Edge-Based Feature Extraction Method and Its Application to Image Retrieval

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Abstract

We propose a novel feature extraction method for content-based image retrieval using graphical rough sketches. The proposed method extracts features based on the shape and texture of objects. This edge-based feature extraction method functions by representing the relative positional relationship between edge pixels, and has the advantage of being shift-, scale-, and rotation-invariant. In order to verify its effectiveness, we applied the proposed method to 1,650 images obtained from the Hamamatsu-city Museum of Musical Instruments and 5,500 images obtained from Corel Photo Gallery. The results verified that the proposed method is an effective tool for achieving accurate image retrieval.
Keyword:Image Retrieval,Feature extraction.

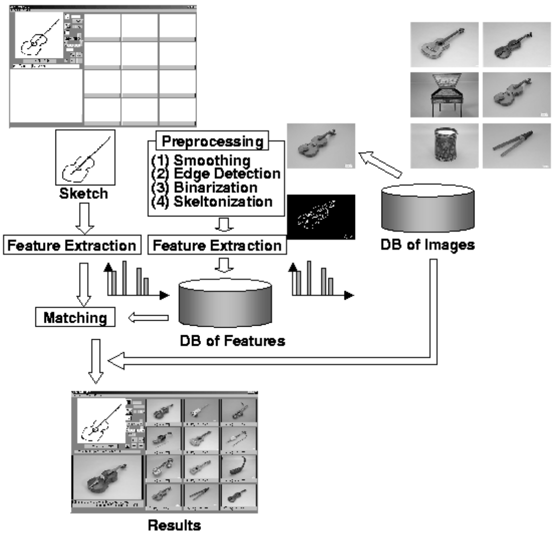


Figure 1: Overview of the proposed image retrieval.

1 Introduction

In recent years, various aspect of image retrieval have been investigated [1]. An important problem in the field of image retrieval is determining the similarity of two images. Widely used measures of similarity include properties such as the color, shape and texture of the object. [2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13]. Image retrieval using these measures is referred to as Content-Based Image Retrieval (CBIR). In CBIR systems, the ability for users to query easily is desirable. Image retrieval systems using graphical rough sketches satisfy this need. Describing the edge-based features of shape and texture is important for image retrieval using graphical rough sketches. Although edge-based feature extraction methods that use a Fourier Descriptor can be applied in order to realize image retrieval systems, these methods can be only applicable to features from limited images consisting of close-curve boundaries. Sufficient edge-based feature extractions of shape information have not yet been developed, because effectively extracting the edge-based features of shape information is difficult.

However, an MPEG-7 multimedia search tool, referred to as the Multimedia content description interface, is currently under development. Although a few CBIR systems [14] based on MPEG-7 are being developed, two major difficulties exist concerning these systems. First, most of the systems being studied are not automatic systems, and second, most of these systems are applicable only for closed-curve objects.

Tht purpose of the present study is to automatically extract shift-, scale-, and rotation-invariant image features from an object's edge and to apply these features to content-based image retrieval.

2 Image Retrieval

2.1 Overview

We provide herein an overview of the proposed image retrieval system. The purpose of the proposed system is to extract image features of the edge shape of objects using the relative positions of edge pixels. Figure 1 shows an overview of the proposed image retrieval process. The image features of the original images in a database are extracted in advance and are stored in a matching table. Since the proposed feature extraction is applied to binary line images, the original images in the database are detected from the edge and are skeletonized as a preprocessing step. Query rough sketches are drawn using input devices (mouse, electronic pen, etc.) as binary lines. The system extracts image features of the query sketch, and compares them to the image features in the matching table by calculating

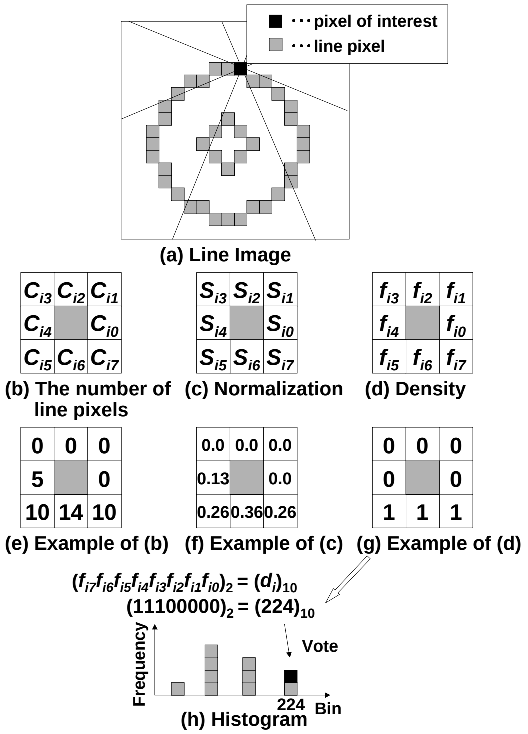


Figure 2: The feature extraction process.

the Euclidean distance in the feature space. The system then outputs images that are sorted according to increasing Euclidian distance.

