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A method for extraction of arbitrary curve using one-dimensional histogram

Shota NAKASHIMA and Seiichi SERIKAWA

Department of Electrical Engineering
Kyushu Institute of Technology
1-1 Sensui-cho, Tobata-ku, Kitakyushu-shi, Fukuoka, 804-8550, JAPAN
(Tel : 81 −93 −884 −3008 ; Fax : 81-93 −844 −3015)
(nakashima@boss.ecs.kyutech.ac.jp)

Abstract: An extraction of a specific curve in image has basic problems in intelligent image sensing. The generalized Hough Transform method (GHT) is the representative method to extract arbitrary curves which are rotated and enlarged or reduced. Many the improvement models were also proposed. However, for extraction of arbitrary curves, it takes much processing time and needs much memory space. In addition, it is impossible to apply the GHT to curves including branches. For an improvement of the problems, a new method to extract arbitrary curve using one-dimensional histogram is proposed in this study. The method utilizes the Polytope method which is one of minimization algorithms. For the extraction of curves, one-dimensional histogram is used. The histogram has two characteristics. (1) The distribution of histogram changes if the parameters representing curve changes. (2) The best parameters are gotten, if the value of most frequency of histogram becomes maximum. Therefore, by using the Polytope method, the best parameters are searched so that the value of most frequency can be maximum. Unlike conventional method, the memory space is very small, processing time is very short and curves including branches can be extracted. In addition, this method is effective for an extraction of arbitrary curve with different aspect ratio.

Keywords: image processing, Polytope method, Generalized Hough Transform, one-dimensional histogram

I. INTRODUCTION

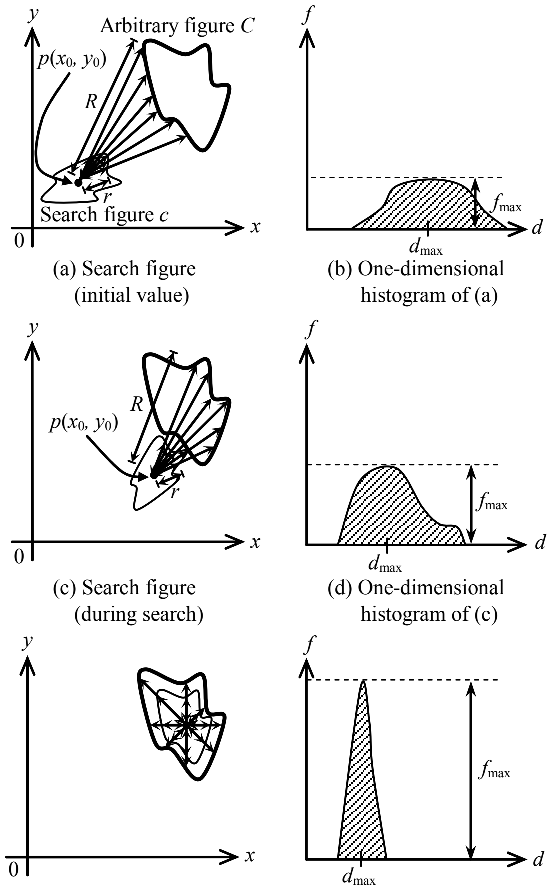
An autonomy robot needs to have an ability of space notation, because it moves and recognizes an object. Especially, a moving robot needs to recognize it fast. Thus the fast image processing has been studied [1]. An extraction of straight line and circle is one of the basic problems of image processing. The Hough Transform method (HT) is the representative method [2][3][4]. It can extract line and circle which are rotated and enlarged or reduced. For the extraction of arbitrary curves, the generalized Hough Transform method (GHT) is usually used [5]. It is an improved method of HT. However, for extraction of arbitrary curves, it takes much processing time and needs much memory space. For the improvement of the problems, many improved models were proposed [6]. In spite of the improvement, these still takes much processing time and needs much memory space. In addition, it is impossible to apply the extraction of curves including branches. We had proposed a method to extract line and circle using one-dimensional histogram and the Polytope method [7]. In comparison with HT, the method takes very small memory space and the processing time is very short. In this study, a new method to extract arbitrary curve is proposed. The method is the extension of the method for line and circle extractions. This is a generalized model. The basic algorithm is the same as those of line, circle and ellipse extractions. Unlike conventional method, the memory space is extremely small, and processing time is greatly short. In addition, it is tough against noise and curves including branches can be extracted. This method can also extract arbitrary curve with different aspect ratio.

