

Interpretation of Fuzzy Logic for Texture Queries in CBIR

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Abstract

This paper presents a novel fuzzy logic based approach for the interpretation of texture queries. Tamura feature extraction technique is used to extract each texture feature of an image in the database. A term set on each Tamura feature is generated by a fuzzy clustering algorithm to pose a query in terms of natural language. The query can be expressed as a logic combination of natural language terms and tamura feature values. The performance of the technique was evaluated on Brodatz texture benchmark database. Experimental results show that the proposed technique is effective and the retrieved images indicate that those images are suitable for the specific queries.

Keywords:

Fuzzy logic, Texture features, Image retrieval, Feature extraction

1. Introduction

Texture is an important characteristic for the analysis of many types of the images including natural scenes, remotely sensed data and biomedical modalities. The perception of texture is believed to play an important role in the visual system for recognition and interpretation. Texture analysis is an important research field in computer vision, image processing and pattern recognition. In order to determine the texture features, which are useful in the classification process, it is necessary to have an intuition as to what constitutes a texture. Texture is a blanket term used to describe the brightness variations observed in almost all surface; it conveys information about a pixel and surrounding. Texture may be regular, for example a smooth surface with a grid painted on it. Texture as a primitive visual cue has been studied for over twenty years now. Texture has been found to provide cues to scene depth and surface orientation¹. People also tend to relate texture elements of varying size to a reasonable 3-D surface. Even in graphics systems greater realism is achieved when textures are mapped to 3-D surfaces. Texture features have been used to identify contents of ariel imagery such as bodies of water, crop fields and mountains. Texture describes the content of many real-world images: for

example, clouds, trees, bricks, hair, fabric all have textural characteristics.

2. Previous Work

Interest in the potential of digital images has increased enormously over the last few years, fuelled at least in part by the rapid growth of imaging on the World Wide Web (WWW). Creating and storing digital images nowadays is easy and getting cheaper all the time as the needed technologies are becoming available to the masses. There already exist a vast number of digital visual data sources, e.g. different kinds of sensors, digital cameras and scanners in addition to the various image collections and databases for all kinds of purposes. There are few image retrieval systems which used content-based retrieval techniques have been developed in both commercial and academic organizations. A few examples of such systems are QBIC², Virage³, Netra^{4, 5} and VisualSEEK^{6, 7}. The goal of these systems is to retrieve images that are meaningful to users by processing their queries. The texture features used in QBIC are modified versions of the mathematical representations of coarseness, contrast and directionality proposed by Tamura⁸. Coarseness measure texture scale (average size of regions that have the same intensity), contrast measure vividness of the texture (depends on the

variance of the gray-level histogram), and directionality gives the main direction of the image texture (depends on the number and shape of peaks of the distribution of gradient directions). Blobworld uses a different technique to represent texture information. It identifies the textured regions and non-textured regions in the images. This helps to separate the background and foreground regions in an image. In addition, the texture patterns are also distinguished into singly oriented (1D) and multiple-oriented (2D) textures⁹. This helps to categorize the texture regions. For example, 1D texture is a strong characteristic of water waves and 2D texture of grass. Texture feature information is derived using the second moment matrix computed within a specified region in the image. Manjunath and Ma⁴ used Gabor filter based multiresolution representations to extract texture information. Most of these feature extraction techniques are used to retrieve the texture images from the database.

Recent research in image retrieval suggests that significant improvement in retrieval performance requires techniques that, in some sense, "understand" the content of the image and queries. Recently, image retrieval researchers have tried to use the application domain knowledge to determine relevant relationships between images and queries. This paper proposes a fuzzy logic based interpretation of queries in terms of natural language. This research aims to investigate a novel query-based, fuzzy learning approach to retrieve images based on texture feature. To investigate a new intelligent CBIR technique through developing: a syntax to represent queries in natural language and a fuzzy logic interface.

The rest of the paper is organized as follows. Section 3 represents a tamura feature representation for texture features, Section 4 details the research methodology, this section is subdivided into small sections. Section 5 describes the experimental results performed on the combinations of the queries and the paper is concluded in Section 6, Conclusion, which also discuss about future research.

3. Tamura Feature Representation

Tamura et al.⁸ took a different approach based on psychological studies on human visual perception. They developed computational approximations for six different visually meaningful texture properties, namely, coarseness, contrast, directionality, line-likeness, regularity, and roughness. This closeness with human perception makes these texture representations interesting also in content-based image retrieval.

