On a Segmentation Algorithm of Lines of Hough Transform Using Discriminant Analysis - on the Enforcement of the Platform of Hough Transform -

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Abstract

It is essential for edge detection of Hough transform to enforce the platform of its availabilities. One of the most important subject of these enforcements is to prepare a robust method for segmenting line segments. We propose two kinds of algorithms: First one is a local algorithm, where a local area moves along the straight lines to judge locally whether the edge points should be on an edge segment or not. Another one is a global algorithm, where a histogram of the edge points along the straight line and the discriminant measure for it collaborate to judge globally whether the straight line should be deviated into some edge segments or not. We discussed also about the integration of these two algorithms to realize a practical line segmentation method.

1. Introduction

It is essential for edge detection of Hough transform to enforce the platform of its availabilities.[1] One of the most important subject of these enforcements is to prepare a robust method for separating a line into segments corresponding to the distribution of edge points in the image.[2] This paper proposes two kinds of algorithms for this segmentation:

(1) First one is a local algorithm, where a local area moves along the straight lines to judge locally whether the edge points should be on edge segments or not.
(2) Another one is a global algorithm, where a histogram of the density of the edge points along the straight line and the discriminat measures for it collaborate to judge globally whether the straight line should be divided into some edge segments or not.

We discuss also about the effect of the integration of these two algorithms to realize a practical line segmentation method.

2. A local algorithm

Our local segmentation algorithm uses only edge points within the local rectangle area which is defined around the referred point on the line detected by Hough transform. This local area is defined by two parameters indicating $ld \times lw$ local rectangle shown in Fig.1[Step 1]. If there is no edge point in this area of the inputted image, then let the area be considered as the blank part of the line, and let this line be separated into two segments. Suppose that (x_1, y_1) is the referred point and (x_2, y_2) is the nearest adjacent point. If the distance $\sqrt{(x_1-x_2)^2+(y_1-y_2)^2}$ between these two points is longer than or equal to ld, then the line is separated into two segments. On the other hand, if that distance is shorter than ld, then these two points are merged into the same segment as shown in Fig.1[Step 2].

$$\sqrt{(x_1-x_2)^2+(y_1-y_2)^2} \geq ld \qquad (1)$$

$$\sqrt{(x_1-x_2)^2+(y_1-y_2)^2} < ld \qquad (2)$$

Thus, we can detect line segments from the line detected by Hough transform by moving the referred point along the line and by repeating these operations as shown in Fig.1[Step 3].

Since this algorithm takes only the local distribution of edge points (length) into consideration, the global state of distribution of edge points on the line is not considered at all. Therefore, from the global viewpoints, it will be difficult to detect segments feasibly. For example, even if only a random noise point happens to appear in a local $ld \times lw$ area, two segments should be unfortunately merged into one segment.

3. Global algorithm using histogram of edge points

Local segmentation algorithm does not consider the global situation of connectivity of the edge points along the line into consideration. So, there exists a necessity to introduce a global segmentation algorithm which can take the connectivity of the edge points on the straight line into consideration. For realizing this algorithm, we designed the following procedure.

(1) First step is to make the histogram from the edge points on a line detected by Hough transform.
(2) Second step is to detect the segmentation threshold by using the discriminant analysis for this histogram defined in the first step.
(3) Last step is to detect end points of the respective segments by using the local algorithm with those segmentation thresholds detected in the second step.

