Data & Knowledge Engineering 86 (2013) 124–145

Contents lists available at SciVerse ScienceDirect

Data & Knowledge Engineering

journal homepage: www.elsevier.com/locate/datak

Comparison of feature-based and image registration-based retrieval of image data using multidimensional data access methods

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ARTICLE INFO

Article history:
Received 22 April 2011
Received in revised form 24 January 2013
Accepted 24 January 2013
Available online 8 February 2013

Keywords:
Access methods
Information retrieval
Filtering
Classification
Summarization and visualization
Indexing methods
Content-based image retrieval
Landmark-based multidimensional scaling
OWA
Multimedia indexing
BitMatrix
SlimTree

ABSTRACT

In information retrieval, efficient similarity search in multimedia collections is a critical task. In this paper, we present a rigorous comparison of three different approaches to the image retrieval problem, including cluster-based indexing, distance-based indexing, and multidimensional scaling methods. The time and accuracy trade-offs for each of these methods are demonstrated on three different image data sets. Similarity of images is obtained either by a feature-based similarity measure using four MPEG-7 low-level descriptors or by a whole image-based similarity measure. The effect of these similarity measurement techniques on the retrieval process is also evaluated through the performance tests performed on several data sets. We show that using low-level features of images in the similarity measurement function results in significantly better accuracy and time performance compared to the whole-image based approach. Moreover, an optimization of feature contributions to the distance measure for feature-based approach can identify the most relevant features and is necessary to obtain maximum accuracy. We further show that multidimensional scaling can achieve comparable accuracy, while speeding-up the query times significantly by allowing the use of spatial access methods.

1. Introduction

As the number of applications in information technologies increases, efficient retrieval of multidimensional data for these applications becomes crucial in order to make the best use of the available data. Classical approaches for accessing multidimensional data are often inapplicable or insufficient, due to the complexity and high dimensionality of the data. Naive applications of classical approaches usually incur an unacceptable penalty in retrieval time or search accuracy.

Improvements in the imaging technologies and the common availability of imaging devices have generated a deluge of multimedia data in scientific, medical, and social applications. The rapid growth of multimedia data has generated the need for new methods that provide efficient content-based retrieval (CBR). In response to this need, a number of content-based retrieval systems have been developed, some of which are listed in Fig. 1. As demonstrated in the figure, retrieval systems can be divided broadly into two categories: feature-based and annotation-based systems. In the former category, low-level features (and/or objects) extracted from multimedia data are used [1,2] to compare and retrieve data; whereas in the latter category, text based

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http://dx.doi.org/10.1016/j.datak.2013.01.007

