AUTOMATIC DETECTION AND TRACKING OF MOTORCYCLES AND CARS FROM MIXED TRAFFIC FLOW

Hiromasa KUBO[1] and Junichi SUSAKI[2]

[1]Student, Department of Civil and Earth Resources Engineering, School of Engineering, Kyoto University
C1-1-209, Kyotodaigakukatsura, Nishikyo-ku, Kyoto 615-8540, Japan
E-mail: kubo.hiromasa.83e@st.kyoto-u.ac.jp

[2]Associate Professor, Department of Civil and Earth Resources Engineering, School of Engineering, Kyoto University,
C1-1-206, Kyotodaigakukatsura, Nishikyo-ku, Kyoto 615-8540, Japan
E-mail: susaki.junichi.3r@kyoto-u.ac.jp

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Abstract: In many cities of Southeast Asia, motorcycles constitute a higher percentage of traffic flow. A safety policy for traffic flow mixed with motorcycles and cars is needed. However, traffic monitoring systems are insufficient that automatically detect the mixed traffic flow because of frequent occlusion of vehicles. Therefore, vehicles are manually detected from video images in most of the previous studies. In this study, we propose a method to automatically detect and track vehicles from video images. First, two kinds of background image are generated; long-term background and short-term background. Next, foreground image is generated by subtracting background for each frame and it is converted into binary data. Stopped vehicles are detected using the two background images, and moving vehicles are detected using the short-term background and the original image. Then, the vehicle region is detected by applying template matching. The templates of vehicles, car and motorcycle, are manually generated from images. Finally, a vehicle is traced by connecting common regions identified between the consecutive frames. In case of failure of vehicle detection at a frame, the track is interpolated using previous and following frames. As a result of experiments to apply the proposed method to images take in Hanoi, Vietnam, it was found that the accuracy of the detected vehicle numbers was more than 80% and template matching approach is robust to occlusion found in the mixed traffic flow in Hanoi. For future works, the algorithm will be improved in terms of the estimation accuracy of vehicle detection and processing time.

1. INTRODUCTION

In many cities of Southeast Asia, motorcycles are mainly used as an urban transportation mode. Recently, as economic grows the proportion of passenger cars have also increased and the traffic flow situation where motorcycles and cars are mutually mixed has been realized. Because such kind of mixed traffic situation is quite unique to Southeast Asian cities, the usual traffic management and operation systems for the traffic flow composed of cars are not suitable. Consequently, both traffic efficiency and safety is badly lost. Thus it is pointed out that mixed traffic situation without any improvement can be a great menace to human security in Asian urban cities. To improve this situation, some policies and measures have been proposed and practically installed. However, these methods are mainly car oriented traffic managements, not suitable for the situation mixed many motorcycles. Therefore, it is necessary to understand the characteristics of motorcycle oriented mixed traffic flow, and consider road and traffic operation measures for improvement of road safety. However, traffic monitoring systems are insufficient that automatically detect the mixed traffic flow, because of frequent vehicle occlusion. Therefore, vehicles are manually detected from video images in most of the previous studies.

In this study, we propose a method to automatically detect and track vehicles from video images, in order to analyze the traffic situation in Hanoi city for the simplification of the safety verification in traffic flow. The locations used in the study, and the data collected from these sites, are described in Section 2, and the proposed method is explained in Section 3. Experimental results are reported in Section 4, and Section 5 concludes the paper.

2. DATA USED

Hanoi, Vietnam was selected as a study area. Video images were taken at the Kim Ma St. – Nguyen Chi Thanh St. intersection in the morning. The intersection was selected so as to satisfy the following requirements: 1) volumes of cars and motorcycles should be large enough to observe mutually mixed traffic flow, 2) a digital video camera can be set from a high position, and 3) not near from obstacles against traffic flow such as bus stops and parking lots. Traffic flow was observed on 29 Sept., 2009 from 9:00 to 11:00. The size of images was reduced to the one with 480 pixel width and 270 pixel height.

3. METHODOLOGY

Figure 1 shows the flowchart of vehicle detection and tracking. The details are explained in the following subsections.