II. EXTRACTION OF FIGURES USING ONE-DIMENSIONAL HISTOGRAM

A proposed method utilizes the Polytope method and one-dimensional histogram. An application of the Polytope method to extract figures and a procedure of extraction of figures using one-dimensional histogram are mentioned as follows.

1. Application of the Polytope method

In this study, one-dimensional histogram is generated from image. The histogram has two characteristics. (1) The distribution of histogram changes if the parameters representing curve changes. (2) The best parameters are gotten, if the value of most

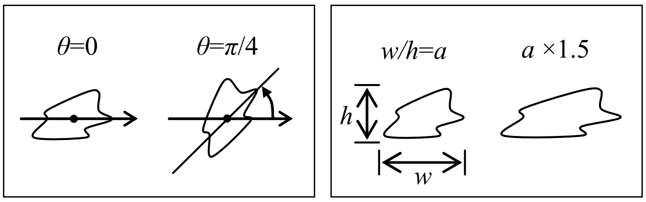


(a) Search figure (initial value)　(b) One-dimensional histogram of (a)

(c) Search figure (during search)　(d) One-dimensional histogram of (c)

(e) Search figure (search completion)　(f) One-dimensional histogram of (e)

Fig. 1. Outline of search for extraction of arbitrary figure.



(a) Rotation angle θ　(b) Aspect ratio a

Fig. 2. Rotation angle and aspect ratio.

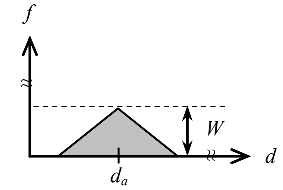
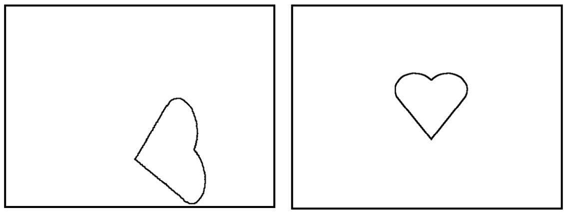
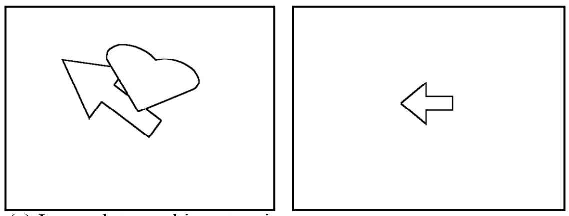


Fig. 3. Weight of voting W



(a) Image data used for extraction experiment of heart symbol　(b) Search figure of heart symbol

Fig. 4. Experiment for extraction of heart symbol.



(a) Image data used in extraction experiment of arrow symbol　(b) Search figure of arrow symbol

Fig. 5. Experiment for extraction of arrow symbol.

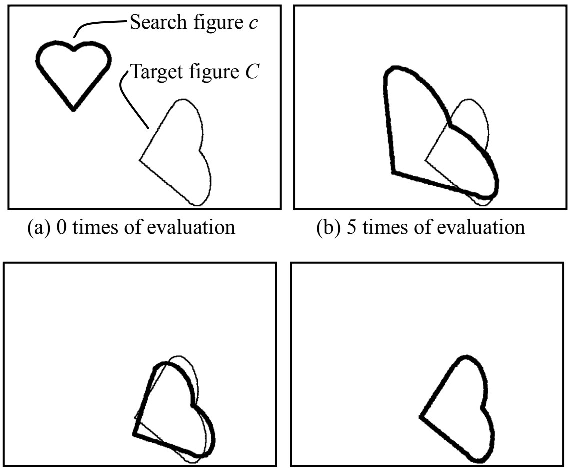
frequency of histogram becomes maximum (see Sect.II-2 for details). By using the Polytope method, the best parameters are searched so that the value of most frequency can be maximum.

