Towards a Theory of Normalization for Multimedia Databases

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Abstract

We present a theory of normalization for multimedia databases. We introduce new types of functional dependencies between different types of media data. Thus, the definition of functional dependency is based upon a specific technology used to detect semantic relationships between complex data types, which need to be compared through approximate match paradigms .

Index terms *–– Multimedia Databases, MDBMS, Anomalies, Functional Dependency, Normal Form.*

1. Introduction

In this paper we describe a framework for defining normal forms in multimedia databases. The concept of functional dependency is extended and parameterized upon the technology used to derive approximate dependencies between data belonging to complex media domains.

The paper is organized as follows. In Section 2 we describe semantics of attributes in multimedia databases. In Section 3 we present our framework for extended functional dependencies, whereas new normal forms are defined in Section 4. Finally, conclusion and further research are discussed in Section 5.

2. Semantics of Multimedia Attributes

Database designers use their understanding of the semantics of attributes to specify functional dependencies among them [3]. Other than alphanumeric data, multimedia databases can store complex data types, such as text, sound, image, and video. Generalized icons [1] can be used as a model for describing complex data. Generalized icons are dual objects (x_m, x_i) with a logical x_m and a physical part x_i. We can associate a generalized icon to each complex data, using the logical part to describe its semantics, and the physical part to describe the physical appearance. Thus, in multimedia databases we can use *icons* for images, *earcons* for sounds, *ticons* for texts, *micons* for motions, and *vicons* for videos [1].

Examples of semantic models for expressing logical parts are Conceptual graphs [1], Frames, Semantic Networks, or visual CD forms [2]. As an example, choosing a frame based representation, an image icon representing the face of a person may be described by a frame with attributes describing the name of the person, the colors of the picture, objects appearing in the picture, including their spatial relationships.

Once the designer has specified the semantics of simple and complex attributes according to the chosen semantic model, the generalized icons for the multimedia database are completely specified. This provides a semantic specification of the tuples in the database. As an example, in a database of singers we might use attributes *name*, *birth day*, *genre*, as alphanumeric attributes, and *picture* as an icon representing the singer picture, one or more earcons to represent some of his/her songs, and one or more vicons to represent his/her video clips. A tuple in this database describes information about a specific singer, including his/her songs and video clips. This provides a complete semantic specification of the tuple.

3. Extended Functional Dependencies

In order to define functional dependencies for multimedia databases we need to choose a method for defining equalities between groups of attributes involving complex data types. As it can be expected, the matching of complex attributes needs to be an approximate match. This means that we can extend the definition of dependency by selecting a specific technique for approximate match, and a threshold for similarity. We denote the similarity technique by associating a subscript to the arrow in the notation for functional dependencies, whereas the threshold is specified as an arrow label. As an example, if we define a functional dependency between groups of attributes X and Y including images, and use the similarity technique used by QBIC[4], we would write

$$X \xrightarrow{t}_{QBIC} Y$$

where t represents the threshold. This constraint says that for any two tuples t_1 and t_2 such that $t_1[X]$ is considered

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similar within the threshold t to $t_2[X]$ by the QBIC, then the same happens for $t_1[Y]$ and $t_2[Y]$.

4. Normal Forms in M- Databases

Since normal forms are generally based on functional dependencies, the normal forms we define depend upon the technology used to derive dependencies. The normal form itself might need a specific technology to handle a specific media type. For instance, we can define a first normal form based upon a specific image segmentation technology S, so that composite images are segmented and distributed in a certain number k of attributes. This criteria can be used to derive a first normal form requiring a composite media type be decomposed into elementary generalized icons stored in separate attributes. For instance, we might have a vicon attribute and might want to separate sounds from images.

We say that a multimedia database schema is in second normal form if each non prime attribute A is fully dependent on the primary key. If A is not alphanumeric, then we need to use a technology S and a threshold t for evaluating similarity. In case there is a partial dependency of A from a subset $(k_i, \ldots k_j)$ of key attributes, then the designer can decide to normalize the schema by splitting the original schema R into two sub-schemes $R_1=R\text{-}\{A\}$, $R_2=\{k_i, ..k_j\}\cup\{A\}\cup\{B_i \mid B_i \in R, (k_i,..k_j) \rightarrow_s B_i\}$. If K is the set of attributes forming the primary key of R, we say that there is a transitive dependency of A on K, if there exists a set of attributes J in R that is neither a candidate key nor a subset of a key, such that

$$K \xrightarrow{t1}_{S1} J, J \xrightarrow{t2}_{S2} A$$

We say that the schema R is in third normal form if no nonprime attribute A is transitively dependent on the primary key K. As an example, let us consider the following simple multimedia database schema :

Singer	Genre	Video

Each tuple in this simple database contains the name of a singer, his/her genre, and a set of his/her video clips. A designer might first decide to apply traditional first normal form to separate the video so that each fits in an elementary attribute. The new schema will be as follows:

Singer	Genre

Singer	Vnum	Video

where the video have been stored in a separate table, with a foreign key *singer* on the original table, since there is a 1 to N relationship between singers and their video. Notice that we needed to add a new attribute *Vnum* on the new table to form a key. The new attribute is a serial number to distinguish the different video of a singer.

At this point, there might be the need to apply an extended first normal form to separate each video into three components, namely a song *title*, a vicon for the video itself, and an earcon for the background song. Thus, the second table will be as follows,

Singer	Title	Song	Video

The extraction of the title attribute made the *Vnum* attribute useless, hence we eliminated it, and made the pair of attributes (*Singer, Title*) the new primary key. We can reasonably imagine a scenario in which a similarity technique S generates the following dependencies:

$$Singer\ , Title \xrightarrow{t}_{S} Song$$

$$Song \xrightarrow{t}_{S} Video$$

Thus, to remove the transitive dependency of the video on the key through the *song* attribute, we need to separate the *song* and *video* attributes to form a third table. However, the designer might decide to limit the splitting of tables due to efficiency issues.

5. Discussion

In this paper we have posed the basis for a theory of normalization for multimedia databases. Our goal is to derive proper design guidelines to be adopted within multimedia software engineering methodologies. The theory we have provided is parametric with respect to similarity match paradigms, and allows many degrees of normalization, depending upon the similarity and segmentation techniques used.

As new standards arise in the field of multimedia databases, our aim is to define specific normal forms to solve specific manipulation and presentation anomalies.

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