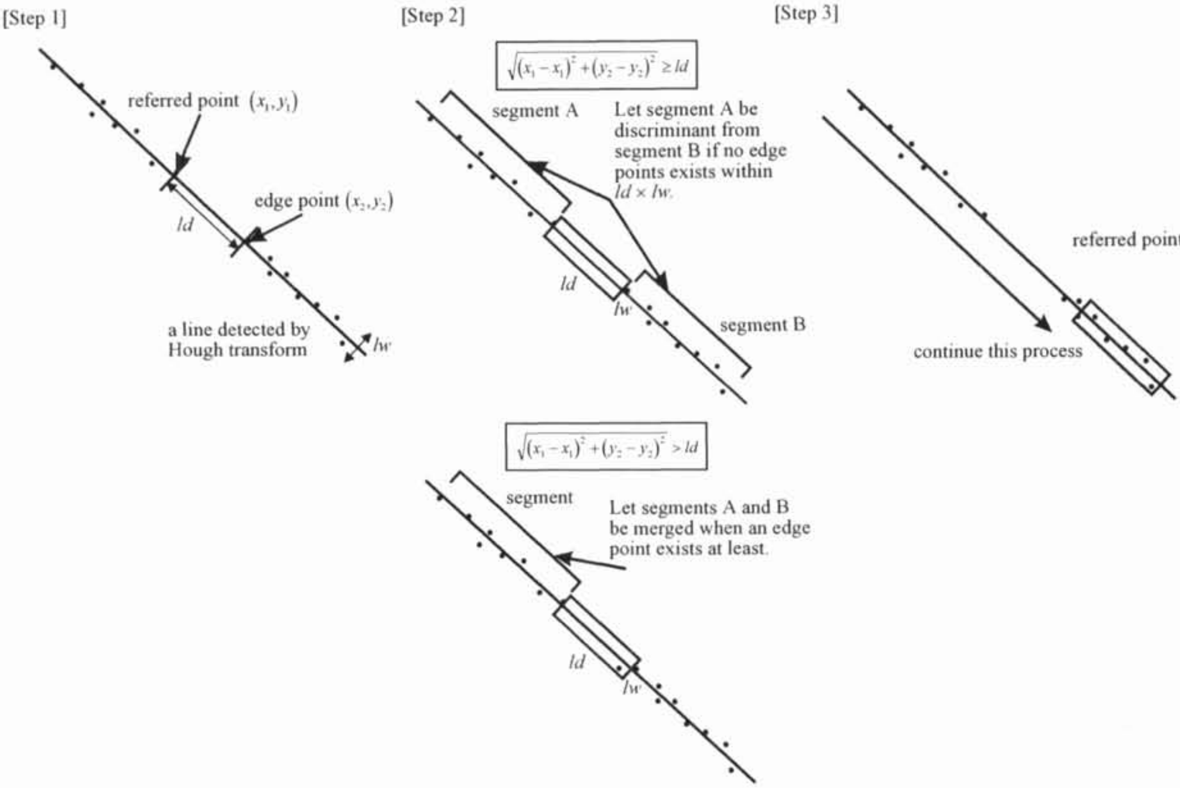


Fig.1 A local algorithm to segment line

3.1. Introduction of histogram

At the beginning, the histogram of the density of the edge points is generated by enumerating the number of edge points along the line detected by Hough transform. Let a referred point on the line be i. The histogram $H[i]$ gives the accumulated number of edge points within an area $(d \times w)$ at a point i. We can introduce this histogram $H[i], i = 1,2,3,\cdots$ by operating this procedure repeatedly from start to end of the line. The histogram $H[i]$ could provide a global information of the distribution of the edge points along a line. An example of the histogram $H[i]$ of the edge points is presented in Fig.2.

3.2. Discriminant analysis for selecting segmentation threshold

A valley in the histogram $H[i]$ indicates a threshold between two segments on the straight line. Therefore, we can detected segmentation thresholds among line segments by extracting valleys of the histogram. In this paper, we apply the discriminant analysis hierarchically to the histogram to detect the segmentation thresholds as given below.

First, let a segmentation threshold be extracted. Then, let the local evaluation measure Dl, defined by eq.(3) be calculated. Only when $Dl \leq T$, let the segmentation procedure be proceeded hierarchically at this threshold as shown in Fig.3.

