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Vehicle Motion Tracking Using Symmetry of Vehicle and Background Subtraction

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Abstract— **We propose a new method of vehicle motion tracking. In our method, we use the template matching method for tracking. The template matching method has been used in many applications. In vehicle tracking, there are some problems, such as vehicle size change, occlusions, and shaded areas. To solve these problems, we divide and update the template at every frame by the background subtraction method. Moreover, we use the information that the front of the vehicle body is symmetric, and we remove areas other than the vehicle area and update the template correctly. We evaluate the efficacy of our method on several video frames.**

I. INTRODUCTION

In recent years, traffic congestion and the frequency of traffic accidents have become serious social problems. To decrease traffic congestion and traffic accidents, it is necessary to construct a traffic information service system. Currently, many private sectors and public organizations are conducting research on transportation systems, and have proposed many methods of improving the safety of road traffic and decreasing traffic congestion. Sensors of ultrasonic vehicle detectors and loop coil systems have been used to detect vehicles moving on a road. These systems can detect vehicles with a high degree of accuracy. However, these systems detect local information of the road. On the other hand, it is possible to track vehicles over a wide area by using images obtained from the camera set up on the road, and it is possible to track vehicle motions automatically by using image processing methods.

Vehicle extraction by image processing methods has been reported by many research institutes, and the method of using a two-dimensional model[1], [2] and the method of using a texture[3] are well known. Moreover, methods of using template matching[4], partitioning[5], and a three dimensional model[6], [7] have been proposed to track moving objects. However, there are some problems in tracking vehicle motion. For instance, the size of a vehicle may change, occlusions may occur, and shaded areas may exist on the vehicles. To solve these problems, we extract vehicles by the background subtraction method and track them by the template matching method. In the matching process, we divide the template to extract the area of the vehicle nearest to the camera, and we update the template at every frame. Moreover, we use the information that the front of a vehicle body is symmetric, and we remove areas other than the vehicle area and update the template correctly. Our method can be used in several applications, e.g., the traffic-actuated signal that operates by tracking the leading vehicle of the vehicle row.

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II. PROPOSED METHOD

In our study, we use the following procedures.

1) Extraction of vehicle area by the background subtraction method between the background image and the first frame image.
2) Tracking vehicle motion
   a) Let the extracted area be a current template.
   b) The current template is used for the template matching to the next frame image.
   c) The background subtraction method is used on the area surrounding the matched area.
   d) The template is divided using the result of c) and the vehicle symmetry, and one of the areas of the template is extracted as the current template.
   e) Vehicle motion is tracked by repeating b), c), and d).

III. EXTRACTION OF VEHICLE AREA

A. Smoothing Process

First, we use the median filter to reduce noise in the images. When we use the median filter, each pixel value is determined from the median value of all pixels in the selected neighborhood. The median filter is normally used to reduce noise in images because only noise is removed and the image do not blur.

B. Background Subtraction Method

The background subtraction method is the method of subtracting the background image from an image that contains a moving object.

After the subtraction, we apply the binarization process to the subtracted image. Then we obtain the moving object area in the image by performing closing and opening processes. Here, let the threshold value be x, the image that contains

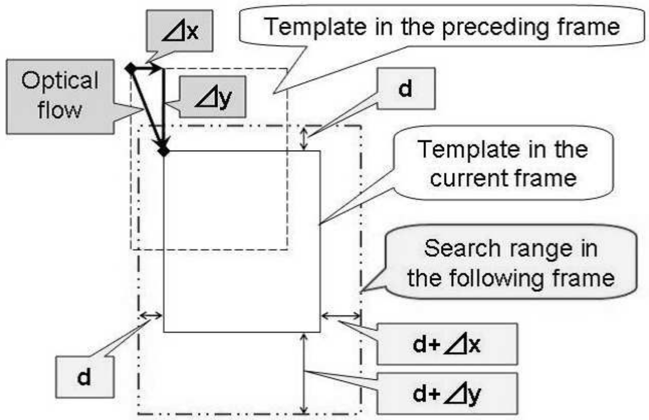


Fig. 1. Search range

the moving object be I_1, the background image be I_2, and R, G, and B be red, green, and blue components of the pixel, respectively. Then the pixels that satisfy the following equation are extracted.

$$|I_1(R) - I_2(R)| + |I_1(G) - I_2(G)| + |I_1(B) - I_2(B)| > \mathrm{x} \quad (1)$$

The areas extracted by the binarization may contain some holes and connected components. Hence, we perform closing and opening processes to remove them, and then we can obtain the vehicle area in the image.

C. Determination of the First Template

If the background subtraction method is applied to the image, the area where brightness changes or moving objects other than vehicles may be extracted. In order to avoid these errors, we apply the background subtraction method to a local area of the road, and we obtain the first template from the extracted vehicle area on the road.

