A Computer Vision Based Vehicle Detection and Counting System

Nilakorn Seenouvong[1] , Ukrit Watchareeruetai[2] and Chaiwat Nuthong[3]
International College,
King Mongkut's Institute of Technology Ladkrabang
Chalongkrung Road, Ladkrabang, Bangkok 10520, Thailand
57610019@kmitl.ac.th[1], ukrit@ieee.org[2],
chaiwat.nu@kmitl.ac.th[3]

Khamphong Khongsomboon
Department of Electronic and Telecommunication Engineering,
Faculty of Engineering, National University of Laos
Lao-Thai Road, Sokpaluang Village, Sisattanark District,
Vientiane Capital, Laos
khongsomboon@fe-nuol.edu.la

Noboru Ohnishi
Graduate School of Information Science
Nagoya University
Furo-cho, Chikusa-ku, Nagoya-shi 464-8601 Japan
ohnishi@is.nagoya-u.ac.jp

***Abstract*—A vehicle detection and counting system plays an important role in an intelligent transportation system, especially for traffic management. This paper proposes a video-based method for vehicle detection and counting system based on computer vision technology. The proposed method uses background subtraction technique to find foreground objects in a video sequence. In order to detect moving vehicles more accurately, several computer vision techniques, including thresholding, hole filling and adaptive morphology operations, are then applied. Finally, vehicle counting is done by using a virtual detection zone. Experimental results show that the accuracy of the proposed vehicle counting system is around 96%.**

Keywords- vehicle detection; vehicle counting; virtual detection zone; computer vision

I. Introduction

Traffic problem is an important issue happening in many cities in the world. There are many important causes of the traffic problem. The number of people moving into an urban area has grown substantially, leading to a dramatic increase in the number of vehicles. However, roadway capacity has grown relatively slow and become insufficient. This causes an imbalance between the numbers of vehicles and roads, resulting in road traffic congestion, especially in large cities. An inadequacy of public transportation systems also causes the same problem. Another cause is an inefficient traffic administration due to a lack of real-time traffic information. The traffic problem mentioned earlier seems to be more severe in the future if it is not solved appropriately.

Nowadays, computer vision—an analysis and interpretation of images and videos captured by a digital camera—has gained more popularity and been used in many fields including industry, robotics, medicine, etc. Computer vision has also been applied for solving traffic and transportation problems. For example, a video sequence of road can be processed and analyzed to detect and count vehicles. Further information, such as the speed of a vehicle or traffic density, can also be calculated by using computer vision. This would directly benefits to two groups of people: road users and traffic administrations. If road users know the real-time traffic information, they can then use the information to choose the best way for traveling and can avoid traffic congestion. On the other hand, traffic administrations can utilize the traffic information in their traffic control systems, resulting to a better traffic management.

There are several methods for vehicle detection and counting proposed so far. Li et al. [1] proposed a real-time vehicle detection, tracking, and counting system. Their proposed system, firstly, used an adaptive background subtraction technique to detect moving objects in a video. Secondly, it performed a binarization process to obtained foreground area, followed by morphological operations to remove noise and shadow. Thirdly, to avoid an over-segmentation problem, the foreground image obtained from the previous step was integrated with the edge image of the same frame, before applying a hole filling process. Then, vehicles were detected and counted by using a detector virtually located on the road. Finally, a blob tracking was done to match vehicles in the current frame and those in the previous frame. Bhaskar and Yong [2] proposed a vehicle detection and tracking method using Gaussian mixture model (GMM) together with a blob detection technique. In particular, GMM was trained to model the background, and was then used to extract foreground pixels based on the Mahalanobis distance. Morphological operations were then applied to remove noises and to combine blob fragments together. Next, a blob analysis was done to identify vehicle blobs. Finally, counting and tracking were done. Kryjak et al. [3] presented a hardware-software system for vehicle detection and counting at road

978-1-4673-8139-0/16/$31.00 ©2016 IEEE

intersections, in which two popular techniques, i.e., background subtraction and optical flow, could not be used to detect vehicles stopping by a red signal. Instead, three similarity measurements of the area around a detector in two consecutive frames were used to detect the presence of vehicles. Patch analysis was then performed to determine the number of vehicles in the detector area. Liu et al. [4] proposed a real-time vehicle counting methods based upon virtual detection line and spatio-temporal contour techniques. Specifically, GMM was used to detect moving foreground pixels on the detection line in each frame. By combining this information of several consecutive frames, a contour of a vehicle in the spatio-temporal domain could be constructed. This contour was then analyzed to determine the number of vehicles. Some other algorithms for shadow detection and shadow removal were proposed in [5,6].