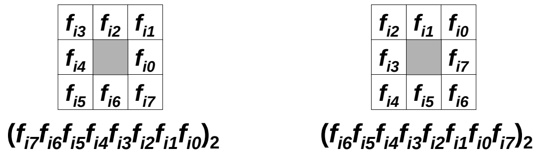
2.2 Feature extraction

The image feature extraction method is applied to binary line images. Figure 2 shows the proposed feature extraction process. On the pixel of interest, the number of other edge pixels in each of eight regions, determined as shown in Figure 2(a), is counted. The number of pixels in each region is denoted as C_{ix}, as shown in Figure 2(b),(e). S_{ix} is the normalized value given by Equation (1) as shown in Figure 2(c),(f). The value of binary pattern f_{ix} is calculated by the thresholding technique using Equation (2), as shown in Figure 2(d),(g). Here, the values of C and Th denote the total number of line pixels and the threshold value, respectively. The threshold value is determined empirically to be 0.15. This process enables scale-invariance to be realized.

$$S_{ix} = \begin{cases} \dfrac{C_{ix}}{C-1} & (C \neq 1\ ) \\ 0 & (C = 1\ ) \end{cases} \tag{1}$$

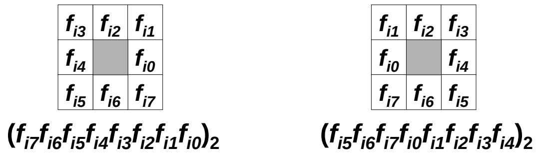
$$f_{ix} = \begin{cases} 0 & (S_{ix} \leq Th\ ) \\ 1 & (S_{ix} > Th\ ) \end{cases} \tag{2}$$

By expanding the concept of the Local Binary Pattern(LBP) [15] in the field of texture analysis, the values "0" or "1" in each direction are arranged counter-clockwise from f_{i0} to express an 8-bit binary number and transform the binary number $(f_{i7}f_{i6}f_{i5}f_{i4}f_{i3}f_{i2}f_{i1}f_{i0})$ into the decimal number



(a) before (b) after

Figure 3: Rotation invariance.



(a) before (b) after

Figure 4: Symmetry invariance.

$d_i (0 \leq d_i \leq 255)$ in Figure 2(h). This process enables the relative position of edge pixels to be preserved. We then vote for the corresponding bin d_i in the histogram shown in Figure 2(d). This process enables shift-invariance to be realized. A 256-dimensional image feature is obtained by applying the above-mentioned process to all edge pixels.

The rotation-invariant feature is easily described by shifting the binary number as shown in Figure 3. In addition, the symmetry-invariant feature is easily described by shifting the binary number as shown in Figure 4.

2.3 Retrieval

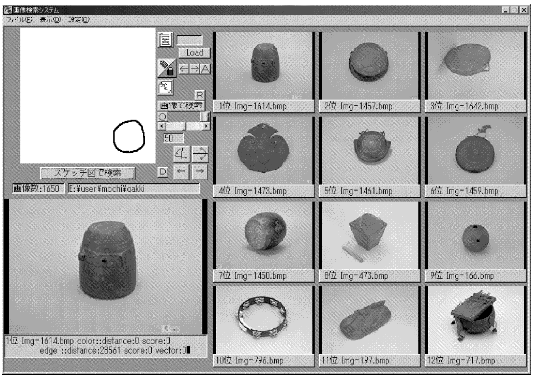
This system calculates the Euclidean distance between the features of a query image and the features in the matching table in 256-dimensional feature space, and then outputs candidate images according to increasing Euclidian distance. The Euclidean distance D_i is given by Equation (3).

$$D_i = \min_{k=1,2,\cdots,K} \{ \sqrt{\sum_{j=0}^{255} (F_{sj} - F_{ij})^2} \} \tag{3}$$

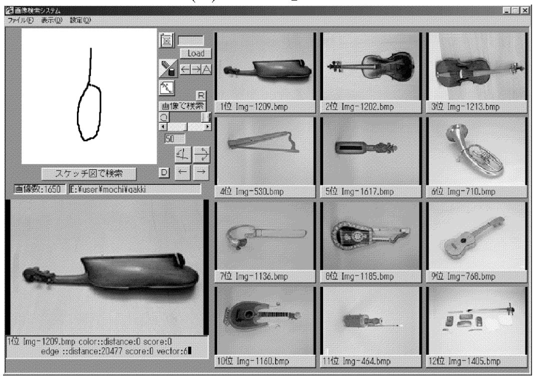
Where F_s is the feature of a query sketch, F_i is the feature of database images, and j is a 256-dimensional feature.