IV. TRACKING OF VEHICLE MOTION

A. Template Matching

We apply the template matching method to the next frame image. We compute SSD (Sum of Squared Difference). Here, let $M \times N$ be the size of the template, (i, j) the coordinates in the template, $T(i, j)$ the pixel value at (i, j) in the template, and $I(i, j)$ the pixel value of the object image which is laid by the template, then the SSD is computed by the following equation.

$$R_{SSD} = \sum_{j=0}^{N-1} \sum_{i=0}^{M-1} (I(i,j) - T(i,j))^2 \quad (2)$$

In the computation, we use the sequential similarity detection algorithm. In the algorithm, if the difference exceeds the threshold during the computation, the computation is stopped, and hence the search is processed at high speed.

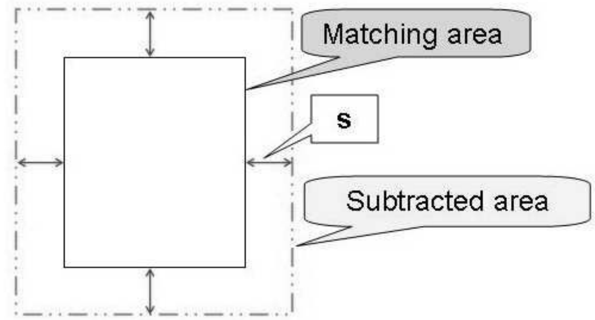


Fig. 2. Subtracted area in updating template

1) Optical Flow: Before we apply the template matching, we use the optical flow between the preceding frame and the current frame to avoid matching error. The motion direction of the vehicle does not change rapidly because the intervals between frames is $1/30$ seconds or less. Hence, we can determine the rough position of the vehicle in the current frame by computing the distance and the motion direction of the vehicle from the optical flows.

Here, we assume Δx is the distance moved in the direction of x, Δy is the distance moved in the direction of y, and d is the search range when the optical flow is 0. If the optical flow is 0 ($\Delta x = \Delta y = 0$), the search range in the current frame is $-d \leq x \leq d$, $-d \leq y \leq d$. If the optical flow is not 0 and Δx is a positive number, the search range is $-d \leq x \leq d + \Delta x$, and if the optical flow is not 0 and Δy is a positive number, $-d \leq y \leq d + \Delta y$ (Fig. 1). Even if the optical flow is 0, we set d as the search range because the vehicle may move in the following frame. By adding Δx and Δy to d, the search range can be kept to the minimum. If Δx is a negative number, the search range is $-(d-\Delta x) \leq x \leq d$, and if Δy is a negative number, the search range is $-(d - \Delta y) \leq y \leq d$.

B. Template Updating

The size of the vehicle area may change in each frame. Hence, it is necessary to update the template at every frame. First, we apply the template matching to the following frame using the template in the current frame. Then we use the background subtraction method in the range of s pixels around the matched position (Fig. 2). The rectangular area surrounding the subtracted result area is used as the new template (Fig. 3).

1) Template Division: When we extract a vehicle area that extends far from the camera, there is the problem that two or more vehicles may overlap in the frame. In this case, these vehicles will be taken in one template because the subtracted result becomes one area in the image even if there are several vehicles. When the vehicles move far from the camera, the template matching can be performed even if several vehicles are taken in the template. However, when the vehicles approach the camera, the template matching cannot be performed because the area of these vehicles is divided into small areas. Hence, it is necessary to divide the

