A Characteristic Value Extraction Method for Content-Based Image Retrieval using Morphological Spatial Frequency

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Abstract: A novel characteristic value extraction method based on morphological spatial frequency is proposed. Morphological spatial frequency defined by morphological pattern distribution function is introduced. Superiority of the method was proved for various images by experiment. Furthermore the fact that the proposed method does not need threshold to obtain binary image provides its applicability to content-based image retrieval

1. Introduction

Today, more and more audio-visual information is available from many sources around the world. Also, there are people who want to use this audio-visual information for various purposes. However, before the information can be used, it must be located. At the same time, the increasing availability of potentially interesting material makes this search more difficult. This challenging situation led to the need of a solution to the problem of quickly and efficiently searching for various types of multimedia material interesting to the user. MPEG-7 enables this type of search.

MPEG-7, formally called 'Multimedia Content Description Interface', standardises: (1)A set of description schemes and descriptors, (2)A language to specify description schemes, i.e. a Description Definition Language (DDL), (3)A scheme for coding the description.

The core of the MPEG-7 is a set of *descriptors* for audio-visual content. In [11] a descriptor is defined as a representation of a feature. A descriptor defines the syntax and semantics of the feature representation. Examples of low-level visual features include colour, shape, motion, and texture. This paper describes a shape feature descriptor. Key functionalities supported by this descriptor includes similarity-based retrieval.

Image shape has emerged as an important visual primitive to search through large collections of similar looking patterns. An image can be considered as a mosaic of shapes and shape features associated with the regions can be used to index the image data.

Mathematical morphology offers very efficient tools for image analysis and segmentation. Segmentation plays a crucial role in content-based image/video databases (MPEG-7).

This paper proposes a novel morphological characteristic value extraction method which can be used to define shape features and to retrieve an image from image database. The proposed method is based on so called 'morphological spatial frequency.'

In Chapter 2, existing characteristic value extraction methods using edge detection are provided. The method using morphological spatial frequency is introduced in chapter 3. Chapter 4 presents experimental results comparing existing and proposed methods. Then we conclude in chapter 5.

2. Characteristic Value Extraction using Edge Detection

2.1 Existing Characteristic Value Extraction Method

Figure 1 shows existing characteristic value extraction method.

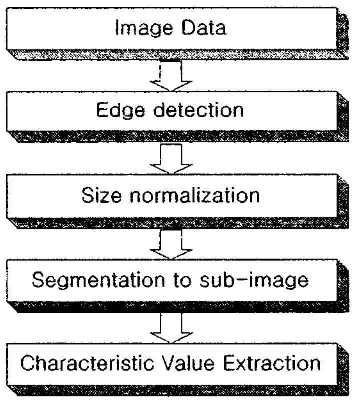

Figure 1. Characteristic Value Extraction Procedure

(1) Edge detection

Edge dection methods used are sobel operator[3] and morphological Laplacian operator[6]. Since sobel operator is popular, we omit to describe.

The morphological Laplacian, $L(f)$, is defined as the residue of the gradient by dilation, $g^{+}(f)$, and gradient by erosion, $g^{-}(f)$, that is:

$$g^{+}(f) = \delta(f) - f$$

$$g^{-}(f) = f - \varepsilon(f)$$

$$L(f) = g^{+}(f) - g^{-}(f)$$

The morphological Laplacian is greater than zero at the lower edge of the transition and smaller than zero at the upper edge. In flat surfaces or slanted planes without convexity changes, it cancels out. The strong edge feature extraction property[4] of the morphological Laplacian provides an effective tool for extracting the contour information.

(2) Size Normalization

Images with various size are to be normalized into a pre-defined size in order to obtain consistant characteristic value interpretation.

(3) Segmentation to sub-image

An image is to be divided into same sized rectangular sub-images. In our experiment we divided size normalized image (255×255) into 9 sub-images(83×83).

(4) Characteristic value calculation

Characteristic value for each sub-image is to be calculate by using the Eq. (1).

$$\text{Charactensric value} = \frac{\text{Number of pixels with value 1}}{\text{Number of pixels in a sub-image}} \times 100(\%) \quad (1)$$

(5) Index key generation

Modified Trie index structure[12] was used to generate index key in our experiment.