The coarseness of a texture is computed as follows. First, for each pixel $x = (x, y)$, the average gray-level values $G_k(x, y)$ over neighborhoods of size $2^k \times 2^k$, $k = 0, 1, \dots, 5$ are computed. Then, the differences between pairs of non-overlapping neighborhoods on opposite sides of a pixel in horizontal and vertical directions are determined. The horizontal difference is

$$E_{k,h}(x, y) = |G_k(x + 2^k, y) - G_k(x - 2^k, y)|$$

The vertical difference is computed accordingly. Now, the size $S_{best}(x, y) = 2^k$ corresponding with the maximum of E in either direction is picked for each pixel (x, y) . The coarseness property of the texture is then the average of S_{best} over image:

$$f_{crs} = \frac{1}{WH} \sum_{x=1}^W \sum_{y=1}^H S_{best}(x, y)$$

The contrast of the texture is defined as

$$f_{con} = \frac{\sigma}{(\alpha_4)^\gamma}$$

where σ is the standard deviation, α_4 the kurtosis of the gray-level probability distribution of the image, and γ a positive number. In their experiments, $\gamma = 1/4$ gave the best correlation with human perception of contrast. In order to determine the directionality of a texture, a histogram of local edge probabilities against their directional angle is used. The magnitude and direction of the gradients are computed by using the Prewitt operators.

To catch the texture element composed of lines or line-likeness, a $M \times M$ -sized direction matrix P_{Dd} is defined. The element $P_{Dd}(i, j)$ of the matrix is the relative frequency of the two pixels separated by distance d , one with the direction code i and the other with j . The line-likeness property is then defined as

$$f_{in} = \frac{\sum_{i=1}^M \sum_{j=1}^M P_{Dd}(i, j) \cos\left[\frac{2\pi}{M}(i-j)\right]}{\sum_{i=1}^M \sum_{j=1}^M P_{Dd}(i, j)}$$

The regularity of repeated patterns in a texture is calculated by taking the sum of the standard deviations of the measures f_{crs} , f_{con} , f_{dir} , and f_{lin} ,

$$f_{reg} = 1 - \gamma(\sigma_{crs} + \sigma_{con} + \sigma_{dir} + \sigma_{lin})$$

where γ is a normalizing factor. Finally, the roughness of the image is approximated by the sum of the coarseness and the contrast values.

4. Research Methodology

The proposed system is divided into two stages. Stage I describes Database Creation and Stage II describes Database Retrieval based on texture patterns. The overview of the proposed system is shown in Figure 1. Database creation consists of texture image database, tamura feature extraction, fuzzy clustering and query terms, while database retrieval consists of visual query, fuzzy interpretation, similarity measure and retrieved images. The following sections details about these terms.

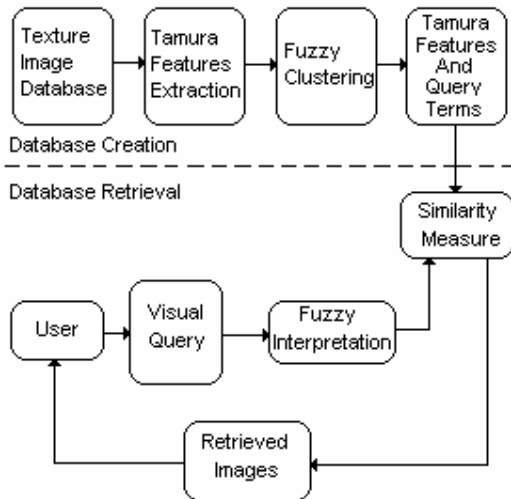


Figure 1: Block Diagram for Fuzzy Texture Query for CBIR

4.1. Database Creation

Texture Image Database: This database contains the images from Brodatz textures. Each texture image in the database is described as six Tamura features. Tamura features characterize low level statistical properties of textures. The properties and computations of the tamura features are described in the last section.

Fuzzy Clustering: A term set on each tamura feature is generated through a fuzzy clustering so that the degrees of the appearance for the feature can be interpreted as five natural language terms. These terms characterize high level textual concepts of textures.

Texture Features and Query Terms: Each texture image along with its tamura features and query terms is organized and stored in a texture feature database. These natural expression terms are described in the next Section 4.2, Fuzzy Interpretation.

Similarity Computation: A user can pose a visual example to find the desired texture patterns. The query can be expressed in terms of composition of natural language terms or feature values. Therefore, the similarity between a texture image and the query can be interpreted as the similarity between the image representation and the query expression. The similarity between a query image and images in database is calculated using distance formula.

4.2. Fuzzy Interpretation

Fuzzy clustering algorithm is proposed so that the term set can be generated and the degrees of the appearance for each tamura feature can be interpreted as five natural language terms. For example, the terms for contrast are interpreted as mostly low, low, medium contrast, normal contrast, and mostly contrast. Table 1 shows the linguistic terms used for the components of the tamura feature.

Therefore some fuzzy values to interpret queries are proposed in this research. In some applications, fuzzy systems often perform better than traditional systems because of their capability to deal with non-linearity and uncertainty. One reason is that while traditional systems make precise decisions at every stage, fuzzy systems retain the information about uncertainty as long as possible and only draw a crisp decision at the last stage. Another advantage is that linguistic rules, when used in fuzzy systems, would not only make tools more intuitive, but also provide better understanding of the outcomes.

Referring to Figure 2, the query to retrieve the images from the database is prepared in terms of natural language, such as mostly, medium and normal of some specific texture. This approach is to make CBIR systems intelligent so that they can interpret human language.