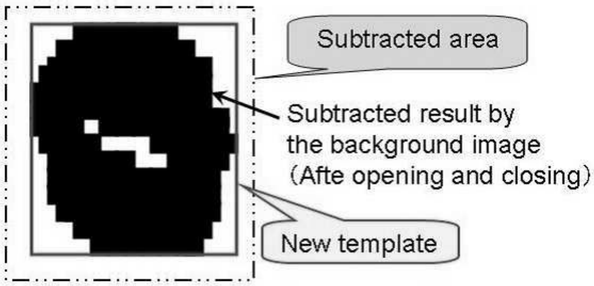


Fig. 3. Template updating

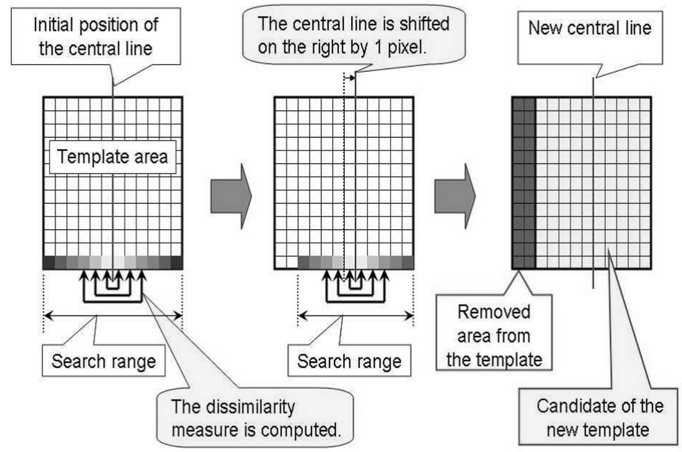


Fig. 4. Updating template using symmetry of vehicle

template area when vehicles approach the camera to some extent, and only one vehicle nearest to the camera is tracked. For such tracking, in the division process, we create a new template whose area surrounds the smallest connected area of the subtracted results.

On the other hand, the subtracted result may be divided into two areas by the influence of light or shadow even if there is only one vehicle. In this case, matching error may arise because only one part of the vehicle area will be extracted as the template. In order to avoid this problem, we use the aspect ratio and area size of the template.

2) Symmetry of Vehicle: The front of most vehicle bodies is symmetric. The template is updated so that it contains, as little as possible, areas other than the vehicle by considering the symmetry of the vehicle. To make use of the symmetry, the vehicle must be approaching and directly facing the camera. The optical flow used in the template matching shows the motion direction of the vehicle. Hence, we determine whether we can use the symmetry at each frame by using the optical flow. In our method, we use the symmetry when the angle between the vehicle motion direction and the direction of the optical axis of the camera is less than $45°$. Our method is described as follows.

1) First, the symmetry of vehicle is considered on the basis of the right end of the template. The initial position of the central line (y direction) is set to pass through the center of the template.
2) The difference between two pixel values are computed. These pixels are located at the symmetrical position around the central line. The dissimilarity measure is computed by summing the differences of all pixels in the template area and dividing the sum by the total number of pixels in the area.
3) The central line is shifted to the right by 1 pixel, and the left end of the template is removed.
4) Processes 2) and 3) are repeated until the central line reaches the right end of the template.
5) The central line position whose dissimilarity measure is the smallest is obtained as the new central line position, and the area centered around the new line position is extracted as the candidate of the new template.
6) Next, the symmetry of the vehicle is considered on the basis of the left end of the template. The initial position of the central line is set to pass through the center of the template.
7) 2) is repeated.
8) The central line is shifted to the left by 1 pixel, and the right end of the template is removed.
9) Processes 2) and 8) are repeated until the central line reaches the left end of the template.
10) The central line position whose dissimilarity measure is the smallest is selected as the new central line position, and the area that centers around the new line position is extracted as the candidate of the new template.
11) The dissimilarity measures obtained by process 5 and process 10) are compared, and the template with the smaller dissimilarity measure is used as the new template.

One example of the process when the left end of the template is removed is shown in Fig. 4.

V. EXPERIMENTS

The input frames are taken with a video camera set up on the pedestrian bridge above the road. The following computer and images are used in our experiments.

- CPU Pentium(R)4 3.2GHz
- RAM 1024MByte
- Image size 640×480pixels, 1 byte each of RGB
- Frame rate 15fps

The background images are updated constantly. Two frame sequences are used in the experiment. The results for the first sequence of 160 input frames are shown in Fig. 7-Fig. 14. The results for the second sequence of 150 input frames are shown in Fig. 15-Fig. 20.

The rectangular frame shows the updating result of the template, and the vertical line shows the central line. The background image is shown in Fig. 5, and the initial area where the background subtraction method is applied is shown in Fig. 6. The background subtraction method is applied between Fig. 5 and frame 1 in the area shown in Fig. 6. The area extracted by the subtraction is used as the first template, which is shown in Fig. 7.

Fig. 5. Background image

Fig. 6. The area of the background subtraction

(a) Frame 1 (b) Expanded image

Fig. 7. First template

Fig. 8- Fig. 10 show the process of the template division. Each image is expanded around the neighborhood of the area of the tracked vehicle. Although there is one area in the subtracted result of frame 5 (Fig. 8), that area is divided into two in the subtracted result of frame 6 (Fig. 9). Then, the template is divided and the vehicle is tracked using the template after division in frame 7 (Fig. 10).

Frames 130 (Fig. 13), 160 (Fig. 14), and 76 (Fig. 18)-150 (Fig. 20) satisfy the conditions for using the symmetry of the vehicle. The shaded area of the vehicle is removed by applying the symmetry, and we can track the vehicle motion correctly. The average processing time per frame is about 0.3 seconds.

