

Paper:

Proposal of a Method to Extract Arbitrary Figures Using One-Dimensional Histograms

Shota Nakashima*, Makoto Miyauchi**, and Seiichi Serikawa*

*Department of Electrical Engineering, Kyushu Institute of Technology, Kitakyushu, Japan
E-mail: nakashima@boss.ecs.kyutech.ac.jp

**Department of Integrated Arts and Sciences, Kitakyushu National College of Technology, Japan
E-mail: miyauchi@kct.ac.jp

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Arbitrary figure extraction, a basic image processing problem, is done typically using the generalized Hough transform (GHT). GHT and its successors tend, however, to consume humongous amounts of processing time and memory space. The arbitrary figure extraction we propose using one-dimensional histograms takes advantage of the Polytope method, which features: (1) The histogram distribution changes if parameters representing figures change. (2) Optimum parameters are obtained, if the value of the highest-frequency histogram becomes maximum. This approach makes memory space very small, processing time very short, effective by extracts arbitrary curves with different aspect ratios, and the algorithm is simple.

Keywords: image processing, polytope method, one-dimensional histogram, generalized hough transform

1. Introduction

An autonomous robot requires space notation because it moves and recognizes objects. Fast robots need fast recognition [1]. Arbitrary figure extraction as a basic of image processing problem is generally solved using the generalized Hough transform (GHT) and its successors [2], even for figures that are rotated and enlarged or reduced [3]. The parameter space, which consists of translation, rotation, and scaling, is usually very large, requiring much processing time and memory space despite many improvements [4, 5]. Approaches have included different aspect ratios [6], Fourier descriptors [7], genetic methods [8], and geometric hashing [9].

The approach we propose uses one-dimensional histograms and minimization even for extracting arbitrary figure with different aspect ratios, yet keeps processing time comparatively short and memory space comparatively small, while remaining robust against noise.

2. Figure Extraction Using One-Dimensional Histograms

The Polytope method and one-dimensional histograms are applied to extract figures as detailed in the sections that follow.

2.1. Approach

One-dimensional histograms generated from figures feature (1) histogram distribution changing if parameters representing figure changes and (2) best parameters gotten if the highest frequency histogram becomes maximum (Section 2.2). The Polytope method searches for the best parameters so that the maximum highest frequency is found.

The Polytope method has three features: (1) It get minimums without derived functions differing from Newton's method, so the concept can be used to search for histograms. (2) The program is small. (3) "Initial values" must be set because this can be used only for a single-peak function [10, 11].

2.2. Figure Extraction Using One-Dimensional Histogram

To extract figures using one-dimensional histograms, a template figure (search figure c) is prepared for extracting arbitrary figure C (**Fig. 1(a)**). To represent arbitrary figure C as parameters, center of gravity $p(x_0, y_0)$ aspect ratio a (width w / height h) and rotation angle θ of template figure are defined (**Figs. 1(a)** and **2**). The template figure thus defined is called "search figure" c . Let the distance between center of gravity $p(x_0, y_0)$ of the search figure and a point on arbitrary figure C be R , let the distance of the search figure to the direction of a point on c be r , and let R/r be distance ratio d . d is calculated for all pixels in arbitrary figure C , yielding a one-dimensional histogram about d (**Fig. 1(b)**) corresponding to the relationship between d and frequency f . Let the highest frequency be f_{\max} .