The Polytope method is one of minimization algorithms. Since it can get a minimum value no using derived function different from the Newton's method, the concept can be used for search of histogram. In addition, the program size is small. For more details, see Ref. [8] and [9]. For the use, the "initial values" must be set because this method is available for only a single-peak function. If these are not suitable, the optimum value may not be obtained.

2. Procedure to extract figure using one-dimensional histogram

A procedure to extract figure using one-dimensional histogram is mentioned here. A template figure (search figure c) is prepared for extraction of arbitrary figure C as shown in Fig. 1(a). To represent arbitrary figure as parameters, gravity point $p(x_0, y_0)$, aspect ratio a(height h / width w), and rotation angle θ are defined as shown in Fig. 1(a) and Fig. 2 are defined. The arbitrary figure defined by the above is called "search figure" c. Let the distance between gravity point $p(x_0, y_0)$ of search figure and a point on arbitrary figure C be R, let the distance of search figure to the direction of a point on C be r, and let R/r be the distance ratio d. The value of d is calculated for all pixels on arbitrary figure C. Thus, one-dimensional histogram about d is obtained as shown in Fig. 1(b). It corresponds to the relationship between d and frequency f.

If the parameters of search figure c which are represented by $p(x_0, y_0)$, a and θ are much different from those of arbitrary figure C, the deviation of distance ratio d is large. As a result, the distribution of



(a) 0 times of evaluation (b) 5 times of evaluation

(c) 40 times of evaluation (d) 188 times of evaluation (search result)

Fig. 6. Search figure c agrees with those of target figure C according as the number of times of the search increases using Polytope method.

the histogram is gentle. In consequence, the value of most frequency f_{max} is low as shown in Fig. 1(b). Here, let the value of d at the position of most frequency $f_{\max}$ be $d_{\max}$. According as the parameters of search figure c approach those of arbitrary figure C, the deviation of d becomes small. Then, the value of most frequency $f_{\max}$ becomes high as shown in Fig. 1(d). If the parameters of search figure c agree with those of arbitrary figure C as shown in Fig. 1(f), the value of most frequency $f_{\max}$ is the highest. At the case, the width w in Fig. 2(b) of arbitrary figure C is obtained as $d_{\max}$, and the height h corresponds to $a \times d_{\max}$.

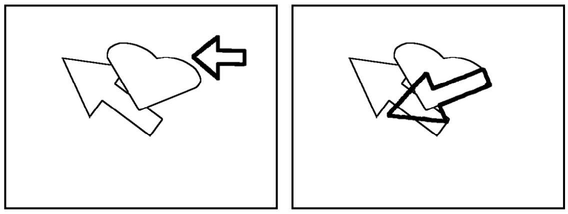
In this way, the arbitrary figure C is gotten, if the value of most frequency $f_{\max}$ of histogram becomes maximum. We define the following evaluation function E to evaluate the histogram.

$$E = 1 - \frac{f_{\max}}{C_{ir} \times W} \tag{1}$$

where, C_{ir} is the perimeter, which is obtained as perimeter of search figure $c_{ir} \times d_{\max}$ when the value of $f_{\max}$ is the highest. Symbol W means a weight which is used when d is voted to one-dimensional histogram. The weight has a distribution. The example is shown in Fig. 3. Let a distance ratio d of a pixel on arbitrary figure C be d_a. First, the frequency at the position of d_a is set to be W. According as the distance ratio d is away from d_a, the frequency is reduced one by one. The function E is the lowest when the value of $f_{\max}$ is the highest. By the use of the Polytope method, $p(x_0,\ y_0)$, a, and θ of arbitrary figure C are searched so that the function E is the lowest.

Table1. Experimental result.

	x	y	a	θ
initial value	150	150	1.0	0
final value	400.0	350.0	1.43	81.0
correct value	400	350	1.5	90



(a) Initial search of arrow symbol (b) Extraction of arrow symbol

Fig. 7. Experiment result for extraction of arrow symbol.

