Proceeding, Seminar of Intelligent Technology and Its Applications (SITIA 2001)
Institut Teknologi Sepuluh Nopember, Surabaya, May 1, 2001

Type of Vehicle Recognition
Using Gabor Filter Representation and Template Matching Method

Thiang, Andre Teguh Guntoro, Resmana Lim

Electrical Engineering Department, Petra Christian University
Siwalankerto 121 – 131 Surabaya, Indonesia
Telp: (031) 8439040, 8494830-31 ext. 1354, 1361 Fax: (031) 8436418
Email: thiang@petra.ac.id, resmana@petra.ac.id

Abstract

This paper describes about type of vehicle recognition using camera as a sensor to recognize moving object, i.e. car. There are four main stages in this process; they are object detection, object segmentation, feature extraction and matching using template matching method.

The experiment was done for various types of vehicle during daylight and at night. The result shows a good similarity level. The highest similarity level is about 0.9 during daylight and 0.75 at night.

KEYWORDS: template matching, recognition, object detection, object segmentation, gabor filter

1. Introduction

People use sensor to count the number of car that enter to park area. The sensor must be able to detect the car and classified it from other object. The conventional sensor cannot do it well. This research will use a camera as a sensor to recognize the car visually. In this case, the car is moving to enter park area.

Generally, there are four stages in car recognizing, i.e. object detection, object segmentation, feature extraction and matching. The first stage gives information whether the camera captures the car or not. The second one does the image segmentation to get the detected car and discard the other. The third stage does the feature extraction process using gabor filter representation. The last stage is to recognize car type by matching it to each image template. This will result similarity value. The highest value will determine the car type. The block diagram of this system is shown at figure 1.

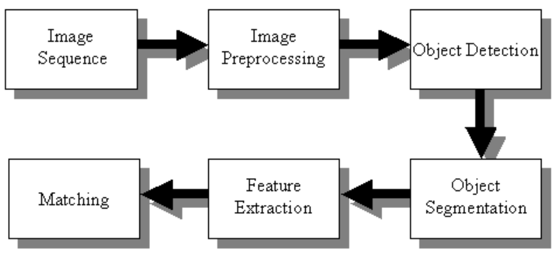


Figure 1. Block diagram of the system

2. Object Detection

Before object detection process, the system will do image preprocessing i.e. converting image from RGB to gray scale, histogram equalization and noise removal. This process will minimize error of the image.

The converting image process uses equation:

$$Gray = 0.299R + 0.587G + 0.114B \quad (1)$$

After converting image to gray scale, system will do histogram equalization process. This process will adjust brightness and contrast of the image. Histogram equalization uses equation:

$$g(x,y) = c.f(x,y) + b \quad (2)$$

$f(x,y)$ is original gray level image, $g(x,y)$ is result of histogram equalization process, c is contrast constant and b is brightness constant.

Then the system will do noise removal process using low pass filter with 3x3 neighborhood. The result is obtained by convolving low pass filter kernel with original image. This process is represented by equation:

$$g_{x,y} = h_{x,y} * f_{x,y} \quad (3)$$

Where $h_{x,y}$ is low pass filter kernel.

After image preprocessing, the system will do object detection process. This process is done in predefined area of the image. To detect the existence of the car, the system will subtract background image from the image. If the color of image is different from the color of background image then there is an object in the image. On the contrary, if the image and background image has the same color, there is no object in the image. This process is represented by equation:

$$g(x,y) = \begin{cases} 0 & if \ \left| f(x,y) - b(x,y) \right| < error \\ f(x,y) & for\ others \end{cases} \quad (4)$$

Figure 2 shows the object detection area and an example of object detection result.

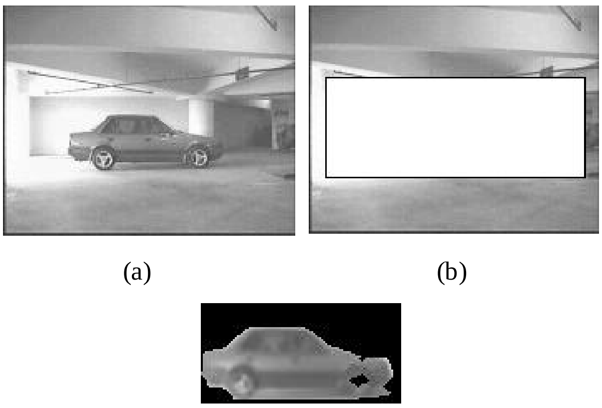
(a) (b)

Figure 2. a) Object detection area b) Object detection result

3. Object Segmentation

Object segmentation process does the image segmentation process to get the detected car and discard the other part. This process is done in the predefined area of image where the car is certainly in that area.