2.2 Some Experimental Results

2.2-1 Results using Sobel Operator

We use Lena image (figure 2) as an original image. Figure 3 shows result of edge detection by Sobel operator. A binary image then is to be generated thresholding at 128. Table 1 shows number of pixels with value 1 for each sub-image in binary image, and table 2 shows characteristic value for each sub-image using Eq. (1).

Figure 2. Original image

Figure 3. Edge detecrtion by Sobel operator

Table 1. Number of pixels with value 1 for each sub-image

815	648	1262
1991	2465	1370
3119	1199	1286

Table 2. Characteristic value for each sub-image

11	9	17
28	34	19
43	16	17

2.2-1 Results using Morphological Laplacian Operator

Figure 4 shows result of edge detection by morphological Laplacian operator. A binary image then is to be generated thresholding at 20. Table 3 shows number of pixels with value 1 for each sub-image in binary image, and table 4 shows characteristic value for each sub-image using Eq. (1).

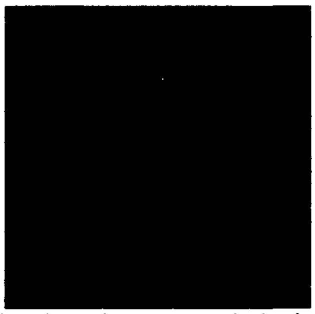

Figure 4. Edge detection by morphological Laplacian operator

. Table 3. Number of pixels with value 1 for each sub-image

492	778	983
2013	2532	1347
3301	1149	1190

Table 4. Characteristic value for each sub-image

7	11	13
28	35	18
45	16	16

3. Characteristic Value Extraction using Morphological Spatial Frequency

3.1 Morphological Spatial Frequency

We here introduce *so-called* morphological spatial frequency defined by morphological pattern distribution function[5] in order to define a new characteristic value extraction algorithm.

Morphological pattern distribution function $r(\lambda)$ of f^*, and morphological pattern density function $p(\lambda)$, as follows :

$$\gamma(\lambda) = Mes(f^* - (f^* \circ S_\lambda)) \quad , \qquad (2)$$

$$p(\lambda) = \gamma(\lambda) - \gamma(\lambda - 1), p(0) = 0, p(1) = \lambda(1) \qquad (3)$$

where $f^*(x) = |f(x) - m|$ with original function f, S_λ denotes $(\lambda - 1)$ times dilayion operation by S, $\circ$ denotes opening operation, and $Mes(g) = \sum_{x \in D} g(x)$.

Next we introduce another morphological measure $h(\lambda)$:

$$h(\lambda) = \sum_{i=\lambda}^{N} \frac{p(i)}{M(S_i)}, \quad \lambda = 1, 2, \cdots, N. \qquad (4)$$

In [5] $h(\lambda)$ was interpreted as an *average height* in the sense that $p(\lambda)/M(S_\lambda)$ is the value of volume divided by the area of S_λ.

The term morphological spatial frequency is used because the pattern distribution and pattern density are similar to spectral distribution and spectral density for Fourier techinique except the difference between pattern and spectrum. Pattern here is the size of spatial(2-D) domain.

3.2 Proposed Characteristic Value Extraction Algorithm using Morphological Spatial Frequency

The following fact should be noted:

Increase (or decrease) of $p(\lambda)$ for a given structuring element, S_λ, i.e., increase (or decrease) of average height corresponds to increase (or decrease) of variance which is usually used as an image feature .

The above fact encouraged us to use average height as a characteristic value. The followings are proposed algorithm:

1. Opening operation by 3×3 structuring element
2. Obtain opening residue from original image.
3. Calculate $r(\lambda), p(\lambda)$, and $h(\lambda)$.
4. Repeat step 1 ~ 3 for each sub-image.
5. Calculate "Characteristic value" for each sub-image using the following Eq. (5):

$$\text{Characteristic value} = \frac{\text{Average height for each sub-image}}{\text{Average height for whole image}} \times 100(\%) \qquad (5)$$

6. Obtain indexing value for each sub-image using the method proposed in [12].

4. Experimental Results

4.1 Result using the Proposed Algorithm

Figure 5 shows averge hights for several morphological operations using Eq. (4). 8 structuring elements (3×3 to 17×17) were used to calculate 3 kinds of average height (using opening residue, closing residue, and average of the two, respectively.) In the following experiment we only used 3×3 structuring element with opening residue which is defined in Eq. (2). Table 5 shows average hight for each sub-image, and table 6 shows characteristic value for each sub-image using Eq. (5).