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

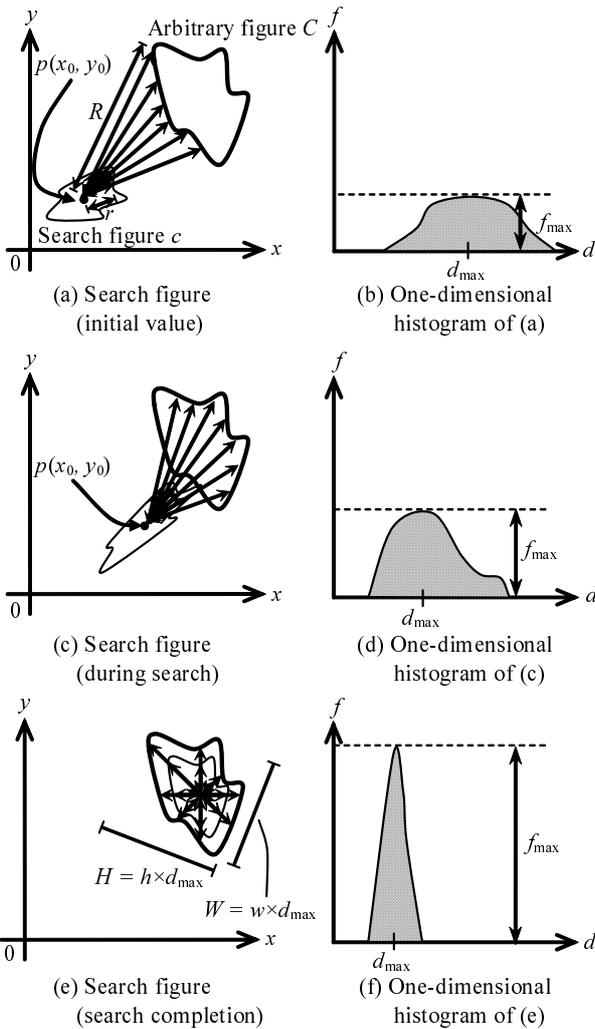


Fig. 1. Search for extraction of arbitrary figure.

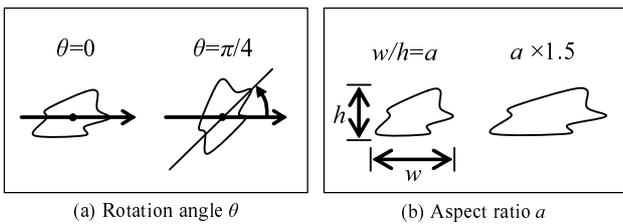


Fig. 2. Rotation angle and aspect ratio.

large, making histogram distribution gentle and highest frequency f_{max} low (Fig. 1(b)). Let d at highest frequency f_{max} be d_{max} . As search figure c parameters approach those of arbitrary figure C , deviation d becomes small and highest frequency f_{max} becomes high (Fig. 1(d)). If search figure c parameters agree with those of arbitrary figure C , highest frequency f_{max} is the highest (Fig. 1(f)). In the last case, height H of arbitrary figure C is obtained as $h \times d_{max}$ and width W corresponds to $w \times d_{max}$ (Fig. 1(e)). Search figure height h is normalized as 1, yielding arbitrary figure C if highest frequency f_{max} of the histogram becomes maximum. We define function E

to evaluate the histogram as

$$E = 1 - \frac{f_{max}}{C_p \times V_w} \dots \dots \dots (1)$$

where $C_p (= c_p \times d_{max})$ is the number of search figure c_p pixels multiplied by d_{max} when f_{max} is highest. Target figure C is similar to search figure c , when f_{max} is highest. C_p corresponds to the number of pixels of target figure C . Symbol V_w means a weight used when d is voted to one-dimensional histogram. Weight has a distribution (Fig. 3). Let distance ratio d , obtained by the relationship between center of gravity $p(x_0, y_0)$ of search figure c and a point in arbitrary figure C , be d_a . The frequency at position d_a is set to W . Based of the distance ratio d is away from d_a , frequency is reduced. Search figure c parameters represented by $p(x_0, y_0)$, a , and θ are much different from those of arbitrary figure C , and highest frequency f_{max} is very low, so function E is nearly 0 (Eq. (1)). As search figure c parameters approach those of arbitrary figure C , f_{max} becomes high, so function E is low. If search figure c parameters agree with those of arbitrary figure C , f_{max} is highest and function E is the lowest. Using the Polytope method, $p(x_0, y_0)$, a and θ of arbitrary figure C are searched for so that function E is lowest. The turn for parameter change and the change for each parameter are automatically determined so the highest frequency of the one-dimensional histogram is high.

Operation-time depends on the number of figures in an image. All center of gravity candidate points are searched, with time roughly estimated as follows: When mean time for one search is t [s] and the number of candidate points is n , processing time becomes $t \times n$ [s]. For 640×480 pixels, t is 1.43 s and $n=3$ (Fig. 10). In general, the number of target images is low. If there are too many, performance deteriorates.

3. Experiment

3.1. Setup

Image data (Fig. 4(a)), used in the experiment includes a heart (Fig. 4(b)), as does another image, which also includes an arrow (Fig. 5).

The image consists of 640×480 pixels. The experiment used a personal computer for (Dell, OptiPlex GX520, OS: Windows XP, CPU: Pentium4-3.2 GHz). "Initial values" of $p(x_0, y_0)$ we are set to 150, and a and θ set to 1 and 0.