Content-Based Retrieval Concept

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INTRODUCTION

Because of the demand for efficient management in images, much attention has been paid to image retrieval over the past few years. The text-based image retrieval system is commonly used in traditional search engines (Ratha et al., 1996), where a query is represented by keywords that are usually identified and classified by human beings. Since people have different understandings on a particular image, the consistency is difficult to maintain. When the database is larger, it is arduous to describe and classify the images because most images are complicated and have many different objects. There has been a trend towards developing the content-based retrieval system, which tries to retrieve images directly and automatically based on their visual contents.

A similar image retrieval system extracts the content of the query example $\boldsymbol{q}$ and compares it with that of each database image during querying. The answer to this query may be one or more images that are the most similar ones to $\boldsymbol{q}$. Similarity retrieval can work effectively when the user fails to express queries in a precise way. In this case, it is no longer necessary to retrieve an image extremely similar to the query example. Hence, similarity retrieval has more practical applications than an exact match does.

Content-Based Image Retrieval Systems

In a typical content-based image retrieval system, the query pattern is queried by an example in which a sample image or sketch is provided. The system then extracts appropriate visual features that can describe the image, and matches these features against the features of the images stored in the database. This type of query is easily expressed and formulated, since the user does not need to be familiar with the syntax of any special purpose image query language. The main advantage is that the retrieval process can be implemented automatically (Chen, 2001). The scope of this article is circumscribed to image abstraction and retrieval based on image content.

Human beings have a unique ability that can easily recognize the complex features in an image by utilizing the attributes of shape, texture, color, and spatial information. Many researchers analyze the color, texture, shape of an object, and spatial attributes of images, and use them as the features of the images. Therefore, one of the most important challenges in building an image retrieval system is the choice and representation of the visual attributes. A brief overview of the commonly used visual attributes shape, texture, color, and spatial relationship will be illustrated as follows.

Commonly Used Image Features in Content-Based Image Retrieval Systems

Shape characterizes the contour of an object that identifies the object in a meaningful form (Gevers & Smeulders, 2000; Zhang & Lu, 2002). Traditionally, shapes are described through a set of features such as area, axis-orientation, certain characteristic points, and so forth. These systems retrieve a subset of images that satisfy certain shape constraints. In the shape retrieval, the degree of similarity between two images is considered as the distance between the corresponding points.

Color attribute may simplify the object's identification and extraction in the image retrieval (Galdino & Borges, 2000; Gevers & Smeulders, 2000). Color may provide multiple measurements at a single pixel of the image, and often enable the classification to be done without complex spatial decision-making. Any resulting difference between colors is then evaluated as a distance between the corresponding color points. The color-based retrieval system measures the similarity of the two images with their distance in color space.

Texture attribute depicts the surface of an image object (Yao & Chen, 2002; Zhang & Tan, 2003). Intuitively, the term refers to properties such as smoothness, coarseness, and regularity of an image object. Generally, the structural homogeneity does not come from the presence of a single color or intensity, but it requires the interaction of various intensities within a region.

Retrieval by spatial constraints facilitates a class of queries based on the 2-D arrangement of objects in an image (Chang Erland & Li, 1989; Chang & Li, 1988; Chang, Shi & Yan, 1987; Lee & Hsu, 1992). The query is composed by placing sketches, symbols or icons on a plane where every symbol or icon is predefined for one type of objects in an image. The relationships between the objects can be broadly

classified as either directional (also referred as projective) (Chang & Li, 1988; Chang, Shi & Yan, 1987) or topological (Lee & Hsu, 1992). Directional relationship is based on the relative location and the metric distance between two image objects. Topological relationships are based on set-theoretical concepts like union, intersection, disjunction and so forth. Spatial information is a higher-level attribute, which is increasingly more specific. For example, facial features are frequently presented in terms of spatial information (Sadeghi, Kittler & Messer, 2001).

Briefly, color attribute depicts the visual appearance of an image, characterized by the luminance and chrominance histograms of the image. Texture attribute refers to three components: bi-dimensional periodicity, mono-dimensional orientation, and complexity obtained through world decomposition. Shape attribute sketches the geometrical properties of objects in images. Spatial attribute represents the relative position relationships between objects of an image.

TYPICAL IMAGE RETRIEVAL SYSTEMS

This section briefly overviews the image retrieval systems based on the most commonly used image features: color, shape, texture, and spatial content.

The Color-Based Image Retrieval Systems

Generally, the color-based image retrieval system does not find the images whose colors are exactly matched, but images with similar pixel color information. This approach has been proven to be very successful in retrieving images since concepts of the color-based similarity measure is simple, and the convention algorithms are very easy to implement. Besides, this feature can resist noise and rotation variants in images.

However, this feature can only be used to take the global characteristics into account rather than the local one in an image, such as the color difference between neighboring objects in an image. For example, if a landscape image with blue sky on the top and green countryside at the bottom is employed as a query example, the system that retrieves the images with similar structures based on these global features often gives very unsatisfactory results. In addition, the color-based image retrieval system often fails to retrieve the images that are taken from the same scene in which the query example is also taken from under different time or conditions, for example, the images of a countryside taken at dusk or dawn under a clear or a cloudy sky. In another scenario, the same scene may be imaged by different devices. Using one image taken by one device as the query example may fail to find the same scene taken by other devices.

The Shape-Based Image Retrieval Systems

A shape-based image retrieval system is used to search for the images containing the objects, which are similar to the objects specified by a query. Since an object can be formed by a set of shapes in most cases (e.g., a car can be made of some little rectangles and circles), most similar objects have a high correlation in their set of shapes (Gevers & Smeulders, 2000; Zhang & Lu, 2002). The shape-based image retrieval system extracts the shapes of objects from images by segmentation, and classifies the shapes, where each shape has its own representation and variants to scaling, rotation, and transition.

Some criteria on shape representation and similarity measure for a well performing content-based image retrieval system should be achieved. Firstly, the representation of a shape should be invariant to scale, translation, and rotation. Secondly, the similarity measure between shape representations should conform to human perception; that is, perceptually similar shapes should have highly similar measures. Thirdly, the shape representation should be compact and easy to derive, and the calculation of similarity measure should be efficient.

However, how to locate and how to recognize objects from images is a real challenge. One of the obstacles is how to separate the objects from the background. Difficulties come from discrimination, occlusions, poor contrast, viewing conditions, noise, complicated objects, complicated backgrounds, and so forth. Moreover, the shape-based image retrieval system can only deal with the images that have simple object shapes. For complex object shapes, the region-based method has to build a binary sequence by using smaller grid cells, so that results that are more accurate can be obtained; nevertheless, the storage of indices and retrieval time may increase tremendously.

The Texture-Based Image Retrieval Systems

Literally, texture relates to the arrangement of the basic constituents of a material. In digital images, texture describes the spatial interrelationships of the image pixels. Texture similarity can often be useful in distinguishing the areas of objects in images with similar color, such as sky and sea as well as leaves and grass. Texture queries can be formulated in the manner that is similar to the color queries by selecting an example of desired textures from a palette, or by supplying an example query image. The system then returns the images which are most similar to the query example in texture measures.

Making texture analysis is a real challenge. One way to perform content-based image retrieval using texture as