This paper proposes a method of vehicle detection and counting system based on a computer vision technology. Firstly, a background subtraction technique is used to find an image of foreground objects. Secondly, a region of interest in the image is then processed by several techniques, including adaptive morphological operations, to remove noises and enhance foreground objects. Next, the centroid of each foreground object is calculated and used to represent the position of a vehicle. Finally, vehicles in a predefined virtual detection zone are recorded and counted.

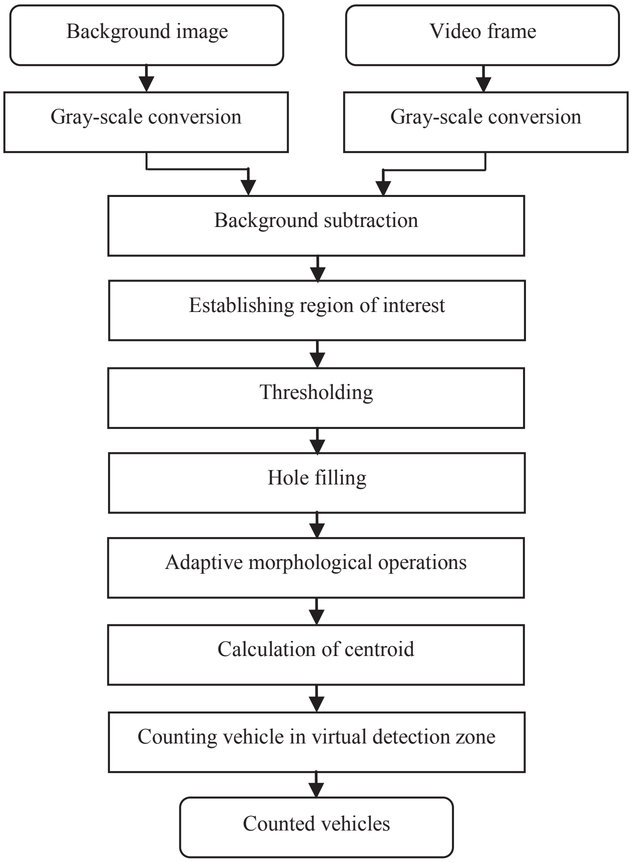
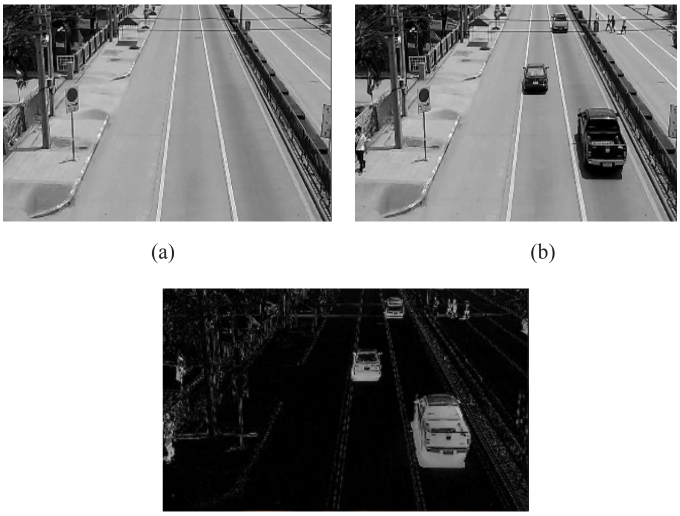
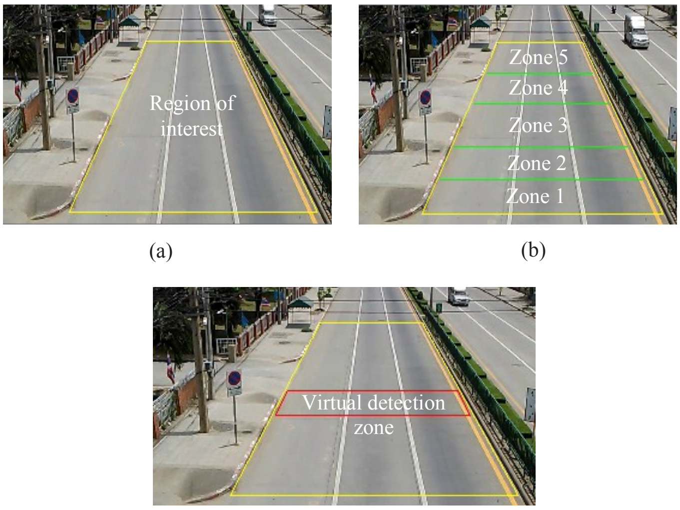