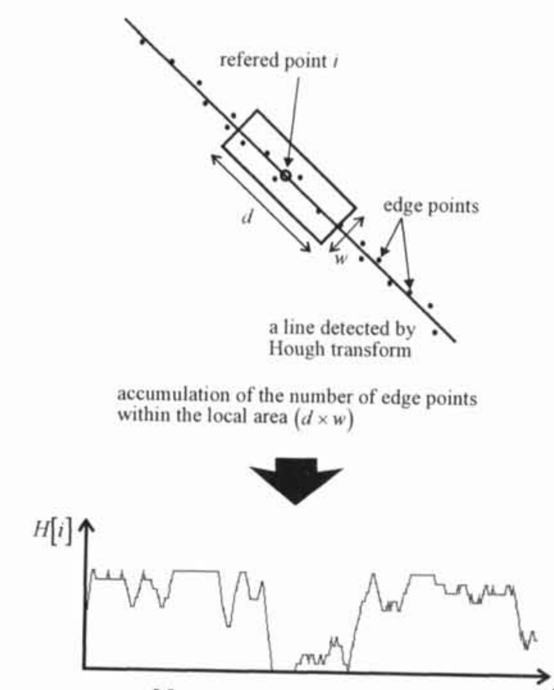


Fig.2 Histogram of the edge points along a line detected by Hough transform

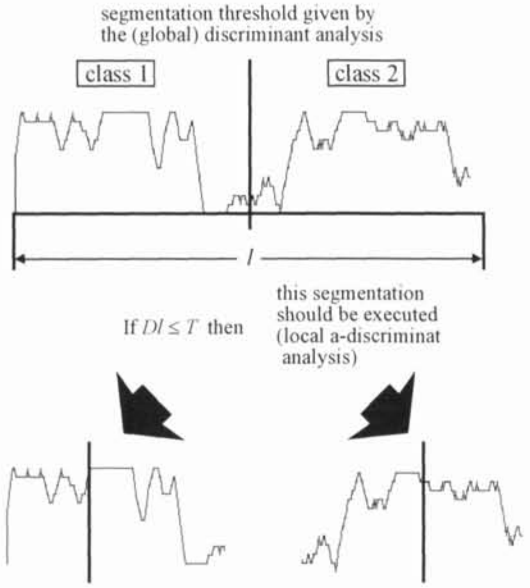


Fig.3 Global segmentation with discriminant analysis

$$Dl = \frac{\dfrac{\sum_{i=k-t/2}^{k+t/2} H[i]}{t}}{\dfrac{\sum_{i=0}^{l} H[i]}{l}} \leq T \qquad (3)$$

$H[i]$: histogram
i : length of histogram
t : area around the threshold
k : threshold detected by discriminat analysis
T : evaluation measure

In this procedure, the measure Dl works as an 'a-discriminant measure' for segmentation from a view point of local distribution of edge points. We can select plural segmentation thresholds hierarchically by applying this operation repeatedly while the judgment equation (3) be satisfied.

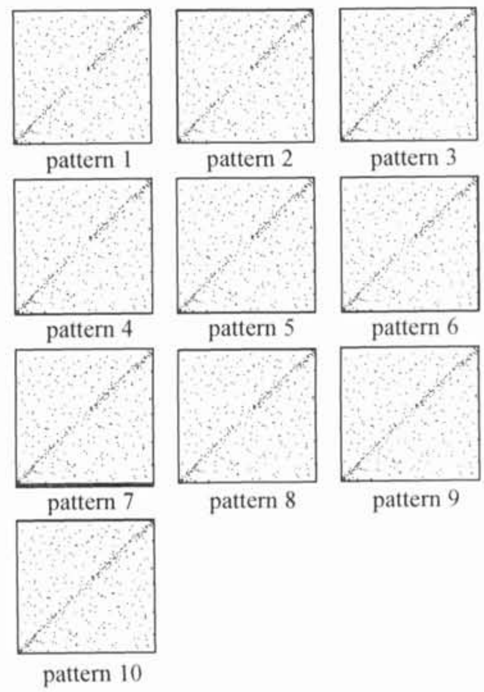
3.3. Detection of the end points of line segments

After applying the discriminant analysis to histogram of the edge points, if the resultant threshold is accepted by the local evaluation using Dl, let this segmentation be executed. At all these segmentations, the precise end points of the line segments can be extracted by the local algorithm given in Section 2.

4. Experiments

4.1. Experiment of threshold of Dl for hierarchical discrimination

We present an experiment of threshold of Dl for hierarchical discrimination. Pattern 1~10 in Figure 4 are artificially generated patterns, and those will be connected gradually into one segment from two segments. And, we calculated local evaluation measure Dl for each patterns, as shown in Figure 4. It was known that the values Dl for patterns 4~7 are bounded between 0.4 and 0.5. So, we can select the bound of the threshold T for local a-discriminant measure Dl around 0.4~0.5.



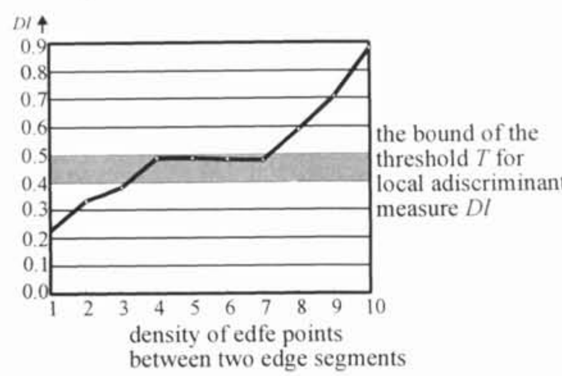


Fig.4 Threshold of Dl for heirachical discrimination

4.2. Experiment of segmentation

We present a few examples of segmentation experiments to show the effectivity of the proposed method. Figure 5 shows an input data for the experiment which is prepared by binarizing the gray image of a soccer ground. We detected the goal and side lines from this image. Figure 6 shows the result of segmentation using local algorithm in Section 2. Figure 7 shows an example of histogram of the edge points on the line detected by Hough transform. A vertical solid line in the histogram shows the segmentation threshold given by the global algorithm. Figure 8 shows the result of segmentation provided by discriminant analysis hierarchically applied to the edge histograms.

