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Image Matching Using the OBIR System with Feature Point Histograms

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Abstract

The main focus of multimedia systems research has been directed towards the design and development of techniques for the management of visual information. Both in images and image sequences, shape and spatial constraints are essential features associated with these objects. This paper presents an image retrieval system called OBIR (Object-Based Image Retrieval). We discuss this and a new histogram-based approach to indexing spatial arrangements of features. Based on some preliminary experiments, we demonstrate the effectiveness and efficiency of our system.

Keywords

Object-based image retrieval, feature point histogram, image indexing

1 INTRODUCTION

The traditional database approach of modeling the real world is based on manual annotations of its salient features in terms of alphanumeric data. However, all such annotations are inherently subjective. In some cases, it is rather difficult to characterize certain important real-world concepts, entities, and attributes by means of text only. The shape of a single object and the various spatial constraints

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among multiple objects in an image are examples of such concepts. Shape and spatial constraints are important data in many applications, ranging from complex space exploration and satellite information management to medical research and entertainment.

Image retrieval can be categorized into exact match searching and similarity-based searching. For either type of retrieval, the dynamic aspects of image content requires expensive computations and sophisticated methodologies in the areas of image processing and database systems. In order to overcome these problems, several schemes for data modeling and image representation have been proposed [AhG97, ChL84]. In general, each of these schemes builds a symbolic image for each given physical image, and symbolic images are then used in conjunction with index structures as proxies for image comparisons to reduce the search space. Once a measure of similarity is determined, the corresponding actual images are retrieved from the database. Due to the lack of any unified framework for image representation, storage, and retrieval (see [MPE97] for information on the emerging MPEG-7 standard), these symbolic representation schemes and retrieval techniques have greatly facilitated image management.

The remainder of the paper is organized as follows. Section 2 presents an overview of the architecture of our object-based image retrieval (OBIR) system. Section 3 describes our new histogram-based approach to indexing spatial arrangements of features. The effectiveness and efficiency of our system are shown by an experiment reported in Section 4. Finally, section 5 presents some concluding remarks.

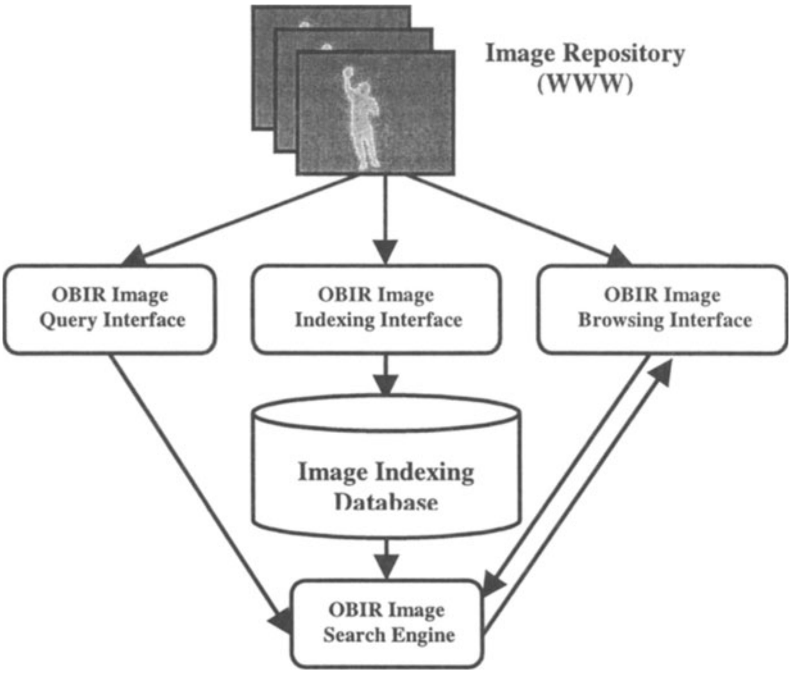

Figure 1 OBIR System Architecture

2 DESIGN AND IMPLEMENTATION OF OBIR

Content-based image retrieval systems use visual features to index images. With the recent development of the client/server architecture using Internet information services, it has become increasingly more desirable to use computers to connect to the Internet to access information via Web browsers. We have been developing such a system, which focuses on exploiting image indexing techniques for shape and spatial similarity-based retrievals; it is called *the OBIR (Object-Based Image Retrieval)* system.

The OBIR system architecture, which is shown in Figure 1, has been designed to allow users to index, query, and browse images on the WWW in an effective and efficient way. The OBIR system is written primarily in Java. Windows and menus of the system provide user-friendly interfaces. The development methodology follows standard software engineering practices, in that the modularization of the OBIR system architecture makes it easily to refineable and extensible. A brief description of each of the system components is as follows.

2.1 Image Indexing Interface

This component of our system allows users to index a URL-referenced image. The actual image is not stored in the database. Instead, those visual features that characterize shape and spatial relationships among objects in the specified image, along with the image URL, are stored in the database for image feature matching. This makes the OBIR system more scalable and allows fast query responses for a large number of users and a voluminous set of images.

2.2 Image Query Interface

This component of our system allows users to flexibly query the image database by simply clicking and moving the mouse in the query specification window to select or deselect shapes and spatial constraints among part or all of query image objects. The selected image objects are visually similar to, and satisfy the spatial constraints of, those objects wanted in the user's mind. This permits users to query the system based on the contents of an image without forcing them to know the exact values of the image features. This query image specification approach is well supported by our new image indexing structure, which will be described shortly.

