MVA2002 IAPR Workshop on Machine Vision Applications, Dec. 11-13, 2002, Nara-ken New Public Hall, Nara, Japan

8—22

Advanced Image Retrieval Using Multi-resolution Image Content

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Abstract

We introduce an image retrieval method for searching an image database by using a query image that has similarity in its global and/or regional image contents to the intended target. Our retrieval method makes use of 2-dimensional wavelet decomposition (2-D WD) of the query and database images. The coefficients of 2-D WD are used as the multi-resolution image contents of the query and database images. The similarity measure between the query and database images is performed after mapping the significant image contents onto the original image. The similarity is estimated by investigating the distance between the positions of the mapped contents and the coincident degree of the operation factors of 2-D WD such as the positive or negative of the coefficients, resolution of decomposition, and frequency information of decomposition. Our method has an advantage to permit a position gap of image contents and a pattern fluctuation, and it is easy to build the image retrieval.

1 Instructions

Up to now, many image retrieval methods have been developed. However, most of them make use of the secondary information such as the image file name, image size, and a date of acquisition etc., and the symbolized and/or categorized image characteristics as the keywords for the query. You can often see the former type image retrieval system on the Internet. These methods suffer from difficulties. It takes much time to manually tag all the images with keys, and it is difficult to describe the visual aspects as keywords. With the quick progress of hardware technology on the digital camera, scanner and large scale storage devices, etc. and rapid spread of world wide web with broad band network, the size of the image database becomes enormously large and more and more people access to the growing database. Such a tendency causes the expansion and diversification of image retrieval method and many approaches to content-based image retrieval [1,2,3] have applied. QBIC [1] that is developed at IBM is one of the most notable retrieval methods using image contents. QBIC system allows users to make queries of large image database based on visual image content -- properties such as color percentages, color layout, and textures occurring in the images. Such queries use the visual properties of images, so users can match colors, textures and their positions without describing them in words. This system will be useful in case that the query image consists of comparatively easy contents. However, in general, it is difficult to make the query image according to the visualized contents in the head, because various features are involved with the queries and it is troublesome to make queries by using these features. Besides, it is the case that we already have images for the query and database images. In this paper, we introduce an advanced image retrieval method for searching an image database by using a query image that has similarity in its global and/or regional image content to the intended target. Our retrieval method makes use of 2-D WD [4,5,6] of the query and database images. In the last decade, the 2-D has received much attention as a promising tool for image analysis, because it can provides not only the localization both in spatial and frequency domains, but also a further advantage in which the window size changes with the frequency content of the image also. That means if we look at an image with a large window size, we would notice gross features of the image. Similarly, if we look at an image with a small window size, we would notice small features of the image. This makes wavelet interesting and useful. In our method, the coefficients of 2-D WD are used as the multi-resolution image contents of the query and database images. The similarity measure between the query and database images is performed after mapping the significant image contents onto the original image. The similarity is estimated by investigating the distance between the positions of the mapped contents and the coincident degree of the operation factors of 2-D WD such as the positive or negative of the coefficients, resolution of decomposition, and frequency information of decomposi-

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tion. Our method has an advantage to permit a position gap of image contents and a pattern fluctuation, because it take the distance between the positions of image contents into similarity measure, and it is easy to build the image retrieval system because of the simplicity of 2-D WD. The flow of image retrieval is explained in section 2. Section 3 describes the explanation of the similarity measure in this paper. In section 4, we show the experimental results of image retrieval by using our advanced image retrieval method. The paper finishes with some conclusions and discussions.

2 Flow of Image Retrieval

The flow of the image retrieval method proposed in this paper is divided into two stages. The one is the preparation stage and the second is the image retrieval stage. In the former, the multi-resolution image contents are extracted from each database image by using 2-D WD and the contents database is built. In the latter, the multi-resolution image contents are extracted from the query image and image retrieval is performed by estimating the similarity of the contents between the query and database images by using contents database.

Here we briefly explain 2-D WD. Set the level of an original image at 0. In the initial level of decomposition, one low-pass subimage (I_{LL}^{-1}) is obtained by low-pass filtering in both row and column directions, and three high-pass subimages ($I_{LH}^{-1}, I_{HL}^{-1}, I_{HH}^{-1}$) containing high frequency components are obtained. In the next level of decomposition, the low-pass subimage (I_{LL}^{-1}) is further decomposed into one low-pass subimage (I_{LL}^{-2}) and three high-pass subimages ($I_{LH}^{-2}, I_{HL}^{-2}, I_{HH}^{-2}$). The input image is first convolved along the rows by the two filters L and H, and the horizontal dimension of these two intermediate results is decimated by 2. Each of the two "column-decimated" images, I_L^{k-1} and I_H^{k-1}, is then convolved along the columns by the two filters L and H and decimated along the rows by 2. This decomposition results into four images I_{LL}^{k-1}, I_{LH}^{k-1}, I_{HL}^{k-1}, and I_{HH}^{k-1}. Each of these images, such as the low-pass image, I_{LL}^{k-1}, is taken as the new input to perform the next level of decomposition and so on. Fig. 1 shows the 3-level decomposition of 2-D WD.

