An Improved Automatic Shape Feature Extraction Method Based on Template Matching

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Abstract. Image shape extraction is an important step in the image analysis, AI electronic industry and automation, as well as a significant part of content-based image retrieval(CBIR), which cannot be separated from contour extraction. However, traditional approach of the border following algorithm is susceptible to noise interference, thus the shape extracted is always complex in real images and cannot express feature of the target image well. Therefore, an improved shape feature extraction method is proposed, which converts color space into HSV model when preprocessing, filters contour by area size, merges adjacent contours by drawing convex hull and filters with template shapes. Lastly, this method is tested on UAV123 and YCB_Video dataset, which showed that the proportion of valid contour improved from less than 10% to 87.7% based on border following algorithm. In the experiment of OPenCV open source library in Visual Studio environment, we hope to improve the extraction efficiency of shape features.

Keywords: Shape retrieval; Contour extraction; Template matching; Machine vision.

1. Introduction

As a fundamental and elementary processing method, mountainous feature extraction algorithms have been used to extract point features, edge features, corner features and region features, etc. The extraction of shape features has also been widely used in retrieving target of users’ interesting regions. Shape features can be regarded as higher-level features than color or texture, and it should be repeatable, that is, features extracted from different images in the same scene should be identical. Compared with point features, edge features and texture features in extracted images, shape features are the best way to express objects with clear boundaries [1]. Shape features in the image are generally divided into two categories: boundary based or region based, which is usually described by Fourier [2], or the contour is smoothed first, and then the area between adjacent peaks and valleys is obtained, and then the contour shape features are obtained by Fourier transform [3]. Hough transformation is limited to extract shapes that only can be expressed analytically, and besides, that is time consuming as well as space occupied [4]. Moreover, extraction results are unreliable when deformation occurs. Border following algorithm [5] only extracts according to the topology structure, which lacks the high-level meaning of extraction content and its edge is complex. In 2013, the contour feature extraction algorithm [6] proposed by ZhangYuhui et al. Deducted the error rate, but not tested on live images. In order to find out target content quickly, information of shape in image can also be extracted by the color feature and spatial feature retrieval [7], or image content retrieval [8]. All these have become the focus of CBIR research. Due to the description of interesting shapes lacks mathematical definition [1] and models, and extraction results are very different from the perception of human eyes, conventional method cannot
adapt to targeted shape retrieval in quantities of images. In order to extract typical feature of shape and get the position of object it includes, in this paper, contours extracted by border following method after series pre-treatments were taken and screened by area size, then convex hulls were drawn to merge adjacent contours. Furthermore, templates including basic shapes such as triangle, rectangle and circle were used to match and filter convex hulls, so as to get brief shapes. Finally, experiments in laboratory scenes, drone pictures and UAV123 data sets were done and compared.

2. Method

2.1. Traditional Method of Finding Contour
After binarization, we try to use the traditional border following algorithm to extract contours, which is shown in Figure 1. S1 is background. S2 is wrapped white points connected to the frame. B1 is outer contour of S2 and B2 is inner contour of S2. Setting boundary value of outer frame NBD as 1 and if one point with pixel value of 1 and pixel 0 on its left calls (i,j), then set the left pixel as (i,j-1), set NBD=NBD+1, and consider this point belongs to an outer contour.

Due to pixel points must be searched adjacently, which is connected to initial one, it is susceptible to noises, and then junky details and duff contours were captured. Experiment results are showed in Figure 2, and some images are from AUV123 dataset.

2.2. Improved Shape Feature Extraction Method

2.2.1. Process design. As Figure 3 indicated, firstly, preprocessing and template matching are used to winnow representative shape contours in image. Secondly, experiments on YCB_Video_Dataset will be done to test its practicality. The ultimate goal is to decrease quantity of contours extracted efficiently and conserve those typical shapes simultaneously. In the whole process, two following aspects have been ameliorated to achieve better experimental results: Color space conversion is shifted from RGB to HSV, which is closer to human visual perception system. So that grayscale image with color or area brightness feature divided in blocks is more accessible. While extracting shape feature,
adjacent contours are combined by drawing convex hulls and then similarity measurement between template shapes and convex hulls is carried out to screen out the simple and representative contours.