On the other hands, as shown in Figure 6, the line was separated into many short segments by using the local algorithm alone. It was experimentally clarified that the proposed method of segmentation could be applicable to the practical images.

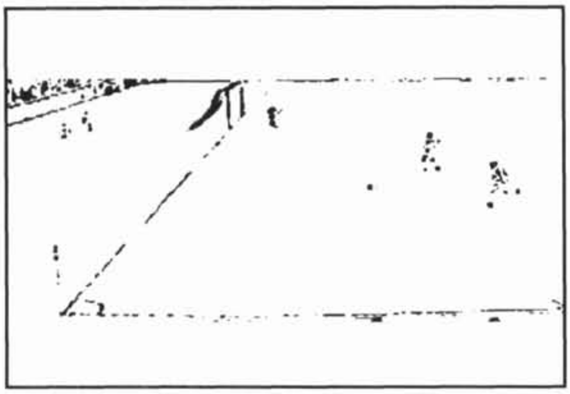


Fig.5 Input image

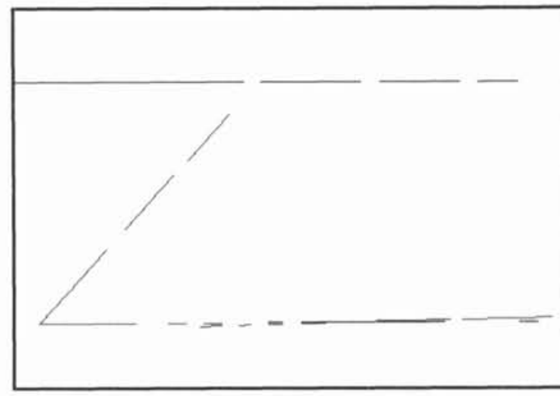


Fig.6 Result of segmentation using local algorithm

$\theta = 1000 \quad ld = 10$

$\rho = 1000 \quad lw = 5$

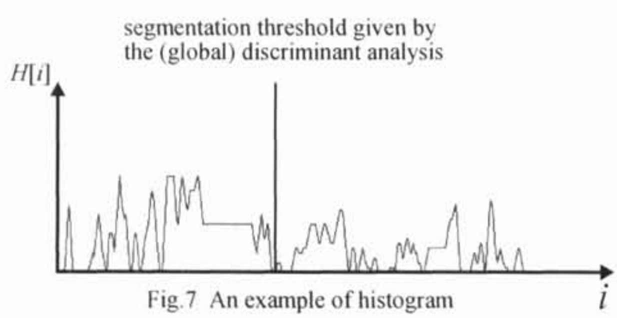


Fig.7 An example of histogram

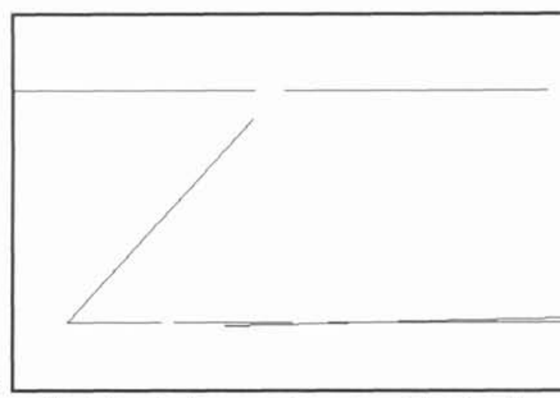


Fig.8 Result of segmentation using global algorithm

$\theta = 1000 \quad d = 5$

$\rho = 1000 \quad w = 5$

$T = 0.5$

5. Conclusions

This paper proposed a segmentation algorithm for line detected by a hierarchical application of the discriminant analysis. This proposed method was enforced to extract line segments by combining a global method with a local method. We experimentally demonstrated the applicability of the proposed method to the practical images. In order to enhance the potential of our method, the following subjects must be investigated.

(1) Improvement of the robustness of histogram, and of the reliability of the threshold selection would be expected. In this case, other selection methods, such as mode method, should be discussed.

(2) Development of the automated method to know how many segments are in the detected line, and the automated method to tune up the parameters are also to be discussed.

(3) The effectivity and robustness of the method must be examined by using several real images.

References

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