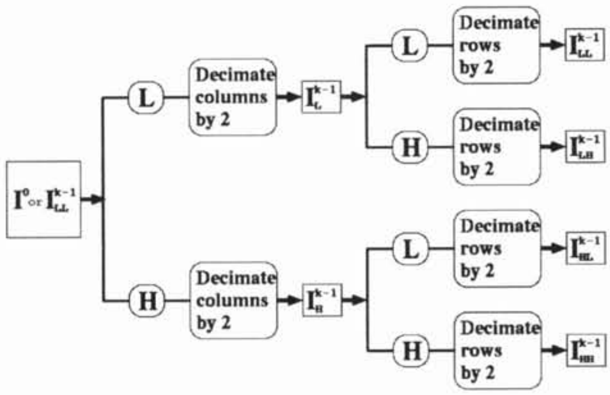

Fig. 2.1: Flow of 2-D DWT

Preparation stage: The multi-resolution image contents are extracted from each database image by using 2-D WD.

Multi-resolution image content extraction: The pixel value of an image is standardized to [0,1]. In case of a color image, YIQ color channel is adopted. The standardized image is decomposed by using 2-D WD and the coefficients of 2-D WD is sorted in order of a large absolute value. The upper *n* coefficients are selected as the significant multi-resolution image contents that represent the global and/or regional pattern in the image. In case of the color image, the upper *n* coefficients are extracted from each YIQ color channel. The contents consist of the coefficients with the position on the 2-dimensional decomposed image space and the operation factors of 2-D WD such as the positive or negative of the coefficients, resolution of decomposition, and frequency information of decomposition.

Image retrieval stage: The multi-resolution image contents are extracted from the query image in the same way. The similarity between the query and database images is estimated by investigating the distance between the positions of contents and the coincident degree of the operation factors of 2-D WD such as the positive or negative of the coefficients, resolution of decomposition, frequency information of decomposition after mapping the upper *n* image contents onto the original image.

In the conventional retrieval method by using 2-D WD [7], the similarity between the query and database images is estimated by counting a pair of image contents at the same position on the 2-dimensional decomposed image space, investigating the coincident degree of the operation factors of 2-D WD such as the positive or negative of the coefficients, resolution of decomposition, and frequency information of decomposition. In our method, the similarity is estimated by counting a pair of mapped image contents less than the fixed distance on the original image, investigating the coincident degree of the direction of positive or negative value of coefficients and frequency information of decomposition. This pairing scheme provides us with precise estimation of the similarity for the image contents that has a position gap of the image contents and a pattern fluctuation. The robustness of image retrieval is improved, even if there is the position gap, distortion and shift of the pattern between the query and database images.

3 Similarity Measure

In this Section, we have the detailed explanation for the similarity measure between the query and database images.

We use Haar wavelets because of its simplicity of implements and fastest in computing time. In our system, 2-D WD is applied to the extraction of significant multi-resolution image contents, so that the drawbacks of the Haar basis for lossy compression is take no account.

The standardized image is decomposed by using 2-D WD and the coefficients of 2-D WD is sorted in order of a large absolute value. The upper n coefficients are selected as the significant multi-resolution image contents. Here we define the resolution of decomposition for i-th image content, $q_i (i = 1,2,3,\cdots,n)$, is q_i^R, and the center position of q_i on the original image after the mapping is q_i^P. In the same way, the resolution of decomposition for the j-th image contents, $t_j (i = 1,2,3,\cdots,n)$, is t_j^R and the center position of t_j on the original image is t_j^P. The permissible difference of resolution of decomposition, R^d, is defined for pairing the image contents with different resolution. For all image contents extracted from both the query and database images by using 2-D WD, the center position, q_i^P and t_j^P, on the original image after mapping are calculated. In case that the direction of positive or negative value of coefficients are the same and $|q_i^R - t_j^R| \le R^d$, calculate the distance, $d_{ij} = |q_i^P - t_j^P|$. If t_j has no pair, pair q_i and t_j, and store d_{ij}. If t_j is in a pair with $q_k (k \ne i)$, calculate the distance, $d_{kj} = |q_k^P - t_j^P|$. In case of $d_{kj} < d_{ij}$, pair q_k and t_j, and store d_{kj}. The above process is repeated for $i, j = 1,2,3,\cdots,n$ and all the pair of the image contents at the nearest distance is made. Here, similarity S is calculated by the following scheme.

$$S = \sum_{i=0}^{n} \begin{cases} 1, d_{ij} \le r_p \\ 0, d_{ij} > r_p \end{cases}$$

where r_p denotes the pairing radius.

