MVA2002 IAPR Workshop on Machine Vision Applications, Dec. 11 - 13, 2002, Nara- ken New Public Hall, Nara, Japan

3—2

A Detection Method of a White Road Line Using Jensen-Shannon Divergence and Morphology

Naoki TANAKA*
Chair of Information Systems Engineering
Kobe University of Mercantile Marine

Abstract

The road surface inspection is proceeded by a human expert with an image that is generated through a laser imaging system. Although the imaging system can provides a fixed lighting condition, it produces a low contrast image for a white and a yellow road line. In this paper, a new detection method of white road line detection from a low contrast road surface image is proposed. The first stage of the processing is an edge detection operation by the Jensen-Shannon divergence method. And the second is a binarization operation using discriminant and least squares threshold selection method. By taking an intersection of the two resulting images of these processing, the final detecting result can be obtained. The experimental results show that the proposed method has a high enough performance for the practical use.

1 Introduction

For the purpose of a road surface inspection, a specially equipped vehicle that has a laser imaging system is used. The advantages of the laser imaging system for the road inspection are following. (i) It provides a fixed lighting condition. (ii) A crack region in the image can be more distinguishable. Unfortunately the image obtained through the laser imaging system dose not have enough contrast for a white or a yellow object, i.e., a white road line or a yellow road line. In this paper, a new detection method of a white road line from a low contrast image is proposed. We use Jensen-Shannon divergence to detect edges of a white line. Then by the morphological operations, the candidate regions for the white road line can be obtained. On the other hand, by a binarization operation using discriminant and least squares threshold selection method, the white regions are also obtained from the input image. The final result is generated by taking an intersection of the candidate region image and the white region image. The experimental results are shown in the last chapter and it shows that the proposed method achieves an extremely high accuracy in detecting a white road line from a low contrast image.

2 Road Surface Image database and Detecting Process

The road surface images used here are obtained through a laser imaging system. A human expert inspects these images to classify them to the appropriate categories and make segmentation into the road objects. Each road surface image belongs to a category and is attached a handwriting segmentation result, called desired output. Figure 1 shows an example of the road surface images and their desired output. And the block diagram of the detecting process is shown in Fig. 2

3 Edge Detection by Jensen-Shannon Divergence

Since road surface images used here are taken along the road, we can assume that a while road line lies in a vertical direction. Therefore only the vertical edges will be detected here. Jensen-Shannon divergence (JS-divergence), as proposed by Lin , has proved to be a powerful tool in segmentation. It is defined as :

$$SD(I_o(x)) = H\left(\sum_{i=1}^{r} \pi_i P_i\right) - \sum_{i=1}^{r} \pi_i H(P_i)$$

where $P_1, P_2, \ldots, P_r$ are discrete probability distributions ,π_i are weights for the distributions.

$H(P_i) = -\sum_{j=1}^{n} P_{ij} log P_{ij}$ is the Shannon entropy for P_i distribution. Using a window made up of two identical subwindows W_1 and W_2,as shown in Fig. 3, JS-divergence can be obtained between the normalized histograms of the subsides. We use the weights values $\pi_1 = 0.5$ $\pi_2 = 0.5$. And JS-divergence reaches maximum value when each sub window lies completely within a single region. An example of the JS-divergence image is shown in Fig. 4.

However, the JS-divergence value changes gradually, i.e. it doesn't have a sharp peak, it is need to be emphasized. The emphasis process is done by a morphological gradient detecting operation as follows.

$$T_w(x) = SD(x) - (SD(x) \oplus K_{hline(3)} - SD(x))$$

The second term of the right side of the above equation correspond to the gradient region of a JS-divergence, and by subtracting it , the peak of a JS-divergence can be enhanced.

Then $T_{w(x)}$ is binarized. The detected edges are the boundary of a white road line, so a pair of edges that are separated within a certain distance can be belonging to the single white road line, where one of a pair edge can be an end of the image. In order to fill valley between a pair edge, a closing operation with a horizontal line shape structure element that has same width as that of a white road line is performed.