Fig. 1 Fowchart of the proposed method



(a) (b) (c)

Fig. 2 Foreground extraction: (a) background frame (b) current frame (c) difference image



(a) (b) (c)

Fig. 3 Establishing conditons for vehicle detection and counting system: (a) region of interest (b) divide to each zone (c) virtual detection zone

The rest of this paper is organized as follows. Section 2 describes the proposed method for vehicle detection and counting. Section 3 presents experimental results and discussion. Section 4 concludes the paper.

II. PROPOSED METHOD

This section describes the details of the proposed method. The flowchart of the proposed method is shown in Fig. 1. The detail of each step will be given in the following subsections.

A. Foreground Extraction

A background subtraction technique is used to firstly detect pixels that would belong to a moving vehicle. In particular, a background image of the road, which contains no vehicle, and the current frame in the video are converted from color (RGB) to gray-scale image (Fig. 2(a) and Fig. 2(b)). Then, for each pixel (x, y), the gray intensity of the background image is subtracted by that of the current frame. The absolute result is stored into the same position in another image, which is called a difference image (Fig. 2(c)).

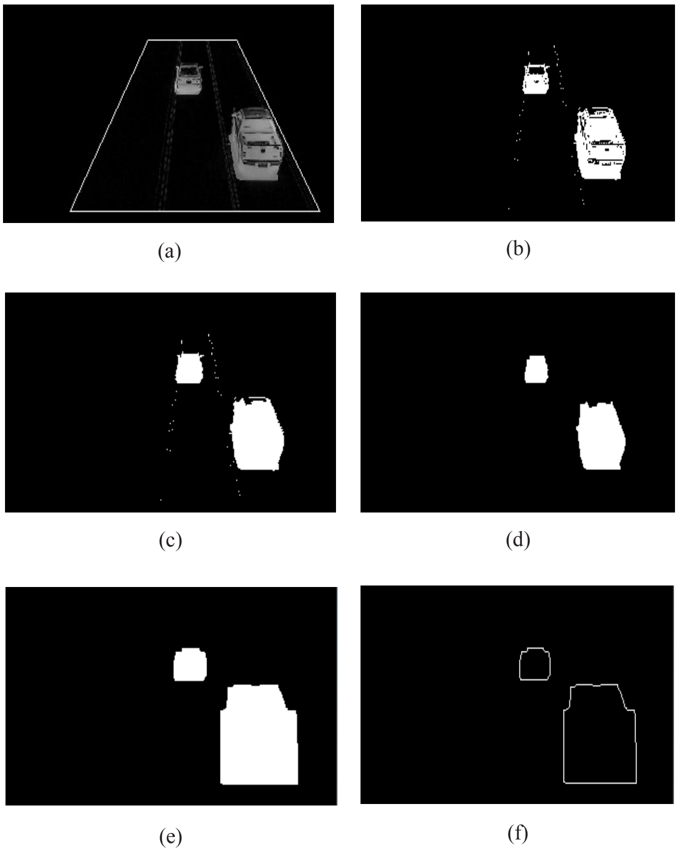


Fig. 4 Vehicle detection: (a) differnce image in ROI (b) binary image (c) hole filling image (d) eroded image (e) dilated image (f) vehicle contour

B. *Establishing the Region of Interest*

A region of interest (ROI), which will be further processed, is defined, as shown in Fig. 3(a). The ROI is divided into five zones, as shown in Fig. 3(b). Each will be processed differently in the following steps. Moreover, another zone, called a virtual detection zone, is predefined for vehicle counting. As shown in Fig. 3(c), the virtual detection zone is located inside zone 3 which is the middle part of ROI.