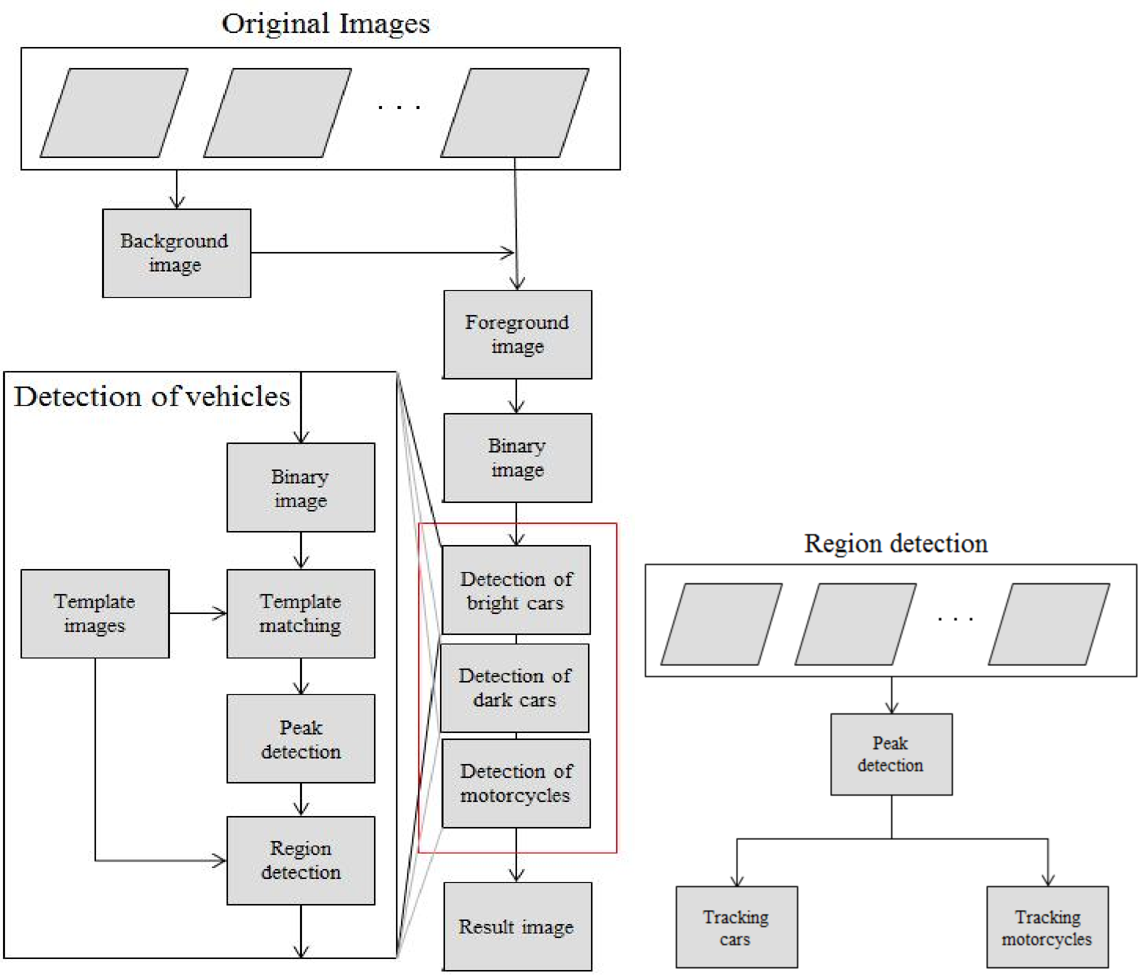

Figure 1: Flowchart of vehicle detection and tracking

3.1 GENERATION OF BACKGROUND IMAGES

Figure 2: Long-term background image

Figure 3: Short-term background image

In the proposed algorithm, two kinds of background image are generated; long-term background and short-term background. Using only long-term background image, vehicles in the foreground image is not well detected by the difference of intensity value with changes of lighting conditions. On the other hand, using only short-term background image, temporary stopped vehicles remain in the background images and cannot be detected in the foreground images.

In case of long-term background, using the 360 original images cut from video images at 10 seconds intervals. RGB color intensity of a specific pixel is recorded for 360 images and sorted by ascending order. The median value of the intensities is regarded as representative intensity for a background image. On the other hand, short-term background is generated using the 20 original images cut from 0.5 seconds intervals. By using median value, background image is generated more stable than using the average value. However, the region in the original image, which vehicle has appeared frequently due to the effects of waiting for the signal, have been detected some noise, and we think that this effect can be ignored.

Figures 2 and 3 show the long-term and short-term background images generated by using this method. In the short-term background image, the temporary stopped cars remain.