*Address: 5-1-1, fukae-minami, higashinada, KOBE 658-0022, JAPAN E-mail: tanaka@athena.ti.kshosen.ac.jp

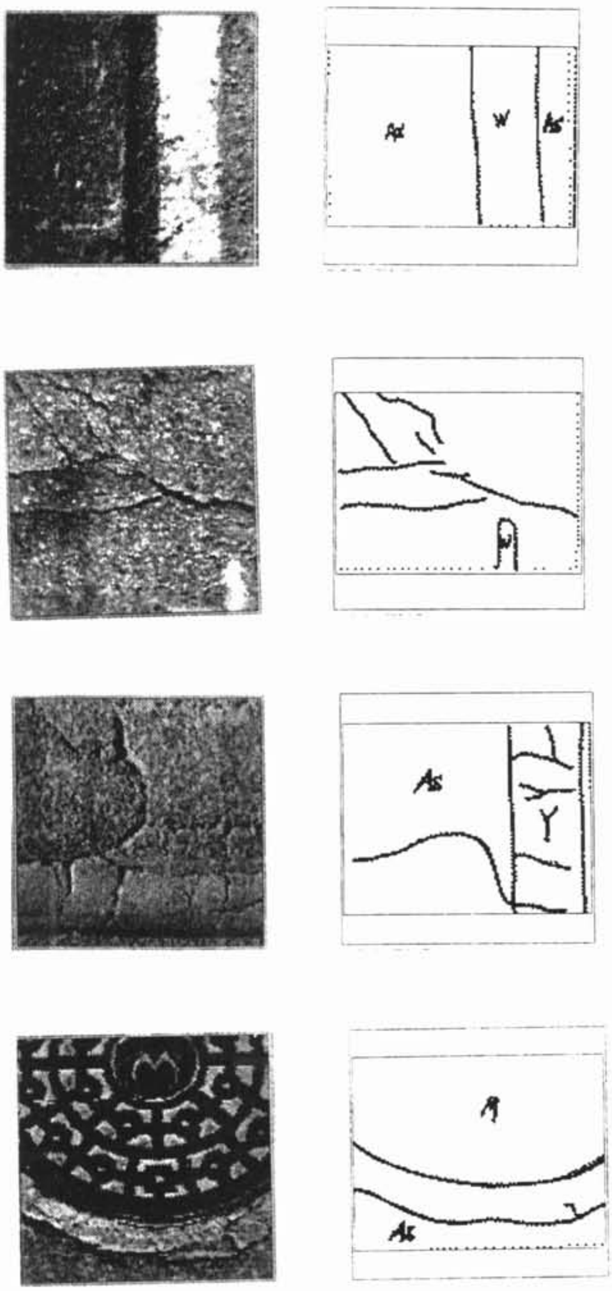

Figure 1: Road Surface Image

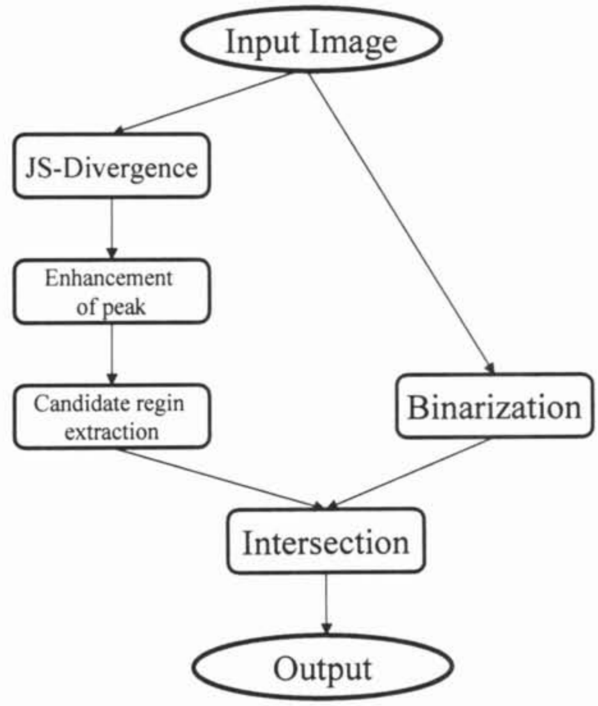

Figure 2: Detecting Process

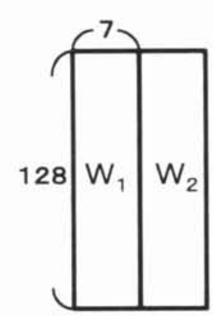

Figure 3: Subwindow

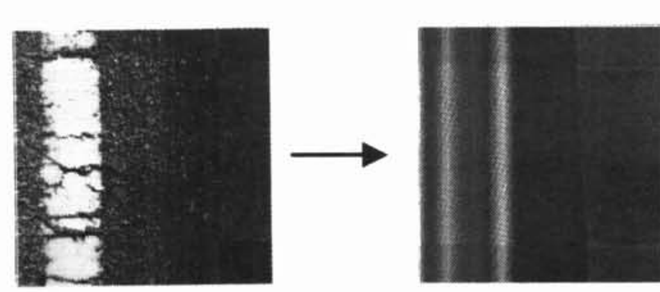

Figure 4: JS-Divergence $SD(x)$

Figure 5: $T_w(x)$

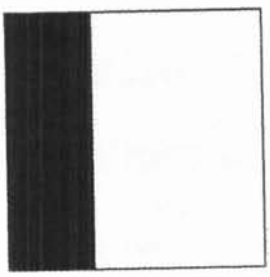

Figure 6: $V_w(x)$

$$V_w(x) = |T_w(x)|_b \bullet K_{hline(41)}$$

The non-zero regions in the binary image $V_w(x)$ are called as the candidate regions for a white road line. An example of $V_w(x)$ is shown in Fig. 6.