2.3 Image Browsing Interface

This component of our system displays the top ranked images among the query results. Any returned image can be used as the basis for subsequent queries. In addition, this component allows users to utilize metadata to intelligently browse indexed images. The assumption that any information about the image can be used to infer information regarding its content is an example of content-based metadata. Thus, a collection of metadata that corresponds to those indexed images is integrated into this component to support metadata mediated browsing, which is discussed in detail in [GFJ97].

2.4 Image Search Engine

This component of our system interacts with the image index database to access stored visual features of indexed images. Upon the request of the image query interface or the image browsing interface, this component finds matching image objects using a similarity measure based on shape and spatial relationships. Several similarity functions may be defined for different requests. A number of top-ranked image URLs and their corresponding similarity values are returned according to a predefined threshold value.

2.5 Image Index Database

This component of our system maintains all of the indexed image features so as to support effective and efficient image retrieval. Since the features collected in the database are computed only once through the image indexing interface, minimal processing is done during image querying or browsing.

2.6 Image Repository

This component of our system can be WWW space. In such cases, instead of manually specifying an image URL through the image indexing interface, a web image crawler could surf the WWW to search for images to be indexed. Because these indexed images are stored where they originally exist, the image can be kept relatively compact. If necessary, all of the OBIR system interfaces and the search engine can access the actual images using their URL's.

3 FEATURE POINT HISTOGRAMS OF IMAGE OBJECTS

In general, those image features which characterize image object shapes and spatial relations of multiple image objects can be represented as a set of points. These points can be tagged with labels to capture any necessary semantics. For example, a corner point of an image region has a precise location and can be labeled with the region's identifier, and a color histogram of an image region can be represented by a point placed at the center-of-mass of the region and labeled by the histogram. We call each of these individual points representing shape and spatial features of image objects a ***feature point***.

We must symbolically represent an image object in such a way that searching for variants (translation, rotation, and scaling) of the object is possible in an efficient way. Corner points, which are generally high-curvature points located along the crossings of image object's edges or boundaries, will serve as the feature points for our experiments. We have argued for representing an image object by the collection of its corner points in [AhG97], which proposed a quadtree-based technique for indexing such collections.

Our methodology is quite simple. We construct a Delaunay triangulation [Oro94] using the spatial arrangement of feature points, and then we compute a histogram of the angles produced by this triangulation. Like color histograms [HSE95], different image objects may have the same feature point histogram, since histogram-based representation is lossy and not unique. In principle, it is easily shown that the angles of the Delaunay triangulation of a set of points remain the same under uniform translations, rotations, and scalings of this point set. See Figure 2 for an example of our approach.

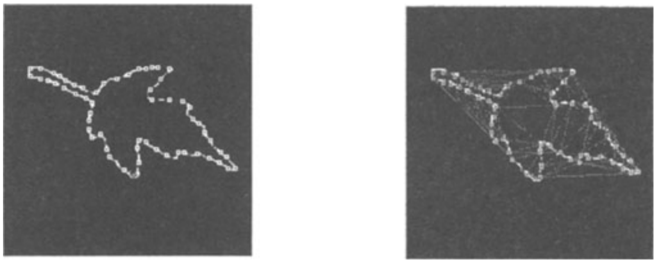

Figure 2 (**a**) Image Corner Points (**b**) Resulting Delaunay Triangulation

4 AN EXPERIMENT

One of our preliminary experiments consists of 100 images, in which five original fish images are from the web site *http://www.ee.surrey.ac.uk/Research/VSSP/imagedb/demo.html*, and five original leaf images are from the web site http://www.prip.tuwien.ac.at/prip/image.html. For each original image, nine variants are constructed: three rotation variants, three rotation, scaled-up variants, and three rotation, scaled-down variants.

SUSAN (Smallest Univalue Segment Assimilation Nucleus) [SmB95] is used for our corner point detection, because SUSAN provides better results than traditional corner detection algorithms under varying levels of image brightness. In addition, we note that there are O(NlogN) algorithms for constructing the Delaunay triangulation of a set of N points. Constructing the histogram corresponding to this triangulation is O(max(N, #bins)).

In the experiment, each image is indexed by a feature point histogram with a bin size of 10°. Assuming that each image is relevant only to itself and to its nine variants, we use each of the original ten images as a database query over the resulting database of 100 images and rank each match using the standard N-dimensional L2 metric, for N the number of bins. The overall retrieval effectiveness is evaluated by using the standard recall-precision curves [WMB94]. As a result, the lowest 3-point average precision out of ten is 80%, and the lowest 11-point average precision out of ten is 79%.

5 CONCLUSION

OBIR is a generic object-based image retrieval system that works in a web-based environment. Using its modular design, we may plug-in various image representation schemes as well as indexing methodologies. In this paper, we have introduced OBIR and have demonstrated the efficacy of our symbolic image representation scheme on a small database of images. This image representation scheme crucially depends on the quality of the technique used to find corner points. This is the weak link in our approach, but even so, we have shown that our system works well in certain environments. To refine and extend the OBIR system, we intend to use better image processing algorithms to extract more precise image feature points. At present, we are working on various nearest neighbor approaches to directly access relevant images. We also intend to extend our approach to work with video indexing.

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7 BIOGRAPHY

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