There are two stages in object segmentation process. The first stage will discard image background, so that the image will show the object only. To discard image background, the system will do subtraction as well as in object detection process by using equation 4 and then morphology operation.



(a) (b)

(c)

Fig 3. a) The object b) Object segmentation area c) Object segmentation result

Type of morphology operation used in this research is opening operation. This operation will smooth edge of the object. Opening operation is represented by equation:

$$G = (X \otimes B) \oplus B \qquad (5)$$

Equation 5 shows opening operation of image X by structuring element B.

In the second stage, system will seek the optimal position of object in the image. It is done by calculate the cumulative histogram value for each possible existence of object in the image. The area with maximum cumulative histogram value shows the optimal position of object. Figure 3 shows example of object segmentation result. After this process, system will clip the object at that optimal area.

4. Feature Extraction

For extracting the feature of image, the system uses gabor filter. Each point is represented by local gabor filter responses. A 2-D Gabor filter is obtained by modulating a 2-D sine wave (at particular frequencies and orientations) with a Gaussian envelope. We follow the notation in [7][8]. The 2-D Gabor filter kernel is defined by

$$f(x,y,q_k,l) = \exp\left[-\frac{1}{2}\left\{\frac{(x\cos q_k + y\sin q_k)^2}{s_x^2} + \frac{(-x\sin q_k + y\cos q_k)^2}{s_y^2}\right\}\right] \qquad (6)$$
$$.\exp\left\{\frac{2p(x\cos q_k + y\sin q_k)}{l}i\right\}$$

where s_x and s_y are the standard deviations of the Gaussian envelope along the x and y-dimensions, respectively. l and q_k are the wavelength and orientation, respectively. The spread of the Gaussian envelope is defined using the wavelength l. A rotation of the $x - y$ plane by an angle q_k result in a Gabor filter at orientation q_k. q_k is defined by

$$q_k = \frac{p}{n}(k-1) \qquad k = 1,2,..,n \qquad (7)$$

where n denotes the number of orientations. The Gabor local feature at a point (X,Y) of an image can be viewed as the response of all different Gabor filters located at that point. A filter response is obtained by convolving the filter kernel (with specific l, q_k) with the image. For sampling point (X,Y), this response, denoted as g(.), is defined as:

$$g(X,Y,q_k,l) = \sum_{x=-X}^{N-X-1}\sum_{y=-Y}^{N-Y-1} I(X+x,Y+y)f(x,y,q_k,l) \qquad (8)$$

where $I(x,y)$ denotes an NxN greyscale image. When we apply all Gabor filters at multiple frequencies (l) and orientations (q_k) at a specific point *(X,Y)* we thus get a set of filter responses for that point. They are denoted as a Gabor jet. A jet J is defined as the set $\{J_j\}$ of complex coefficients obtained from one image point, and can be written as

$$J_j = a_j \exp(i f_j) \quad j=1,..,n \qquad (9)$$

where a_j is magnitude and f_j is phase of Gabor features/coefficients.

5. Matching

This research uses template-matching method to recognize car type. This method will compare the gabor jet of image with several gabor jet of template images. The image will have similarity values for each template image. The system will identify type of the car using the highest similarity value.

The highest similarity value can be calculated using following equation:

$$\max_{\forall J'} S_a\left(J, J'\right) \tag{10}$$

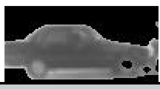
Where J is gabor jet of the image and J' is gabor jet of template image. $S_a(J, J')$ can be defined by this equation:

$$S_a\left(J, J'\right) = \frac{\sum_j a_j \cdot a'_j}{\sqrt{\sum_j a_j^2 \cdot \sum_j a'^2_j}} \tag{11}$$

6. Experiment Result

In this research, there are three types of car, i.e. sedan, van and pickup and 12 images for template image. The experiment was done for various type of car during daylight and at night. Table 1 shows the comparison between template matching with and without gabor filter. Template matching without gabor filter gives high similarity value results for image that similar to its template, but it will also happen to other images those are not similar to the template at all. Template matching with gabor filter gives better results. There is big difference between the highest similarity value and others. But, the highest similarity value in template matching with gabor filter is smaller than the highest similarity value in template matching without gabor filter. Table 2 shows experiment results for another unknown object during daylight and table 3 shows experiment results at night. Table 4 shows several experimental results of unknown objects. We can see from this table that the system can recognize the type of the car well.