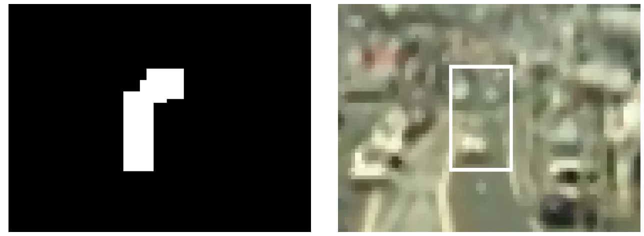
VI. CONCLUSIONS AND FUTURE WORKS

A. Conclusions

In this study, we proposed the method of vehicle motion tracking using the symmetry of the vehicle and the background subtraction method. The results of our experiments show that our proposed algorithm enables stable vehicle motion tracking in video frames. If we integrate some other functions to our method, the position and speed of vehicles can be easily obtained. For example, our method can be used in the traffic-actuated signal that operates by tracking the three-dimensional coordinates of vehicles using the stereo system or by converting an oblique image to an overhead image taken by a monocular camera.

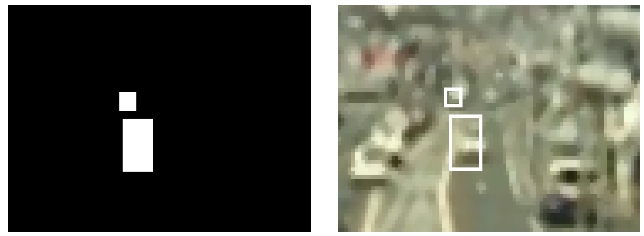
B. Future Works

The experiments yielded results under the limited conditions. In the future, we would like to perform experiments under more complicated conditions, for example, disappearance of vehicle, lane change, and time conditions (daytime or night). These cases should be considered for practical applications. Moreover, we now obtain the first template semiautomatically by the background subtraction method, but we will obtain the template area automatically by extracting the road area. We would like to consider and create a system that can be used in any actual situation.



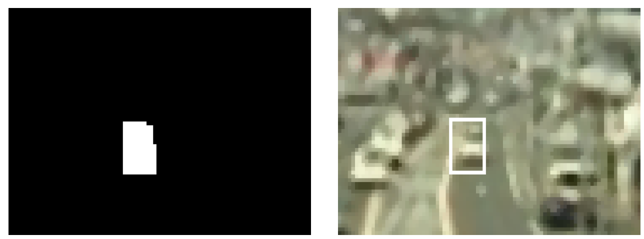
(a) Subtracted result (b) Frame 5

Fig. 8. Template before division



(a) Subtracted result (b) Frame 6

Fig. 9. Template division



(a) Subtracted result (b) Frame 7

Fig. 10. Template after division

VII. ACKNOWLEDGMENTS

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REFERENCES

[1] H.Kuboyama and S.Ozawa: Measurement of Heavy Traffic in a Tunnel from Image Sequences, *The Institute of Electronics, Information and Communication Engineers*, Vol.J85-D-2, No.2, pp.210-218, 2002.

[2] M.-P.D. Jolly,S. Lakshmanan, and A.K. Jain: Vehicle segmentation and classification using deformable templates, *IEEE Trans. Pattern Anal. & Mach. Intell*, vol.18, no.3, pp.293-308, 1996.

[3] S.Kamijo and Y.Matsushita and K.Ikeuchi and M.Sakauchi: Occlusion Robust Tracking Utilizing Spatio-Temporal Markov Random Field Model, *The Institute of Electronics, Information and Communication Engineers*, Vol.J83-D2, No.12, pp.2597-2609, 2000.

[4] S.Muramatsu and Y.Kobayashi and K.Takahashi and E.Shimizu: Development of Template Matching Hardware and Its High Speed Processing Strategy, *The Institute of Electronics, Information and Communication Engineers*, Vol.J83-D2 No.7, pp.1667-1675, 2000.

[5] M.Ambai and S.Ozawa: Robust Tracking Algorithm for Traffic Monitoring in Various Environments,*The Institute of Electronics, Information and Communication Engineers*, Vol.J88-A, No.8, pp.983-993, 2005.

[6] H. Leuck and H.-H. Nagel: Automatic differentiation facilitates OF-integration into steering-angle-based road vehicle tracking, *Proc. Computer Vision and Pattern Recognition (CVPR) '99*, pp.360-365, 1999.

[7] W.F. Gardner and D.T. Lawton: Interactive model- based vehicle tracking, *IEEE Trans. Pattern Anal. Mach. Intell.*, vol.18, no.11, pp.1115-1121, 1996.

Fig. 11. Frame 80

Fig. 12. Frame 120

Fig. 13. Frame 130

Fig. 14. Frame 160

Fig. 15. Frame 3

Fig. 16. Frame 50

Fig. 17. Frame 75

Fig. 18. Frame 76

Fig. 19. Frame 100

Fig. 20. Frame 150