3.2 DETECTION OF VEHICLES

A foreground image is generated by subtracting original image from background image, and it is converted into binary data. Stopped vehicles are detected using the two background images, and moving vehicles are detected using the short-term background and the original image. Because vehicles in the binary image are partially detected lacking the vehicle region, region growing process is applied for the binary images to interpolate the lacking. If 8 pixels around the target pixel have more than some white pixels, the target pixel is converted white pixel. This process is iterated several times. In this study, the number of iteration was empirically determined as four. Then, the vehicle region is detected by applying template matching. The templates of vehicles, two types of cars and motorcycle, are manually selected up from binary images. Because dark color cars are uniquely detected in background subtraction method, one of the templates of cars is bright color, and the other is dark color. The intensity of template images is $T(i,j)$, and the intensity of binary images is $I(i,j)$. Template images are scanned binary images in a raster, the score of a pixel is added depending on both intensity of the same position. The score in this template matching shows Table 1. In this study, this score are experimentally decided. The higher scored regions are likely vehicle regions.

Figure 4: Original image

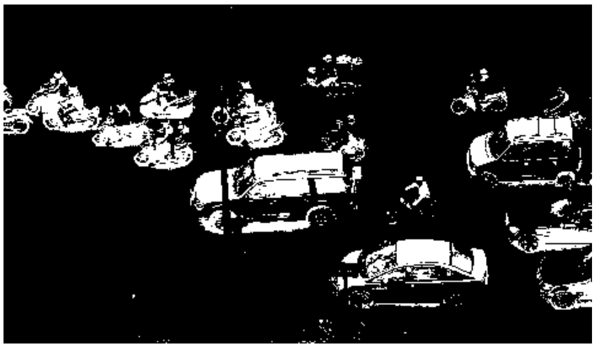

Figure 5: Foreground image (binary data)

Figure 6: Template images

		Binary images $I(i,j)$	
		Black	White
Template images $T(i,j)$	Black	+1	-1
	White	-3	+3

Table 1: Score Given by Template Matching

The score in this template matching shows Table 1. Figure 8 is the scored image after applying template matching. From this image, highest intensity pixels (peak) of 8 pixels surrounding are regarded as the center of vehicles. This process is called for peak detection in this paper. Then, the vehicle region is detected using template image. In case of using car templates, the pixels of detected vehicle region are converted into black pixels. The error detection is decreased in the following template matching using other template, especially motorcycle template.

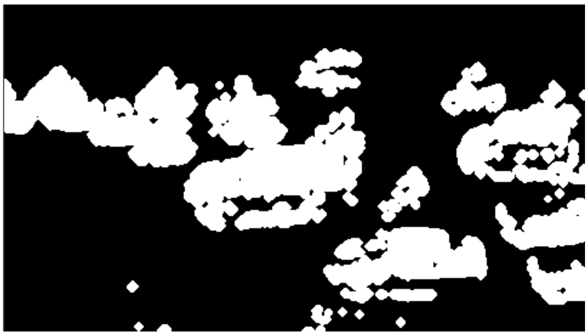

Figure 7: Binary image after region growing process

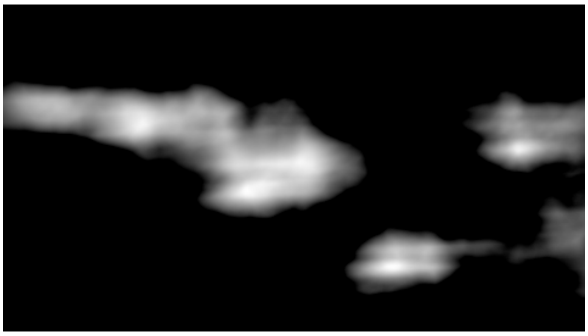

Figure 8: Scored image after template matching

Then, the lacking pixels of vehicle region are interpolated by expansion and contraction process repeatedly. Then, labeling the detected vehicle region of binary images, the width and height of the vehicle are determined using labeled pixels.

3.3 TRACKING OF VEHICLES

Tracking of vehicles is based on the vehicle detection results. The detected peak after template matching is connected between the consecutive frames. In that case, vehicle search area is manually set by size and speed of vehicles. A vehicle is traced by connecting common regions identified between the consecutive frames. In case of failure of vehicle detection at a frame, the tracking is interpolated using previous and following frames. About motorcycle, two kinds of search area are set to increase the tracking accuracy for the behavior of high degree of freedom.

4. EXPERIMENTAL RESULTS

The percentage of detected vehicles and the false detection was calculated using equations (1) and (2).

$$detection\ rate = \frac{number\ of\ detected\ vehicles}{number\ of\ all\ vehicles} \quad (1)$$

$$false\ detection\ rate = \frac{number\ of\ false\ detected\ vehicles}{number\ of\ all\ vehicles} \quad (2)$$

As a result of experiments, it was found that detection rate (the percentage of the detected vehicle numbers) was 88 % for cars and 74 % for motorcycles, and template matching approach was robust to occlusion found in the mixed traffic flow in Hanoi. In addition, false detection rate was 9 % about cars and 10 % about motorcycles. Most of false detection was congested motorcycles regarded as a car and vice versa.