Table 1. Comparison between template matching with and without gabor filter

Unknown object 

	Similarity Value	
	w/o Gabor Filter	w/ Gabor Filter
	0.85395	0,59360

Table 1. Continued

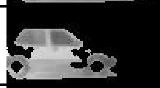
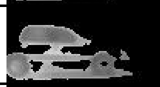
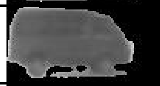
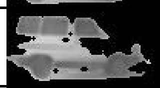
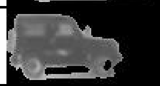
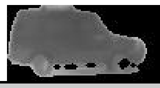
	**0.92499**	**0,85995**
	0.80402	0,35079
	0.82019	0,34643
	0.84744	0,51477
	0.82592	0,32208
	0.85190	0,56469
	0.80719	0,34463
	0.80378	0,56870
	0.84302	0,53214
	0.85034	0,50135
	0.82101	0,57449

Table 2. Similarity value of an unknown object with gabor filter

Unknown object 

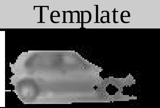
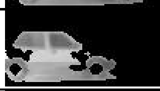
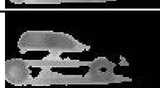
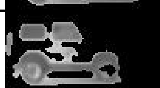
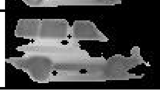
Template	Similarity
	0,32256
	0,44837
	0,24369
	0,25080
	0,33497
	0,48761
	**0,91404**
	0,24294
	0,49339

Table 2. Continued

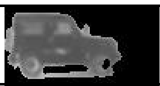
	0,51508
	0,60461
	0,32979

Table 3. Experiment result at night

Unknown object 

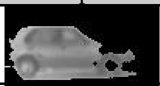
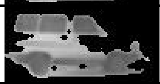
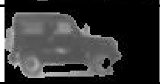
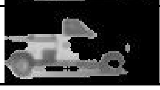
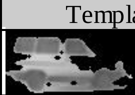
Template	Similarity
	0,47388
	0,66080
	0,30865
	0,32365
	0,34412
	0,64056
	**0,74638**
	0,30545
	0,49179
	0,46551
	0,51339
	0,40318

Table 4. Several experiment results of unknown object

Unknown object		Template		Similarity
	Van		Van	0,68042
	Sedan		Sedan	0,87689
	Pickup		Pickup	0,89012
	Van		Van	0,89843
	Sedan		Sedan	0,82060

7. Conclusion

Template matching method gives a good result in recognizing the type of the car. It results high similarity value for image that similar to its template, but it will also happen to other images those are not similar to the template at all. Template matching with gabor filter gives better result. There is a big difference between the highest similarity value and others. But, similarity value in template matching with gabor filter is smaller than similarity value in template matching without gabor filter

8. Reference

[1] Milan Sonka, "Image Processing, Analysis and Machine Vision", Chapman & Hall, London, 1993.
[2] Kenneth R Castleman, "Digital Image Processing", Prentice Hall International, Inc., New Jersey, 1996.
[3] Ferdinand van der Heijden, "Image Based Measurement Systems", John Wiley & Sons, Inc., West Sussex, 1994.
[4] Gregory A Baxes, "Digital Image Processing", John Wiley & Sons Inc., Canada, 1994.
[5] Andrian Low, "Introductory Computer Vision and Image Processing", McGraw-Hill Book Company, London, 1991.
[6] Bryan S. Morse, "Segmentation (Matching, Advanced)", Brigham Young University. 1998.
[7] Hamamoto, Y., A Gabor Filter-based Method for Fingerprint Identification, "Intelligent Biometric Techniques in Fingerprint and Face Recognition, eds. L.C. Jain et al", CRC Press, NJ, pp.137-151, 1999
[8] Resmana Lim, and M.J.T. Reinders, "Facial Landmark Detection using a Gabor Filter Representation and a Genetic Search Algorithm", proceeding of ASCI 2000 conference
[9] "Gabor Features", [http://ams.egeo.sai.jrc.it/eurostat/lot16-supcom95/ node17.html].
[10] Chris Seal. "Two-Dimensional Gabor Filters", [http://www.labs.bt.com/library/papers/pamipaper/node5.html]. 1997