4 Numerical Examples

In order to show the validity of our advanced image retrieval method using multi-resolution image content, the experimental image retrieval using color landscape images of VisTex [8] and gray-scale texture images [9] is performed. The size of images is 256×256, the number of significant multi-resolution image contents extracted for every image is 400. The retrieval results by using our proposed method are shown in Fig. 2 and 3. In the figures, the image at the upper left is the query image, the lower left is the reconstructed image based on 400 image contents, and others are retrieved images that have the similarity with the query image. In Fig. 2, the images that have the pattern fluctuation to the query image can be precisely retrieved. In Fig. 3, the image with parallel translation of four directions can be precisely retrieved. It cannot obtain such precise retrieval results by the conventional method [7]. Thus, it turns out that our image retrieval method is effective to enhance the robustness in the image retrieval in case that the image has the position gap and distortion, and pattern fluctuation.

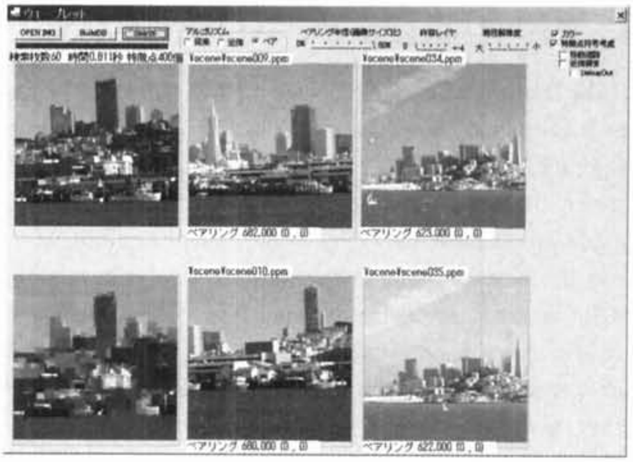

Fig. 2: Image retrieval results by using VisTex color scene images.

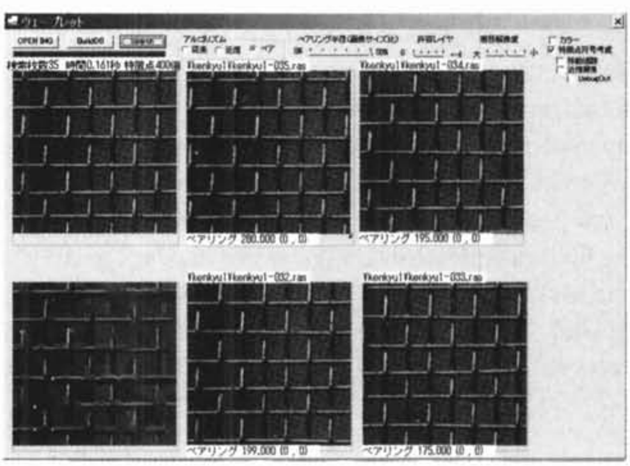

Fig. 3: Image retrieval results by using gray-scale texture images.

5 Conclusions

In this paper, we propose an advanced image retrieval method using multi-resolution image content and verify the validity of the proposed method for the image retrieval. The method has the advantage to permit a position gap of the image contents and a pattern fluctuation, because it take the distance between the positions of the significant image contents into similarity measure, and it is easy to build the image retrieval system because of the simplicity of 2-D WD. For the further study, more advanced use of the multi-resolution image contents is pursued.

References

[1] W. Niblack, R. Barber, W. Equitz, M. Flickner, E. Glasman, D. Petkovic, P. Yanker, C. Faloutsos, and G. Taubin, "The QBIC project: Querying images by content using color, texture, and shape, *Storage and Retrieval for Image and Video Databases*, pp. 173–187, 1993.

[2] C. Faloutsos, R. Barber, M. Flickner, J. Hafner, W. Niblack, D. Petkovic, and W. Equitz, "Efficient and effective querying by image content," *Journal of Intelligent Information Systems: Integrating Artificial Intelligence and Database Technologies*, 3(3-4):231–262, 1994.

[3] R. Barber,W. Equitz,W. Niblack, D. Petkovic, and P. Yanker, "Efficient query by image content for very large image databases," *COMPCON Spring '93*, pp 17–19, San Francisco, CA, USA, 1993.

[4] A. Grossman and J. Morlet, "Decompostion of Hardy Functions into Square Integrable Wavelets of Constant Shape," *SIAM Journal on Mathematical Analysis*, vol. 15, no. 4, pp. 723-736, 1984.

[5] I. Daubechies, "Orthonormal Bases of Compactly Supported Wavelets," *Communications on Pure and Applied Mathematics*, vol. 41, pp. 909-996, 1988.

[6] S. G. Mallat, "A Theory for Multi-resolution Signal Decomposition: The Wavelet representation," *IEEE Trans. on Pattern Analysis and Machine Intelligence*, vol.11, no.7, pp.674-693, 1989.

[7] C. E. Jacobs, A. Finkelstein, and D. H. Salesin, "Fast multiresolution image querying," *Computer Graphics Proc., Annual Conf. Series (SIGGRAPH 95)*, pp 277--286, 1995.

[8] MIT Media Labo., http://www-white.media.mit.edu/vismod/imagery/VisionTexture/vistex.html

[9] P. Brodatz, *Textures*, Dover(1996).