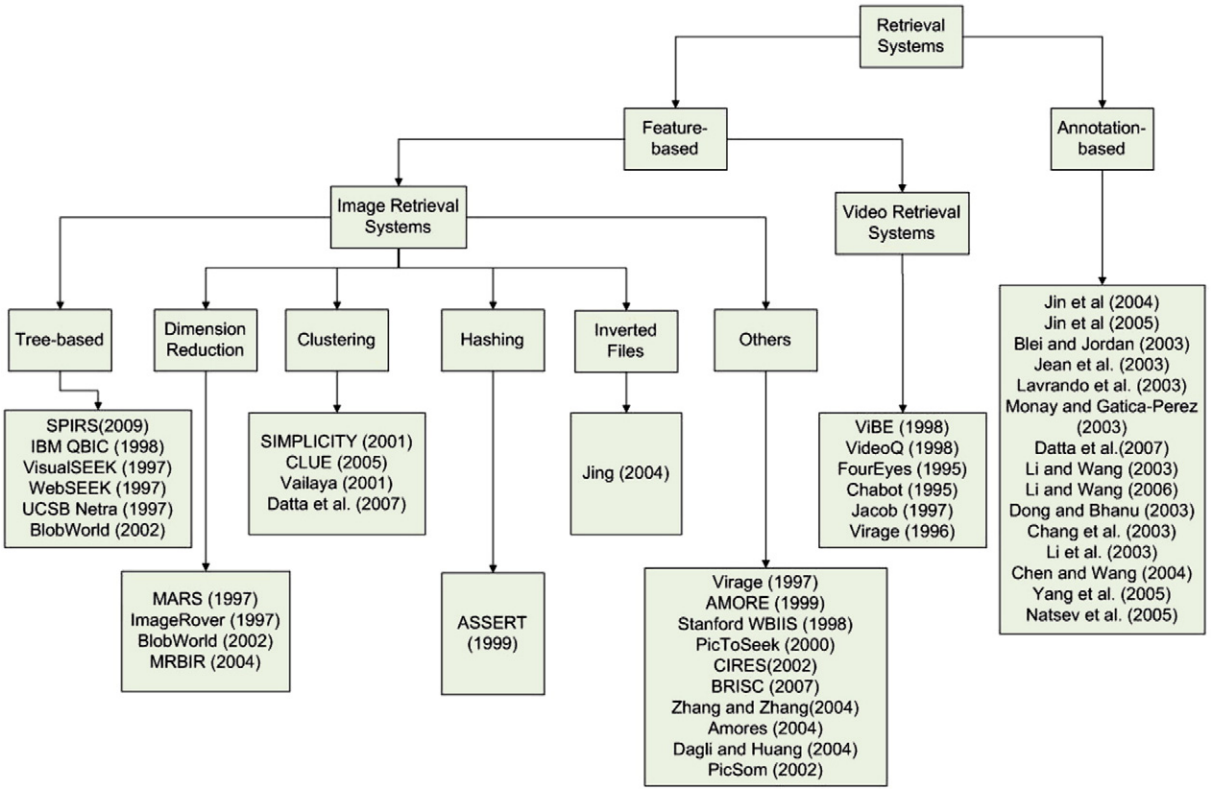

Fig. 1. Retrieval systems proposed for accessing multimedia data.

semantic information is used to characterize the multimedia data and form the basis for the retrieval process. Annotation-based image retrieval systems have traditionally relied on manual annotation of images and retrieval by search of keywords within the annotation database. Several image segmentation methods have been proposed to perform automated segmentation and association of images to a pre-defined vocabulary [3,4]. The feature-based retrieval systems, which are the focus of this study, allow identification of similar images using low-level image features [5–10]. While most of these systems use tree-based or cluster-based data access structures, other access methods have also been applied, such as hashing and dimension reduction techniques.

Besides using low-level features in CBR systems, image registration techniques are used in the areas of image processing and pattern recognition to estimate the degree to which two given patterns are correlated in remote sensing, medical imaging, computer vision etc. The choice of an image similarity measure depends on the nature of the images to be registered in these techniques. Common examples of image similarity measures are Cross-Correlation, Mutual Information, Mean-square difference and Ratio Image Uniformity. Mutual Information (MI) and Cross Correlation (CC) have emerged in recent years as an effective similarity measure for comparing images [11,12].

In addition to efforts to provide efficient and accurate multimedia data retrieval, there are also several high-level systems that attempt to address the problem in a different manner, via storage and management of multimedia data as they are perceived by humans [13–15]. These high-level systems define a data model to represent the multimedia objects and the temporal relations among them. They also define appropriate query languages to facilitate access to multidimensional data.

In each of these proposed CBR systems, retrieval performance becomes a critical factor that determines the scaling of their application to real-life databases. In order to meet the performance requirements of information retrieval in complex data domains, several approaches [16] and multidimensional access methods have been proposed [17,18].

Spatial Access Methods (SAM) [19,20] index the multidimensional space defined by data feature vectors. These index structures are based on a tree data structure with the data nodes in the leaves of the tree and a cluster hierarchy built on top [21,22]. SAMs partition either the multidimensional data to be indexed or its underlying data space [17]. The main drawback of spatial-access methods is the drastic decrease in the retrieval performance as the dimensionality of the feature vectors of data objects increases, a phenomenon known as the *curse of dimensionality* [18]. The SAMs are generally outperformed by simple sequential scan when the number of data dimensions exceeds a certain threshold [17,21].

Point Access Methods (PAM) try to index objects represented as points in a multidimensional space. In PAMs, the points in the database are organized in a number of buckets. These buckets correspond to some subspace of the universe and are accessed by