We should note that thresholding procedure is not to be necessary, whereas it should be carefully considered in the methods using edge detection.

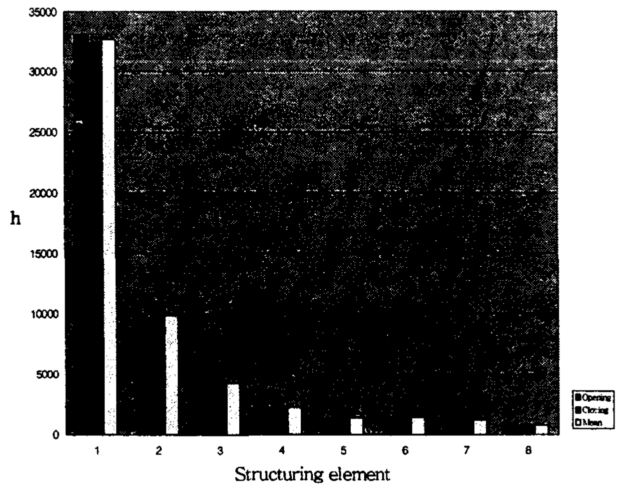

Figure 5. Averge hights for several morphological operations

Table 5. Average hight for each sub-image

2188.22	3032.88	2049.33
5151.66	5477.88	2660.33
7384.77	3176.11	1967.66

Table 6. Characteristic value for each sub-image

7	9	6
16	17	8
22	10	6

4.2 Comparison of Index Keys Generated by Existing and Proposed Algorithms

Table 7 shows index keys generated by Sobel operation, morphological Laplacian operation, and morphological spatial frequency, using similar images obtained by using various functions in Adobe Photoshop. In table 7, row (a) represents the results using the original image (figure 2), the other rows are the results using images (b) set quality to 6, (c) highpass filtered , (d) rippled, (e) solarized, and (f) sharpened, respectively. The Value in < > represents number of different values from Index key values of original image. Smaller value in < > represents higher priority to be retrieved.

We note here that the proposed method shows superior result than existing methods. The results using various original images (not shown here) were similar to the result using Lena image. Furthermore the proposed method does not need threshold to obtain binary image as mentioned in section 4..1.

Table 7. Index keys for Lena image

	Sobel operator	Morphological Laplacian operator	Morphological spatial frequency
(a)	1 0 1 2 3 1 4 1 1	0 1 1 2 3 1 4 1 1	1 1 1 3 3 1 4 2 1
(b)	1 0 1 2 3 1 4 1 1 <0>	0 1 1 2 3 1 4 1 1 <0>	1 1 1 3 3 1 4 2 1 <0>
(c)	1 0 1 2 3 1 4 1 1 <0>	0 0 1 2 3 1 4 1 1 <1>	1 1 1 2 3 1 4 2 1 <1>
(d)	1 0 1 2 3 1 3 1 1 <1>	0 0 1 2 3 1 3 1 1 <2>	1 1 1 2 3 1 4 2 1 <1>
(e)	0 0 1 2 2 1 3 1 1 <3>	0 0 1 2 3 1 3 1 1 <2>	1 1 1 2 3 1 4 1 1 <2>
(f)	1 1 2 3 4 2 4 2 2 <7>	1 3 2 4 4 2 4 2 2 <8>	1 1 1 3 3 1 4 1 1 <1>

*Number in <> represents number of different values from Indexing key values of original image (a)

5. Conclusions

A novel characteristic value extraction method based on morphological spatial frequency is proposed. Superiority of the method was proved for various images by experiment. Furthermore the fact that the proposed method does not need threshold to obtain binary image provides its applicability to content-based image retrieval.

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