4 Binarization Using Discriminant and Least Squares Threshold Selection Method

Since a white road line is thought to be a bright object against a dark background, a binarization operation is curried out with an input image $I_o(x)$ to get brighter regions . The binarization operation used here is based on the discriminant and least squares threshold selection method that is proposed by Otsu.

$$Z_w(x) = |I_o(x)|_{k^*}$$

The threshold value k^* can be obtained by following equation.

$$\sigma_B^2(k^*) = \max_k \frac{[\mu_T\omega(k) - \mu(k)]^2}{\omega(k)[1-\omega(k)]}$$

$$\omega(k) = \omega(k-1) + p_k$$

$$\mu(k) = \mu(k-1) + kp_k$$

where

p_k : *normalized histogram of* $I_o(x)$
μ_T : *mean grey level of* $I_o(x)$

An example of $Z_w(x)$ is shown in Fig. 7

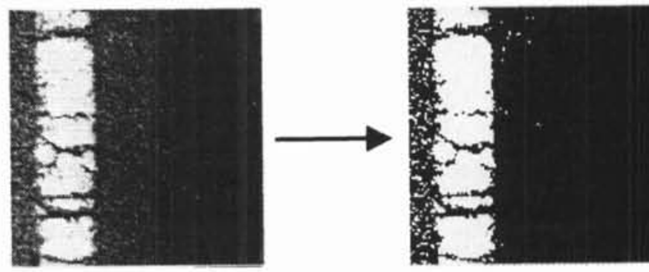

Figure 7: $Z_w(x)$

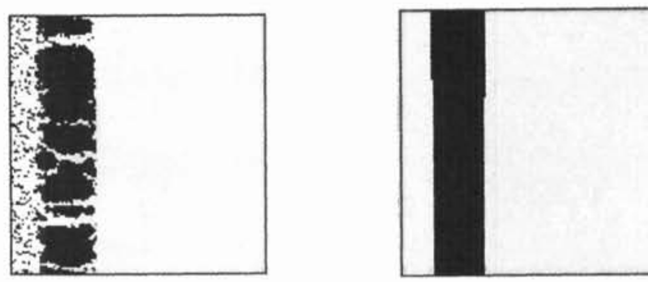

Figure 8: Intersection and $White_w(x)$

5 Extraction processing of White Road Line

By taking an intersection of $V_w(x)$ and $Z_w(x)$ followed by an opening and closing operations, the white road line image $White(x)$ is obtained as the final detecting result.

$$White(x) = [V_w(x) \cap Z_w(x)] \circ K_{rec(2\times10)} \bullet K_{vline(71)} \bullet K_{hline(3)}$$

By the opening operation, small regions are eliminated, and the first closing operation fills large vertical gaps and the second closing operation fills small horizontal gaps. An example of the intersection of $V_w(x)$ and $Z_w(x)$, and a white road line image $White_w(x)$ is shown in Fig. 8.

6 Results and Conclusions

The number of the images used here is 319, which includes 40 white road line images, 28 white paint images, and 17 yellow road line images. 8 of 28 white paint images can be reconsidered as a white road image. Similarly 8 of 17 yellow road line images can be considered as a white road line image. Therefore 40 white line, 8 white paint and 8 yellow road line images must be counted in white road line images and the others be in non-white road line images.

category	correct	# of images
White Road Line	37	40
White Paint	8	8
Yellow Road Line	8	8
Non-White Road Line	0	263
Total	53	319

