Chapter 7.20
Managing Uncertainties in Image Databases

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ABSTRACT

In this chapter, we focus on those functionalities of multimedia databases that are not present in traditional databases but are needed when dealing with multimedia information. Multimedia data are inherently subjective; for example, the association of a meaning and the corresponding content description of an image as well as the evaluation of the differences between two images or two pieces of music usually depend on the user who is involved in the evaluation process. For retrieval, such subjective information needs to be combined with objective information, such as image color histograms or sound frequencies, that is obtained through (generally imprecise) data analysis processes. Therefore, the inherently fuzzy nature of multimedia data, both at subjective and objective levels, may lead to multiple, possibly inconsistent, interpretations of data. Here, we present the FNF^2 data model, a Non-First Normal Form extension of the relational model, which takes into account subjectivity and fuzziness while being intuitive and enabling user-friendly information access and manipulation mechanisms.

INTRODUCTION

In the multimedia age, which is characterized by new emergent kinds of data such as images, sounds, texts, and video objects, the need for information storage and retrieval requirements cannot be satisfied simply by relying on traditional databases. The various properties of these objects cannot be captured properly by relational or object-oriented models. Therefore, multimedia databases have to provide new functionalities, depending on the type of —possibly heterogeneous—multimedia data being stored. Within this context, new challenges ranging from problems related to data representation to challenges related

to the indexing and retrieval of such complex information, have to be addressed.

In this chapter, we focus on those functionalities of multimedia databases that are not present in traditional databases but are needed when dealing with multimedia information. Multimedia data are inherently subjective; for example, the association of a meaning and the corresponding content description of an image as well as the evaluation of the differences between two images or two pieces of music usually depend on the user who is involved in the evaluation process. Furthermore, such subjective information usually needs to be combined with objective information, such as image color histograms or sound frequencies, that are obtained through data analysis. Data analysis processes generally are imprecise. Therefore, the inherently *fuzzy* nature of multimedia data, both at the subjective and objective levels, may lead to multiple, possibly inconsistent interpretations of data. Thus, providing a data model that can take into account subjectivity and fuzziness, while being intuitive and enabling user-friendly information access and manipulation mechanisms, is not trivial.

Although most of the content presented in this chapter also applies to diverse multimedia information management scenarios, for the purposes of illustration, we focus on image data that illustrate the subjectivity and fuzziness aspects that are common to all such scenarios.

In order to store a collection of images properly in a database, the system must offer appropriate capabilities to explore the relationships among the different images, to recognize the relevant image features, to provide methods and techniques to express those relationships and features, and to query on them. As opposed to the classical relational data model in which queries are posed textually (or through some visual interface that does not increase the expressive power of the textual format), in image databases, queries usually are expressed in nontextual forms. This is the case, for example, when using *Query By Example* or *Query by Content* forms, in which a query may include an image as part of it, and the returned result does not rely on a crisp evaluation process but rather on a notion of similarity between the query and the images in the database. In particular, each returned image has a degree of satisfaction relative to the query, which represents to which extent the result image can be considered similar to the query image according to the chosen notion of similarity.

Fuzziness and uncertainty related to image query processing cannot be represented directly in the relational data model. Therefore, several approaches (Raju & Majumdar, 1998; Takashi, 1993; Yang, Zhang, Wu, Nakajima, & Rishe, 2001) have been proposed to extend the relational data model to include these aspects appropriately. Zaniolo et al. (1997) extend the relational model to incorporate uncertainty at tuple as well as attribute levels. In the *tuple-level* approaches, the schema of the relations can include attributes representing uncertainty values. Thus, each tuple may contain one or more uncertainty attributes, each one representing the fuzziness degree associated with a different interpretation of the data values stored in the remaining attributes of the tuple. The uncertainty attributes usually have real values or are expressed in terms of intervals on real numbers. In the *attribute-level* approaches, on the other hand, instead of associating a value representing the uncertainty of the data to the tuple as a whole, a degree of uncertainty is associated directly to every single attribute value. In image databases (in which images are represented in terms of their various feature values that are extracted from the image using appropriate image processing and analysis processes) attribute-level approaches are more applicable; it is easier to store and maintain detailed information about the various relevant aspects of a given image using an attribute-based approach instead of associating a unique, global value to the overall image tuple.

In the next section, we present the background on modeling and accessing image data collections