3 Experiments and discussion

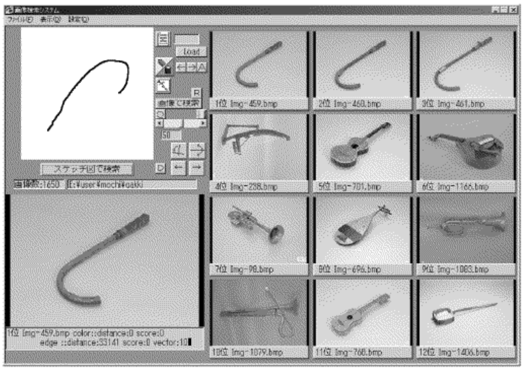
In order to verify the effectiveness of the proposed method, we retrieved 1,650 images using images obtained from the Hamamatsu-city Museum of Musical Instruments and 5,500 images using images obtained from Corel Photo Gallery. Figures 5 and 6 show examples of the retrieval results. Figures 5 shows examples of the retrieval results obtained for the images from the Hamamatsu-city Museum of Musical Instruments. Figure 5(a) demonstrates that the extracted feature is shift- and scale- invariant. Figure



(a) example 1

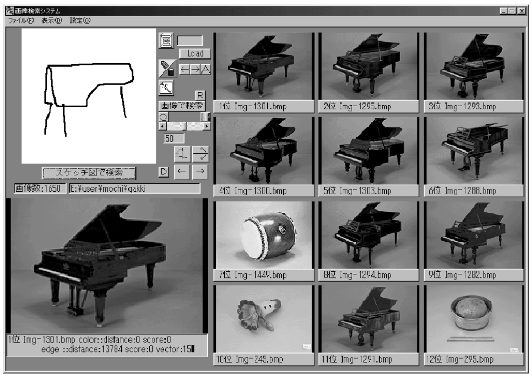


(b) example 2

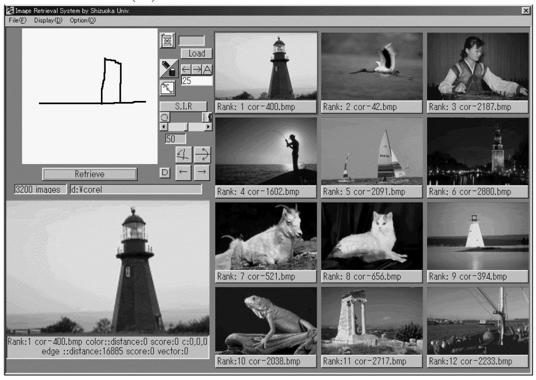


(c) example 3

Figure 5: Retrival results(musical instruments).



(a) musucal instruments



(b) Corel photo gallery

Figure 6: Retrival results.

5(b) demonstrates that this feature is rotation invariant. Figure 5(c) demonstrates that this feature is rotation- and symmetry-invariant. Figure 6(a) shows an example of retrieval results for the case of “piano”. Figure 6(b) shows an example of retrieval results for the case of “tower” from Corel Photo Gallery. These figures show that the proposed method achieves shift-, scale-, rotation-, and symmetry-invariance, and thus is applicable to image retrieval using rough sketches.

We compared the proposed method to a conventional method reported by Anil K. Jain et al., which uses a histogram of local edge direction. We evaluated the results of this comparison in terms of retrieval efficiency. The retrieval efficiency is expressed using precision p and recall r, as plotted in Figures 7(a) and 7(b), which show the retrieval efficiency of Figures 6(a) and 6(b), respectively. Precision p and recall r are given by Equations (4) and (5), respectively.