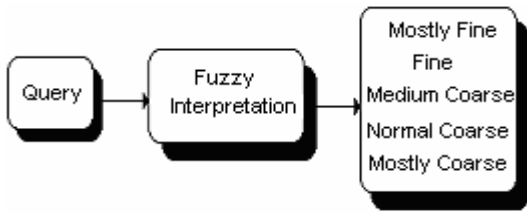


Figure 2: Query Interpretation for Coarseness

4.3. Database Retrieval

The user can pose a query in terms of composition of the textual descriptors in terms of natural language. The logic operators such as AND, OR and NOT are used to pose a query more precisely. The query can be posed like this: Retrieve all the texture images which are “fine on Coarseness OR regular on Regularity AND very high on Contrast.” The membership function for the coarseness is shown in the Figure 3.

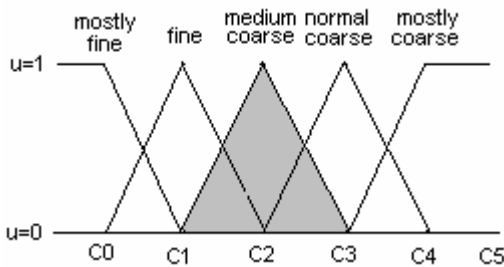


Figure 3: Membership Function for Coarseness (medium)

The user can also pose a query based on visual examples. From the set of random images, the user can select an image. The query will search for all the texture images similar to this texture image. The similarity function for each tamura feature value is defined.

5. Experimental Results

The texture database used to check the proposed technique consists of 96 different texture images. Each image is 512 x 512 pixels. Images D1 – D96 are from the Brodatz album¹⁰. The collection of Brodatz textures consists of textures of both statistical and structural natures. Structural textures are considered to be consists of texture primitives which are repeated systematically within the texture. In statistical texture usually no repetitive texture can be identified. These are gray scale texture images that contain the texture of brick wall, wood grain, woolen cloth, beach sand, lizard skin etc. The user can pose a query in terms of textual descriptors in natural language term and

tamura feature such as fine coarseness and normal contrast. The Figure 4 shows natural language query and the retrieved images. The retrieved images are displayed in descending similarity order from left to right. Experiments were conducted by different combinations of the queries and achieved promising results.

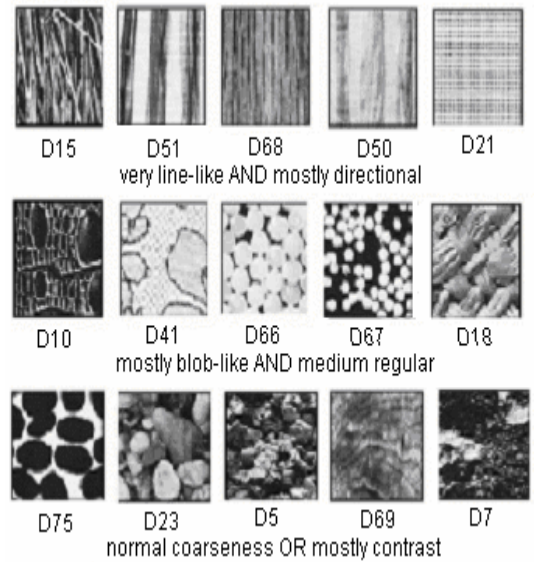


Figure 4: Results of the Queries in terms of Tamura Features and Fuzzy Logic

Figure 5 shows the results obtained for querying by visual examples. The left image is the query and the retrieved images are displayed in order of similarity.

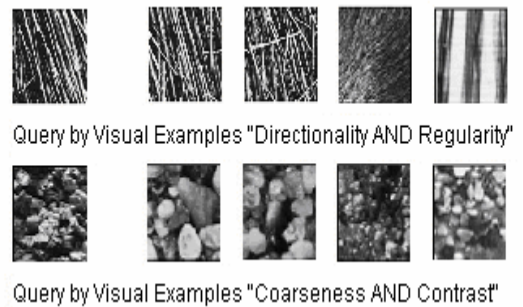


Figure 5: Results of the Query by Visual Examples

6. Conclusion

Fuzzy logic for the interpretation of the texture queries for content-based image retrieval is proposed in this paper. User can pose a textual description or visual examples to find the desired image from the database. In Tamura features, all six properties are visually meaningful so this

texture representation becomes attractive in CBIR. This technique simplifies the similarity between the query image and the images in the database and works well for CBIR. The future research may include proposing a neural network based to learn the meaning of the queries and use of neuro-fuzzy technique to retrieve texture images from the database.

Table 1: Natural Language Query Terms for Tamura Features

Tamura Features	Natural Language Query Terms				
Coarseness	mostly fine	fine	medium coarse	normal coarse	mostly coarse
Contrast	mostly low	low	medium contrast	normal contrast	mostly contrast
Directionality	mostly non-directional	non-directional	medium directional	directional	mostly directional
Line-likeness	mostly blob-like	blob-like	medium line-like	line-like	mostly line-like
Regularity	Mostly irregular	irregular	medium regular	regular	mostly regular
Roughness	Mostly smooth	smooth	medium rough	rough	mostly rough

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