C. *Vehicle Detection*

In this step, only pixels in the ROI are considered while the others are deleted (Fig. 4(a)). Thresholding operation is applied to the difference image to separate foreground pixels from background pixels based on their intensity. If the intensity of a pixel in the difference image is greater than a predefined threshold value, it will be set to 255 (white); otherwise, it will be set to 0 (black). The threshold value in this paper is chosen to be 50. The result after thresholding operation, which is a binary image, is shown in Fig. 4(b).

It is noted that at this step, the binary image contains both spurious and missing foreground pixels. Therefore, a number of techniques are used to remove noises and enhance foreground objects. Firstly, hole filling operation is applied to remove black pixels enclosed by white regions. The image after hole filling process is shown in Fig.4 (c). Then, morphology operations are used to remove noises and some fail regions in the image. In particular, small foreground objects are converted into background by morphological erosion operation with a rectangle structuring element of size 3×3. The result after erosion operation is shown in Fig. 4(d).

Next, an adaptive morphological dilation is applied to recover some missing foreground pixels and to connect foreground fragments together. Here, a rectangle structuring element is also used but its size is adaptively chosen based on the zone defined in Section II-B. The size of structuring element is set to be 13×13, 11×11, 9×9, 7×7 and 5×5 rectangles, for zones 1 to 5, respectively. It is observed that foreground objects become smoother, clearer and more appropriate for detection and counting process. Fig. 4(e) is the result after adaptive morphological dilation. The contours of each foreground object is then extracted (Fig. 4(f)). This information will be used in the next step for vehicle counting.

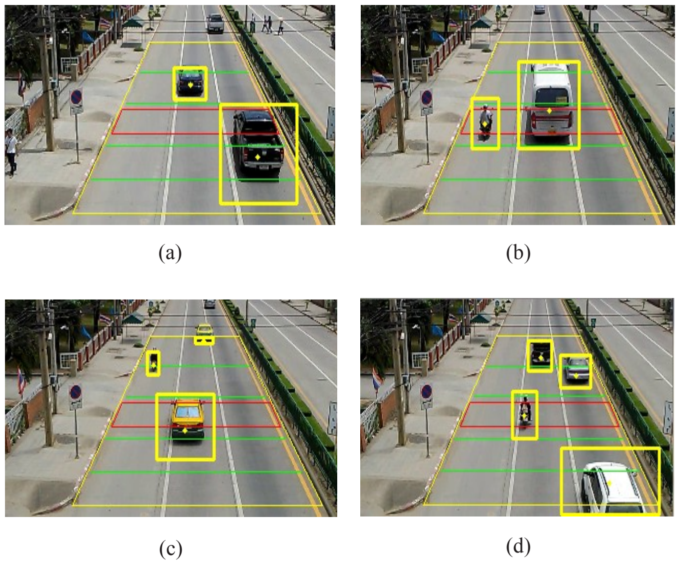


Fig. 5 Vehicle counting: (a), (b), (c) and (d) examples of vehicle counting

D. *Vehicle Counting*

After vehicle contours are obtained, the virtual detection zone defined in Section II-B is used to count the vehicles. The height of the virtual detection zone in this paper is set to 21 pixels. The centroid of each foreground object is calculated and tracked. When the centroid of a vehicle is detected for the first time, normally in zones 1 or 2, its status is set to 0 (have not been counted). Then its position is tracked. If it reaches the virtual detection, its status will be set to 1 (counted), indicating that it has been counted and will not be counted in the subsequent frames. The examples of vehicle counting are shown in Fig. 5.