III. EXPERIMENTAL EXTRACTION OF A RBITRARY FIGURE

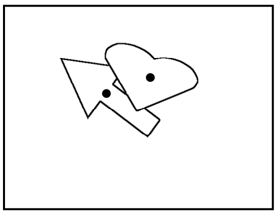
1. Experimental conditions

Image data in Fig. 4(a), which is used in this experiment, includes a heart symbol. The search figure is shown in Fig. 4(b). Another image which includes a heart symbol and an arrow symbol is also prepared as shown in Fig. 5(a). The search figure is shown in Fig. 5(b).

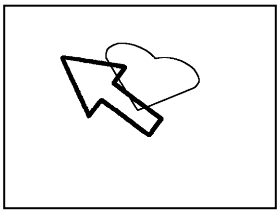
The image consists of 640 × 480 pixels. For the experiments, we used a personal computer (Dell, OptiPlex GX520, OS: Windows XP, CPU: Pentium4 - 3.2GHz). In the case of this experiment, the "initial values" of $p(x_0,\ y_0)$ are set to both 150, a and θ are set to 0 and 0 respectively. The scale factor of $p(x_0,\ y_0)$ are set to 200, a and θ are set to 1 and 1 respectively for the Polytope method.

2. Experimental results

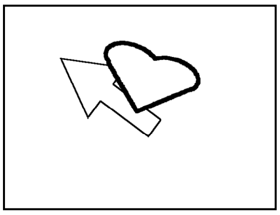
An experimental result for Fig. 4(a) is shown in Fig. 6. Here, the target for extraction is called "target figure" C. In Fig. 6, "search figure" c is also drawn for reference. The parameters of the search figure before the search and it after the search are listed in Table 1. As for extraction of a heart symbol, memory space is 3.2[KB] (for one-dimensional histogram, horizontal axis d[=800Byte] ×vertical axis f[=4Byte]). In this study, memory space is the same as 3.2[kB] for any image data. The processing time of them are 0.9[s].



(a) Gravity points of arrow symbol and heart symbol



(b) Extraction of arrow symbol



(c) Extraction of heart symbol

Fig.8. Experimental result using improved method.

As understood from Fig. 6, the search figure c agrees with target figure C according as the number of times of the search increases. As a result, the heart symbol is correctly extracted in this experiment. In Table 1, the parameters of search figure c (final value) almost agree with those of target figure C (correct value).

In contrast to Fig. 6, the extraction in Fig. 7 is not correct. This is attributed to "initial values" as mentioned in Sect. II-1. The Polytope method is available for only a single-peak function, so the determination of initial values is important for use of multi-peak function. If the values are not suitable, the optimum value may not be obtained. For initial values, it is desirable that the values of parameters of search figure c are as near as those of target figure C possible.

IV. DISCUSSION

1. Initial values of parameters

As understood from the above results, the success of figure extraction depends on "initial value". If most frequency f_{max} of the one-dimensional histogram becomes highest, a gravity point of $p(x_0, y_0)$, target figure C, rotation angle θ and aspect ratio a are estimated by proposed method. Therefore, we examine the relationship between "initial value" of $p(x_0, y_0)$, θ, and a, and most frequency f_{max}. If $p(x_0, y_0)$ of search figure c are much different from those of target figure C, the value of f_{max} is not high even if θ and a agree with those of C. In contrast, if $p(x_0, y_0)$ of c agrees with those of C, the value of f_{max} is relatively high even if θ and a are quite different from those of C. Thus, if the "initial value" of $p(x_0, y_0)$ of c is inappropriate, most frequency f_{max} does not become high. That is to say, it falls into a local minimum. Thus, the "initial value" of $p(x_0, y_0)$ is much correlated with most frequency f_{max} more than θ and a.

The "initial value" of $p(x_0, y_0)$ is important especially. The method to determine "initial value" of $p(x_0, y_0)$ is mentioned the followings.