Figure 9 shows the vehicle detection results. The detected vehicle regions are shown in three boxes; while box for bright car, blue box for dark car, and red box for motorcycle.

When vehicles were detected automatically, there were some miss detected vehicles due to occlusions, dark cars, congested motorcycles, vehicle size, bright condition, and so on. In this study, one of the problems, occlusions, was solved by applying template matching in most of cases. Because template matching in this paper was sensitive for the irregular shape, the vehicle with partial occlusions could be detected. Then, dark cars partially lacking in binary images were detected by the dark car template prepared. Because the analyzed video image was taken from a perpendicular angle to the traffic flow like Figure 9, the size of vehicles did not almost vary and affect the detection accuracy. It was difficult for template matching in this study to solve the congested motorcycles, because the score of a car was almost the same as the score of congested motorcycles. The congested motorcycles in the upper left corner of this image are detected as a vehicle in the lower left image of Figure 9.

Figure 9: Results of vehicle detection. While box denotes bright car, blue box denotes dark car, and red box denotes motorcycle.

Experimental results were compared with manually detected data in terms of the location error and tracking of vehicles. Figures 10 and 11 show the estimated location error of vehicles in 32 original images. Table 2 shows the estimated location error of all vehicles and the vehicles after excluding outliner vehicles. Figure 12 shows the tracking result of 8 cars automatically and manually of 8 cars in 32 images. In this figure, the solid lines indicate automatic tracking cars, and the dot lines indicate manual tracking cars. Figure 13 shows the tracking result of 19 motorcycles automatically and manually in 32 original images. Compared the tracking of vehicles automatically and manually, automatic tracking was often interrupted or wrong, because the detected peak of vehicle in this study was less accurate. Then, tracking of vehicles considerably depended on the detection of vehicle, and tracking of vehicles was less accurate for the utilization in the traffic management system.

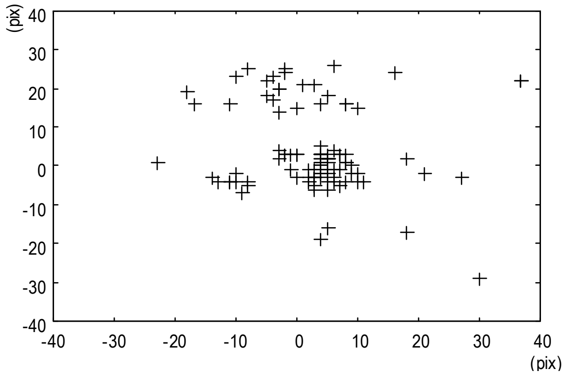

Figure 10: Estimated location error of cars

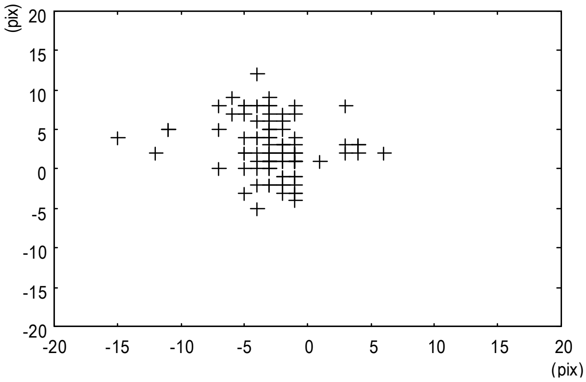

Figure 11: Estimated location error of motorcycles

Table 2: Estimated Location Error

	RMSE (all vehicles)		RMSE (outliers excluded)	
	Δx	*Δy*	*Δx*	*Δy*
Cars	9.8 pix (39 cm)	11.2 pix (45 cm)	6.1 pix (24 cm)	3.5 pix (14 cm)
Motor-cycles	3.8 pix (15 cm)	4.0pix (16 cm)	3.0 pix (12 cm)	3.9 pix (16 cm)