III. Experimental Results and Discussion

To collect a database of road videos, a digital camera was set-up on a flyover. Seven input videos of road, around three to seven minutes, were recorded during 10 am to 2 pm. The spatial resolution of the recorded videos was 1280×720 pixels, with temporal resolution of 30 frames per second.

The proposed method was implemented in C++ language using OpenCV library [7]. An experiment was done to measure the accuracy of vehicle detection. In particular, when an input video was fed into the proposed method, the number of vehicles detected by the proposed method would be shown and be compared with those obtained by a manual counting (ground truth). The experiment was done on a laptop powered by an Intel(R) Core i5 (1.7-2.4 GHz) CPU and 4 GB RAM.

Experimental results are shown in Table I. The accuracy of the proposed vehicle counting method varied from 95-99%, depending on the input videos. It suggests that the proposed method could perform quite well on every tested video. In total, 646 vehicles out of 667 in all seven input videos could be detected, resulting in an accuracy of 96.85%.

TABLE I. Experiment Results

Video no.	***Total number of vehicles***	***Number of counted vehicles***	***Accuracy (%)***
1	111	106	95.49
2	107	103	96.26
3	113	112	99.11
4	60	59	98.33
5	114	109	95.61
6	91	89	97.80
7	71	68	95.77
Total	667	646	96.85

IV. Conclusion

This paper presented a detailed description of using computer vision techniques to vehicle detection and counting system. To achieve the goal, firstly, we used background subtraction technique to find foreground objects in each frame in video. Second, to perform vehicle detection and counting accurately, we established conditions to manage vehicle's blob through the controlling the region of interest, divided to each zone for to detect and count vehicle. Then, several computer vision techniques, including thresholding, hole filling, morphology operation, were applied to remove noise and to enhance foreground objects. Next, we extracted the contour of detected foreground objects and calculated their centroids. Finally, the vehicles were detected and counted when their centroid passed into the virtual detection zone. Experimental results showed that the accuracy of the proposed vehicle counting method was 96%.

It should be noted that there are limitations of the proposed method to be concerned with. Firstly, the vehicles appeared in the video are assumed to be clear and not occluded inside the virtual detection zone and secondly, the width of the virtual detection zone should be large enough for counting the vehicles. Furthermore, there are additional vehicles' features to be taking into account for vehicle detection in various setups. These issues will be the major concerns in the future work.

Acknowledgment

This work was supported by King Mongkut's Institute of Technology Ladkrabang Research Fund (KREF015808).

References

[1] D. Li, B. Liang and W. Zhang, "Real-time moving vehicle detection, tracking, and counting system implemented with OpenCV," Proceedings of 4th IEEE International Conference on Information Science and Technology (ICIST), pp.631–634, April 2014.

[2] P.K. Bhaskar and S.P. Yong, "Image processing based vehicle detection and tracking method," Proceedings of 2014 International Conference on Computer and Information Sciences (ICCOINS), pp.1–5, June 2014.

[3] T. Kryjak, M. Komorkiewicz and M. Gorgon, "Hardware-software implementation of vehicle detection and counting using virtual detection lines," Proceedings of 2014 Conference on Design and Architectures for Signal and Image Processing (DASIP), pp.1–8, October 2014.

[4] Y. Liu, G. Li, S. Hu and T. Ye, "Real-time detection of traffic flow combining virtual detection-line and contour feature," Proceedings of 2011 International Conference on Transportation, Mechanical, and Electrical Engineering (TMEE), pp. 408–413, December 2011.

[5] B. Jianyong, Y. Runfeng and Y. Yang, "A novel vehicle's shadow detection and removal algorithm," Proceedings of 2nd International Conference on Consumer Electronics, Communication and Networks (CECNet), pp.822–826, April 2012.

[6] Y. Lu, H. Xin, J. Kong, B. Li and Y. Wang, "Shadow removal based on shadow direction and shadow attributes," Proceedings of International Conference on Computational Intelligence for Modelling, Control and Automation, 2006 and International Conference on Intelligent Agents, Web Technologies and Internet Commerce, pp.37–37, November-December 2006.

[7] L. Robert, "OpenCV 2 Computer vision Application Programming Cookbook," May 2011.