2. How to determine initial value of gravity point of search figure

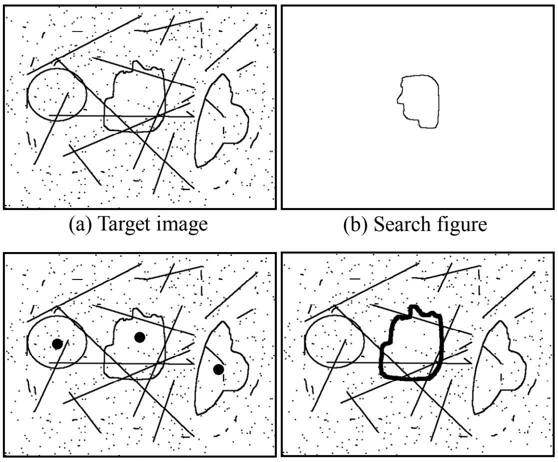
The success of figure extraction may depend on "initial value" of gravity point p (x_0, y_0). For avoiding the failure of extraction, we roughly estimate the gravity candidate point $p(x_0, y_0)$ of target figure C before the practice of proposed method. The roughly estimated point is regarded as initial value of gravity point $p(x_0, y_0)$ in this study. The procedures are as follows.

1) Enlargement operation：The line which broke off is connected. After binarization, closed lines are sometimes broke off by noise. The lines are connected by "enlargement operation".
2) Extraction of small regions： If a size of region is more than threshold value t_1, the region is removed. Large sizes of noises are removed by "extraction of small regions".
3) Extraction of large regions： If a size of region is less than threshold value t_2, the region is removed. Small sizes of noises are removed by "extraction of large regions".
4) Extraction of gravity point： From closed curves, the gravities are extracted.

By the above procedures, some gravities are extracted. We utilize the gravities as the "initial value" of the search figure.

3. A method improved to extract arbitrary figure using one-dimensional histogram

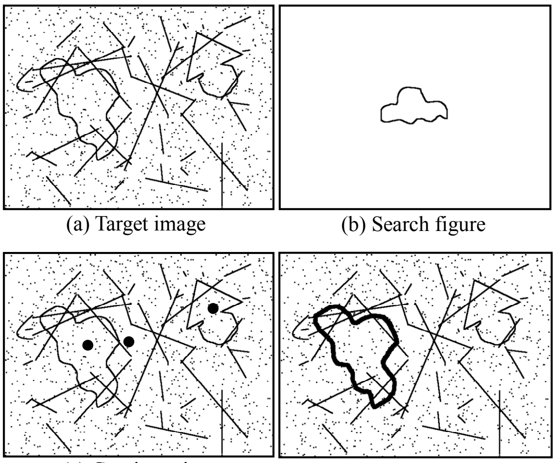
In this experiment, Fig. 5(a) is used as image data. Fig. 4(b) and Fig. 5(b) are used as search figures to detect the heart symbol and the arrow symbol, respectively. The dots (●) in Fig. 8(a) show the gravities extracted from Fig. 5(a) according as the above procedures. The points are regarded as initial values of $p(x_0, y_0)$. The other initial values are the same as those of Sect. III-2. However, scale factor of $p(x_0, y_0)$ is



(a) Target image (b) Search figure

(c) Gravity points (d) Experimental result

Fig. 9. Example of other experiment (1).



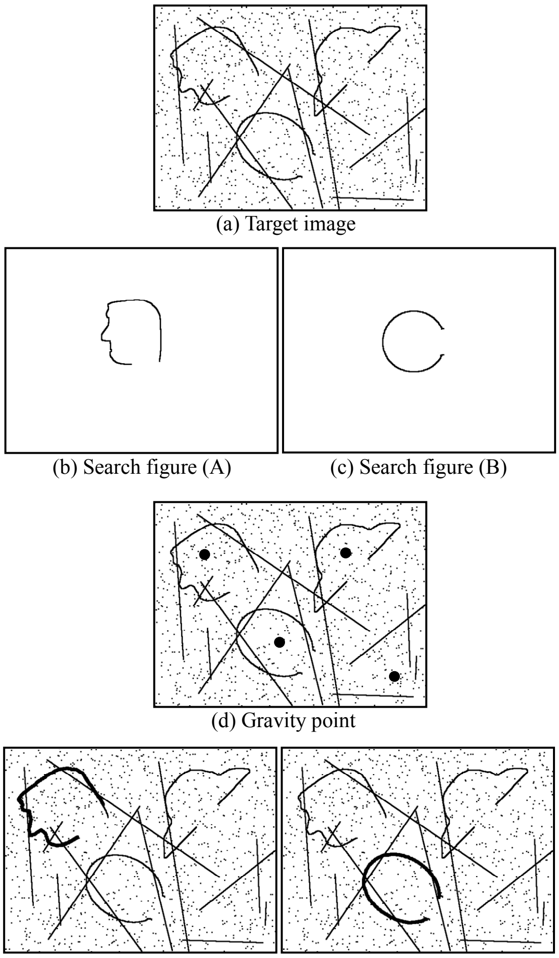
(a) Target image (b) Search figure

(c) Gravity points (d) Experimental result

Fig. 10. Example of other experiment (2).