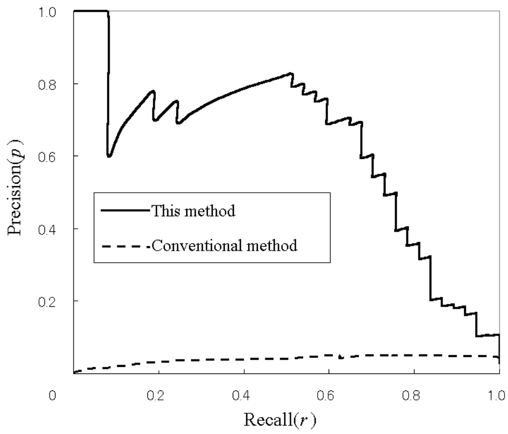
$$r = \frac{n}{N} \quad (4)$$

$$p = \frac{n}{T} \quad (5)$$

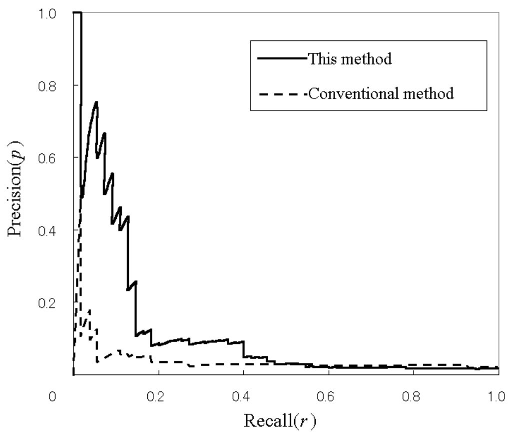
where T is a shortlist of the T most similar images, n is the number of retrieved similar images, and N is the total number of similar images in the database. The obtained results confirm that the proposed method is suitable for content-based image retrieval using rough sketches.

4 Conclusion

We have described a novel image retrieval system which uses the features of edge shapes for content-based image retrieval. In the proposed system, edge shape features are represented by the relative position edges of objects. The proposed system has the advantage of realizing shift-, scale-, and rotation-invariance of objects, which enables similar images to be retrieved using rough sketches. The effectiveness of this approach was tested by applying the proposed to 1,650 images obtained from the Hamamatsu-city Museum of Musical Instruments and 5,500 images obtained from Corel Photo Gallery. The obtained results demonstrated that the proposed method is a valid approach to content-based image retrieval.



(a) musucal instruments



(b) Corel photo gallery

Figure 7: Retrival efficiency.

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References

[1] David Forsyth, Jitendra Malik, Robert Wilensky, “Searching for Digital Pictures”, Scientific American, Vol.276, No.6, 1997.

[2] Mohan S. Kankanhalli, Babu M. Mehtre, Hock Yiung Huang, “Color and Spatial Feature for Content-Based Image Retrieval”, Pattern Recognition Letters, Vol.20, pp.109-118, 1999.

[3] Mohamed Abdel-Mottaleb, Nevenka Dimitrova, “CONIVAS: CONtent-based Image and Video Access System”, ACM Multimedia 96, pp.427-428, 1996.

[4] M.Flickner,H., Sawhney, W., Niblack, J., et. al., “Query by Image and Video Content: The QBIC System”, IEEE Computer, Vol.28, No.9, pp.23-32, 1996.

[5] A. Pentland, R. W. Picard, S. Sclaroff, “Photobook: Content-Based Manipulation of Image Databases”, International Journal of Computer Vision, Vol.18, No.3, pp.233-254, 1996.

[6] Michael Ortega, Yong Rui, Kaushik Chakrabarti, Sharad Mehrotra and Thomas S. Huang “Supporting similarity queries in MARS”, Proceedings of the 5th ACM International Multimedia Conference, 8-14, pp.403-413, 1997.

[7] Wei-Ying Ma and B. S. Manjunath, “Netra: A toolbox for navigating large image databases”, Multimedia Systems, Vol.7, No.3,pp.184-198, 1999.

[8] Zijun Yang, C.-C. Jay Kuo, “A Semantic Classification and Composite Indexing Approach to Robust Image Retrieval”, The Proceeding of IEEE International Conference on Image Processing, 1999.

[9] K. Hirata, T. Kato, “Query by Visual Example”, Extending Database Technology ’92, pp.56-71, 1992.

[10] Anil K. Jain, Aditya Vailaya, “Shape-Based Retrieval: A Case Study With Trademark Image Databases”, Pattern Recognition, Vol.31, No.9, pp.1369-1390, 1998.

[11] Mohamed Abdel-Mottaleb, “Image Retrieval Based on Edge Representation”, The Proceeding of IEEE International Conference on Image Processing, 2000.

[12] Babu M. Mehtre, Mohan S. Kankanhalli, Wing Foon Lee, “Shape Measure for Content Based Image Retrieval: A Comparison”, Pattern Recognition, Vol.33, No.3, pp.319-337, 1997.

[13] M. Kobayakawa, M.Hoshi, T.Ohmori, T.Terui, “Interactive Image Retrieval Based on Wavelet Transform and Its Application to Japanese Historical Image Data”, J. of Information Processing Society of Japan, Vol.40, No.3, pp.899-911, 1999(in japanese).

[14] Farzin Mokhtarian and Alan Mackworth, “Scal-Based Description and Recognition of Planar Curves and Two-Dimensional Shapes”, IEEE Trans. on PAMI, Vol.8, No.1, pp.34-43, 1986.

[15] Timo Ojala, Matti Pietikainen, David Harwood, “A Comparative Study of Texture Measures With Classification Based on Feature Distributions”, Pattern Recognition, Vol.29, No.1, pp.51-59, 1996.