![Figure 3. Refined flow processing.](image)

2.2.2. Preprocessing. Since discrete digital images gain more operation accessibility for computer, two-scale array is used to the describe image. In order to combine further alteration, pre-treatment is indispensable. Firstly, the color space is converted. Generally, RGB model showed in Figure 4 (a), which meets industry standard, become widespread. It contains red, green and blue, blending in different proportions. However, HSV model, showed in Figure 4 (b), established by replacing the above three primary colors with hue, saturation and value, which is closer to human eye perception[9], becomes easier to extract objects or areas of multiple colors and variable brightness in pictures. The conversion of RGB space to HSV space has following relations:

$$
H = \begin{cases} 
\frac{G-B}{MAX-MIN} \times 60^\circ, & (R = \text{MAX}) \\
\frac{B-R}{MAX-MIN} \times 60^\circ, & (G = \text{MAX}) \\
\frac{R-G}{MAX-MIN} \times 60^\circ, & (B = \text{MAX}) 
\end{cases} \quad (1)
$$

$$
S = \frac{MAX - MIN}{MAX} \quad (2)
$$

$$
V = \text{MAX} \quad (3)
$$

Secondly, compressing the information image. Image consists of three channels in HSV model, shown in Figure 5 (a), while only one channel is enough for finding edge details, shown in Figure 5 (b). Therefore, channel separation, taking out single channel, devalues calculation and accelerates speed. The value of single channel grayscale image, vary from 0 to 255, still has a large amount of information. But if it is binarized, redundant message can be compressed further. For example, Figure 6 is binary image of Figure 5(b).

![Figure 4. Two color space models.](image)

![Figure 5. Channel separation.](image) ![Figure 6. Binary image.](image)

2.2.3. Formatting author affiliations. Traditional method of contour extraction seems to be aimless in content. But if pre-judge by template before extraction, such as several fundamental geometries in Figure 7, will make the shapes extracted more targeted. Contours will be classified to categories that most similar[10] and those mismatching one will be shifted out. To improve speed of template matching, the search strategy can be changed[11], or the image of smallest scale can be used to find possible contour positions and then accurate positioning[12].
Description of the shape is roughly divided into two kinds of the algorithm, one is based on the boundary, such as Freeman, Sobel, Laplacian, and Prewitt, etc. Another is based on area, such as Hu moment, which can describe shape information of whole area better[13]. Since Hu moment is invariant with rotation, translation, and scaling, it can be applied to extract shape features of images[14], and contour matching and image recognition. Definition of geometric moment and central moment are as following formula. After normalization according to shape area, central moment transfer to \[ \{m_{11}, m_{02}, m_{20}, m_{12}, m_{03}, m_{30}\} \], which can be turned into Hu moment by the formula following.

\[
M_{pq} = \int \int x^p y^q f(x, y) \, dx \, dy, \quad p, q = 0, 1, 2...
\]

\[
u_{pq} = \int \int (x - \bar{x})^p (y - \bar{y})^q f(x, y) \, dx \, dy, \quad p, q = 0, 1, 2...
\]

\[
u_1 = m_{20} + m_{02}, \quad \nu_2 = (m_{20} - m_{02})^2 + 4m_{11}^2
\]

\[
u_3 = (m_{30} - m_{12})^2 + (3m_{21} + m_{03})^2, \quad \nu_4 = (m_{30} + m_{12})^2 + (m_{21} + m_{03})^2
\]

\[
u_5 = (m_{30} - m_{12})^2 + (3m_{21} + m_{03})[(m_{30} - m_{12})^2 - 3(3m_{21} + m_{03})^2]
\]

\[
u_6 = (m_{30} - m_{12})^2 - (m_{21} + m_{03})^2 + 4m_{11}(m_{30} + m_{12})(m_{21} + m_{03})
\]

\[
u_7 = (3m_{12} - m_{30})(m_{30} + m_{12})[(m_{30} - m_{12})^2 - 3(3m_{21} + m_{03})^2]
\]

\[
u_8 = (3m_{12} - m_{30})(m_{30} + m_{12})[(3m_{03} - m_{12})^2 - (m_{12} + m_{03})^2]
\]

2.2.4. Contour size filter and convex hull. Containing implicit information of contour, area is significant for screening. Those small ones may be the noise in the image, and they should be moved out. In Figure 8, (b) is the filtered results of (a). Since those adjacent contours are possibly the same object, drawing convex hulls can effectively combine them and decrease the complexity of edges. (d) shows the convex hull of (c). Finally, templates in Figure 7 are used to match this convex hull contour in (d) and similarity with the ellipse is the highest, so it is retained. After these filtering, only simple outline of shape features are left. But method in [16], used adaptive threshold in Gaussian filter and Canny operator, and the line are not closed. So it is hard to shift them out by area, as shown in Figure 9. Though shape is clear in Figure 9 (b), the line still too complex.