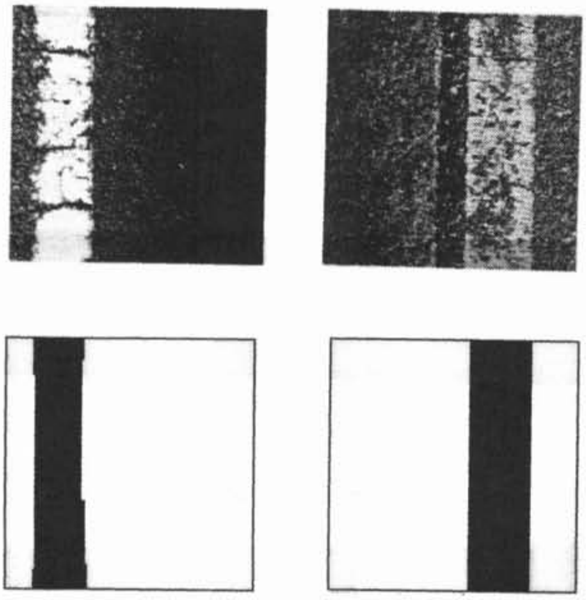

Figure 9: White Road Line

Experimental results show the effectiveness of the white road line detection method. The overall rate of correct detection is higher than 98%. The performance of the proposed method is thought to be high enough for the practical use. We can find, in addition, two cases that the proposed method can detect correctly though the classification results by a human expert are wrong. Fig. 9, Fig. 10 and Fig. 11 show the detecting results for white road line, white paint and yellow road line respectively.

References

[1] V.Barranco-Lopez, P.Luque-Escamilla, J.Matinez-Aroza, and Rroman-Roldan, "Entropic Texture Edge-detection for Image Segmentation, " Electronic Letters, 1995.

[2] J. Lin ", "Divergence Measures Based on the Shannon Entropy, " IEEE Transactions on Information Theory, 1991.

[3] N. Otsu, "Discriminat and Least Square Threshold Selection , " Proc. of 4th Inter. Joint Conf. on Pattern Recognition, 1978.

[4] N.Tanaka, M.Masayo, "A Detection Method of Crack and Structural Object of the Road Surface Images," Proc. of MVA2000 , 2000.

[5] R.M. Haralick, "Computer and Robot Vision, " Addison-Wesley Publishing Co. , 1992.

[6] H.Talbot, "A Morphological Algorithm for Liner Segment Detection", Kluwer Academic Publishers, 1996.

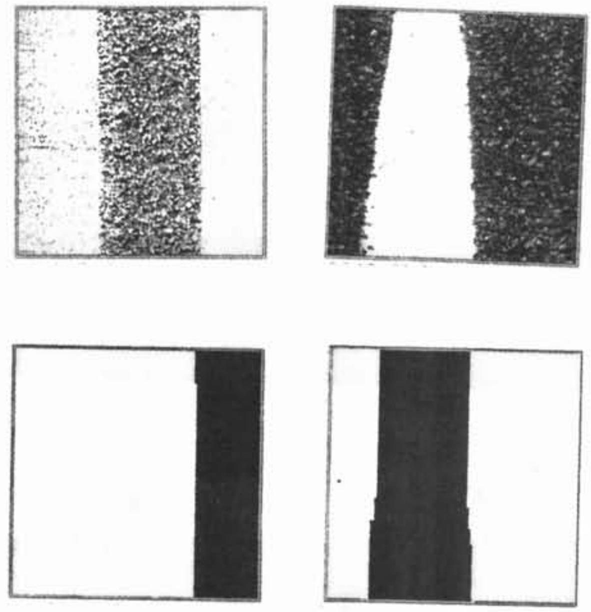

Figure 10: White Paint

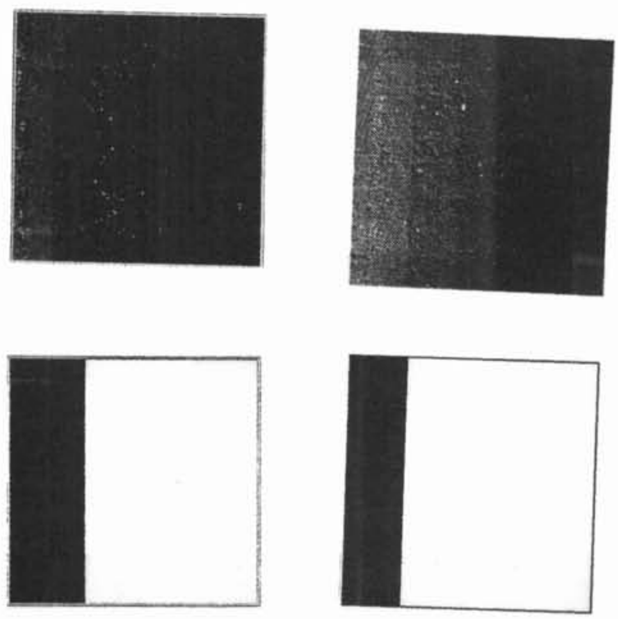

Figure 11: Yellow Road Line