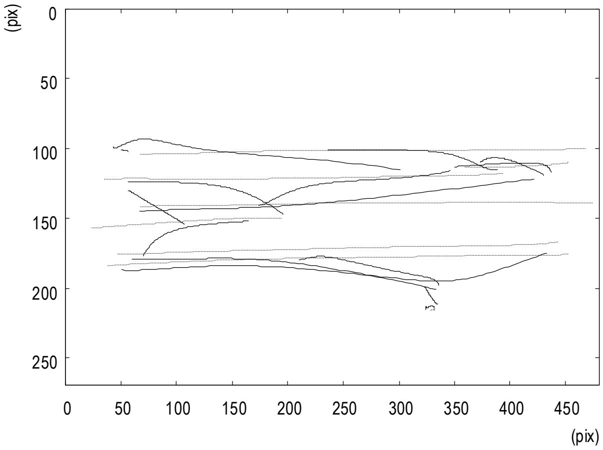

Figure 12: Tracks of 8 cars extracted automatically (solid lines) and manually (dot lines)

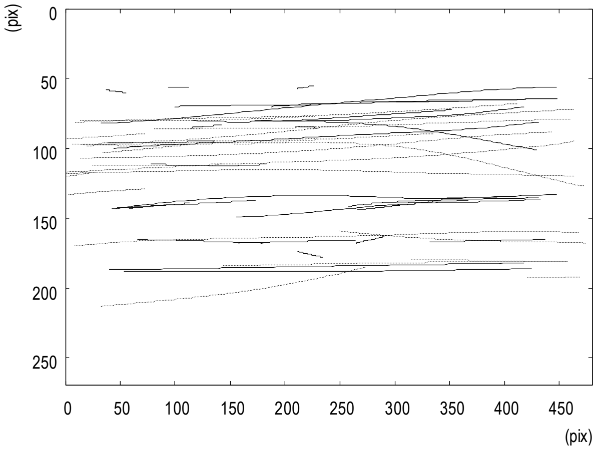

Figure 13: Tracks of 19 motorcycles extracted automatically (solid lines) and manually (dot lines)

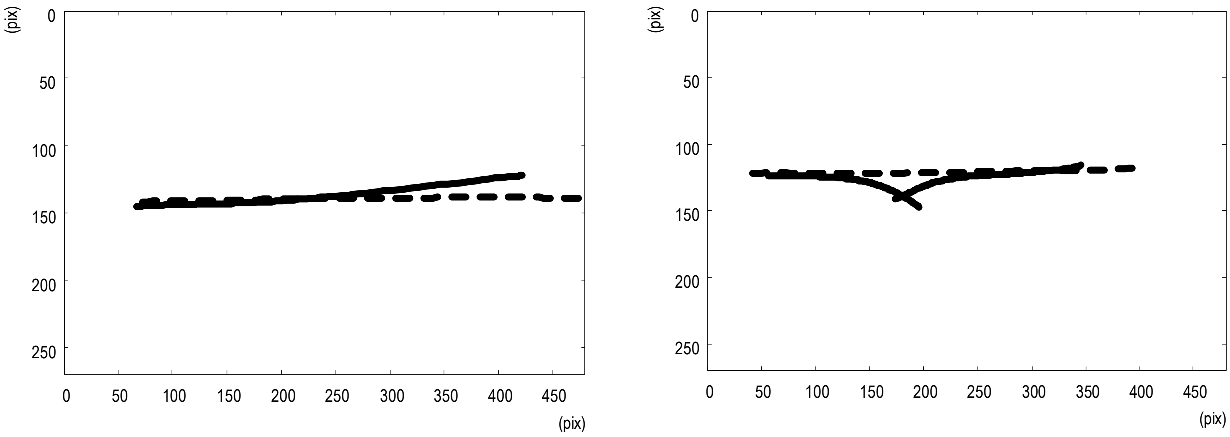

Figure 14: Examples of tracks of cars. (Upper) good extraction and (lower) poor extraction example.

In upper image of Figure 14, the track of a car automatically extracted shows agreement with the track manually extracted. However, in the right side of this figure, the automatic track has small difference from manual tracking because of the congested vehicles. On the other hand, lower image of Figure 14 shows a big gap between the track automatically extracted and the one manually extracted. In this figure, the automatic tracking is interrupted because of the unstable peak detection. Thus, the tracking accuracy of vehicles varies widely for each vehicle. In future work, the proposed method should be improved so that it is robust to such factors as interruption.

5. CONCLUSIONS

We proposed a novel vehicle detection and tracking method based on template matching. The approach to generate the background images is suitable for the road condition in this study. Two kinds of background images enable to successfully detect stopped vehicles. With applying template matching, high detected precision of vehicles with partial occlusions was obtained. This method is robust to the vehicle occlusion, and it is suitable for road surveillance systems. For future works, the algorithm will be improved in terms of the estimation accuracy of vehicle detection and processing time. After the improvement, tracking vehicles will be better.

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