Figure 8. Area filter and convex hull.

Figure 9. Canny edge detection.

Some experiments have been done to test improved flow chat and identical initial image with Figure 2 are used again as comparison. We can see there has been a huge drop in contour numbers and representative contours are conserved, which reached 87.7% in these experiments. Qualitative result is evident in Figure 10 and quantitative analyze is listed in Table 1.
2.2.5. **Centroid extraction.** As imaginary and does not exist, barycentre can be regarded as centralized contours. Thinking every pixel an unit of mass, then arbitrary rectilinear line through barycentre will divide contours into two areas, and they have equivalent pixels. Pixel points only need to be counted from two different directions in a plane, and X axis and Y axis are selected in order to simplify the calculation. When testing on YCB_Video_Dataset, centroid is marked after the shape feature extracted, shown in Figure 11, which can represent the position of object quite well.

3. **Analysis of Experimental Results**

Because image in YCB_Video_Dataset is simpler and divided more obvious into blocks than AUV123 data set, it is more convenient to get a simpler preprocessing image, which makes it easier to find out shape of objects. Can be seen from table 1 results also, results of shape extraction were better when the area in the image is relatively simple and large.

| Table 1. Comparison of the number of extracted contours in Figure 2 and Figure 10. |
|---------------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                                | 1     | 2     | 3     | 4     | 5     | 6     | 7     | 8     | 9     | 10    | 11    | 12    | Total               |
| quantity in Fig.2              | 64    | 58    | 36    | 1482  | 325   | 850   | 2078  | 17    | 1382  | 1294  | 536   | 1939  | 10061             |
| quantity in Fig.10             | 1     | 3     | 2     | 2     | 4     | 2     | 4     | 2     | 1     | 26    | 1     | 1     | 49                |
| Valid quantity                 | 1     | 2     | 2     | 1     | 4     | 2     | 4     | 2     | 1     | 22    | 1     | 1     | 43                |
| valid contour %                | 100%  | 66.7% | 100%  | 50%   | 100%  | 100%  | 100%  | 100%  | 100%  | 84.6% | 100%  | 100%  | 87.7%             |

Due to the characteristic of Hu moment, the shape contours and templates does not necessary to be identical. Instead, a value is set, less than which will be considered parallel. Because we used HSV color space model, objects are easier to find when there is an obvious shift of light or color between them and environment. For example, a black pliers on a black table was not found by the computer in Figure 10. Extracted contour is not according to actual contour of object precisely, so it can deducts the information and shifts focus on general shape, size and position of objects. Compared with the borderfollowing algorithm, which only extracts contours based on the gray-scale gradient value, improved method has the following three advantages: Firstly, shape extraction can express image information more accurately and succinct. Secondly, it has stronger anti-noise ability,
and even fuzzy image can be extracted accurately. Thirdly, position of objects can be determined more accurately, so that the moving direction and distance of them can be judged by Manhattan distance in two pictures later.

4. Conclusion

Firstly, this paper introduced the shortcomings of extracting contours and shape features in traditional way, such as the lack of distinction and screening for target contours, and the complexity of contour shape. Therefore, method of area screening and merging adjacent contour with convex hull is proposed to simplify contour shape, then matching with template shapes to solve this problem. Secondly, without template matching, outcome can be lack of satisfaction by taking edge detection and contour extraction after filter instantly, because numerous contours in complex shapes may lead to disturbance in the following operations. Template here is somewhat similar to an extremely simplified classification. We know that in machine learning, neural networks are trained to differentiate new uncharted inputs, and assort them into previous classifications, but using the template contour is easier. Through experiments, we can see amelioration in counter extraction and matching, because it diminished the amount of contour and augmented efficiency.

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