Conditions," *IEEE Electrotechnical Conference*, no. 9075001, pp. 537–540, 2006.
5. Z. Huang, "Extensions to the k-Means Algorithm for Clustering Large Data Sets with Categorical Values," *Data Mining and Knowledge Discovery*, vol. 2, pp. 283–304, 1998.
6. H. Fleyeh, "Shadow And Highlight Invariant Colour Segmentation Algorithm For Traffic Signs," *IEEE Cybernetics and Intelligent Systems*, no. 9220901, pp. 1–7, 2006.
7. C. Paulo, "Automatic Detection and Classification of Traffic Signs," *IEEE Image Analysis for Multimedia Interactive Services*, no. 9863768, p. 11, 2007.
8. S. Perez-Perez, S. Gonzalez-Reyna, S. Ledesma-Orozco, and J. Avina-Cervantes, "Principal component analysis for speed limit Traffic Sign Recognition," *IEEE Power, Electronics and Computing*, no. 14026194, pp. 1–5, 2013.
9. "Wiki: Road signs in Sweden."
10. H. Fleyeh, "Road and Traffic Sign Detection and Recognition," *Proc. 10th EWGT Meet./16th Mini-EURO Conf.*, pp. 644–653, 2005.
11. T. Kanungo, D. Mount, N. Netanyahu, and C. Piatko, "An Efficient k-Means Clustering Algorithm: Analysis and Implementation," *IEEE Pattern Analysis*

and Machine Intelligence, vol. 24, no. 7324832, pp. 881–892, 2002.

12. V. Faber, "Clustering and the continuous k-means algorithm," *Los Alamos Science*, pp. 138–144, 1994.

13. M. Shi, W. Haifeng, and H. Fleyeh, "Support Vector Machines for Traffic Signs Recognition," *IEEE Neural Networks, IEEE World Congress on Computational Intelligence*, no. 10365646, pp. 3820–3827, 2008.

14. "Wiki: Support Vector Machine."

15. "H. Fleyeh. Traffic Signs Database [Online]," November.

16. S. Vij, I. Amritsar, S. Sharma, and C. Marwaha, "Performance Evaluation of Color Image Segmentation Using K means Clustering and Watershed Technique," *IEEE Computing, Communications and Networking Technologies*, no. 14063478, pp. 1–4, 2013.

17. L. Chengjun, "Gabor-based Kernel PCA with Fractional Power Polynomial Models for Face Recognition," *IEEE Pattern Analysis and Machine Intelligence*, vol. 26, no. 8004314, pp. 572–581, 2004.

18. M. Turk, "Eigenfaces for Recognition," *IEEE Cognitive Neuroscience*, vol. 3, no. 0898-929X, pp. 71–86, 1991.

19. "LIBSVM: a Library for Support Vector Machines," November 2006.