changed to 10, θ and a are changed to 0.5, which are smaller than those of Sect. III-2. This is because it is easily estimated that the initial points are near the correct gravity points as shown in Fig. 8(a), so large size of scale factor does not need. The extraction is practiced twice as for Fig. 5(a), because two gravities are extracted in Fig. 8(a). After twice extractions, the minimum value of evaluation function E is selected, and the parameters are regarded as final values.

The results are shown in Figs. 8(b) and (c). In these figures, the thick curves show the extracted figures. As understood from these figures, the heart symbol and the arrow symbol are correctly extracted in this experiment. In spite of including branches, the symbols are correctly extracted. As for extraction of gravities, the processing time is 0.2[s]. As for extraction of symbol, it takes



(a) Target image

(b) Search figure (A) (c) Search figure (B)

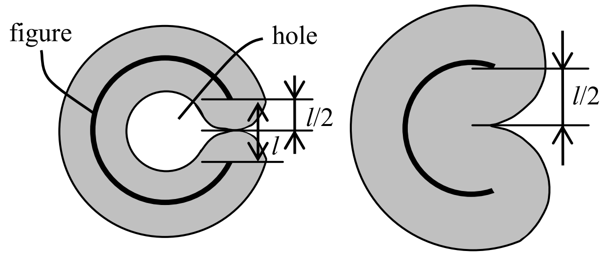
(d) Gravity point

(e) Experimental result (A) (f) Experimental result (B)

Fig. 11. Experiment for extraction of opened curve

1.8[s] for the heart symbol, and 1.4[s] for the arrow symbol.

Examples of other experiments are shown in Fig. 9, Fig. 10 and Fig. 11. In Fig. 9(c), Fig.10 (c) and Fig.11 (b), the extracted gravities are shown as dots (●). In case of the number of dots is 3, the extraction is practiced three times. The search figures are shown in Fig. 9(b), Fig. 10(b), Fig. 11(c) and Fig. 11(d). The results are shown in Fig. 9(d), Fig. 10(d), Fig. 11(e) and Fig. 11(f). In these figures, the thick curves show the extracted curves. As understood from these figures, each symbol is correctly extracted in this experiment. Although target images include many noises, correct symbols are extracted. Thus, the proposed method has tough against noise. As for extraction of gravities, processing time is 0.2[s] for Fig. 9(c), 0.2[s] for Fig.10 (c), and 0.2[s] for Fig.11(d), respectively. As for extraction of symbol, it takes 4.3[s] for Fig. 9(d), takes 4.7[s] for Fig. 10(d), takes 4.6[s] for Fig. 11(e), and takes 5.5[s] for Fig. 11(f).



(a) applicable figure (b)not applicable figure

Fig. 12. Extractive condition of gravity point for opened curve

4. Extraction of gravity point for opened curve

The proposed method can be applied to the extraction of opened curve as shown in shown Fig. 11. It can not be, however, applied for all opened curves. It has a limitation. As mentioned in *Sect*. IV-2, enlargement operation is used for the extraction of gravity point. A gravity point is not extracted if a hall does not exist within a curve. The example is shown in Fig. 12. In Fig. 12(a), a hall exists after enlargement operation, while it does not exist in Fig. 12(b). The proposed method can not be applied for an opened curve such as Fig. 12(b).

V. CONCLUDION

A new method to extract arbitrary curve using one-dimensional histogram and the Polytope method are proposed in this study. Unlike conventional method, the memory space is very small, processing time is very short, it is tough against noise and figures including branches can be extracted. In addition, this method is effective for an extraction of arbitrary figure with different aspect ratio.

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