Chapter XVI
Data Model of FRDB with Different Data Types and PFSQL

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ABSTRACT
This chapter introduces a way to extend the relational model with mechanisms that can handle imprecise, uncertain, and inconsistent attribute values using fuzzy logic. It describes details on how the relational model is extended in order to include fuzzy capabilities. In addition, we describe a query language called PFSQL for this fuzzy database model. Besides basic fuzzy capabilities, this query language adds the possibility to specify priorities for fuzzy statements. This appears to be the first implementation that has such capabilities. Also we describe the relations on FRDB (fuzzy relational database) and PFCSP (priority fuzzy constraint satisfaction problems) and GPFCSP (generalized priority fuzzy constraint satisfaction problems), theoretical concepts vital for the implementation of PFSQL. The authors propose several points in which this research and implementation can be continued and extended, contributing to better understanding of fuzzy database concepts and techniques and giving numerous possibilities for further development in this area.

INTRODUCTION

Related Work
One of the disadvantages of the relational model is its disability to model uncertain and incomplete data. The idea to use fuzzy sets and fuzzy logic to extend existing database models to include these possibilities has been utilized since the 1980s. Although this area has been researched for a long time, concrete implementations are rare. Literature contains references to several models of fuzzy knowledge representation in relational databases. One of the early works, the Buckles-Petry model (Buckles & Petry, 1982), is the first model that introduces similarity relations in the relational model. This chapter gives a structure for representing inexact information in the form of a relational database. The structure differs from ordinary relational databases in two important
aspects: components of tuples need not be single values and a similarity relation is required for each domain set of the database.

Zvieli and Chen (1986) offered a first approach to incorporate fuzzy logic in the entity relationship (ER) model. Their model allows fuzzy attributes in entities and relationships. They define three levels of fuzziness in the ER model. At the first level, entity sets, relationships, and attribute sets may be fuzzy; that is, they have a membership degree to the model. The second level is related to the fuzzy occurrences of entities and relationships and the notion which instances belong to the entity or relationship with different membership degrees. Finally, the third level concerns the fuzzy values of attributes of special entities and relationships. The GEFRED (generalized model of fuzzy relational databases) model (Medina, Pons, & Vila, 1994) is a possibilistic model that refers to generalized fuzzy domains and admits the possibility distribution in domains. This is a fuzzy relational database model that has representation capabilities for a wide range of fuzzy information. In addition, it describes a flexible way to handle this information. Also, it contains the notion of unknown, undefined, and null values. This notion was defined earlier in Umano and Fukami (1994). The GEFRED model experienced subsequent expansions (Galindo, Medina, & Aranda, 1999; Galindo, Medina, Cubero, & Garcia, 2001).

Chen and Kerre (1998) and Kerre and Chen (2000) introduced the fuzzy extension of several major extended entity-relationship (EER) concepts. Fuzzy logic was applied to some of the basic EER concepts connected to the notion of subclass and superclass. Chaudhry, Moyne, and Rundensteiner (1994) proposed a method for designing fuzzy relational databases following the extension of the ER model of Zvieli and Chen. They also proposed a design methodology for fuzzy relational databases (FRDBs), which contains extensions for representing the imprecision of data in the ER data model and a set of steps for the derivation of a FRDB from this extended ER model.

Galindo, Urrutia, and Piattini (2006) describe a way to use the fuzzy EER model to model the database and represent modeled fuzzy knowledge using a relational database in detail. This work gives insight into some new semantic aspects and extends the EER model with fuzzy capabilities. This model is called the FuzzyEER model. Also, a way to translate the FuzzyEER model to the FIRST-2, a database schema that allows representation of fuzzy attributes in relational databases, is given. The FIRST-2 schema introduces a concept of fuzzy metaknowledge base (FMB). For each attribute type, it defines how to represent values and what information about them has to be stored in the FMB. In addition, in this work, authors introduce and describe specification and implementation of the fuzzy structured query language (FSQL), an SQL language with fuzzy capabilities in great detail. This language is an extension of the SQL language that allows users to write flexible conditions in queries, using all extensions defined by the FuzzyEER model. In this book, you can find a chapter by Urrutia, Tineo, and Gonzalez, comparing SQLf and FSQL languages. Another chapter of this book includes a review about flexible querying, and it has been written by Kacprzyk, Zadrożny, de Tré, and de Caluwe.

The concept of constraint satisfaction problem (CSP) has been known for years. The aim of CSP is to find a solution that satisfies all the constraints in optimal time (Dubois & Fortemps, 1999). If the satisfaction of the constraint is not a Boolean value; that is, if there can be many levels of constraint satisfaction, it is clear that there is room for inserting fuzzy values and fuzzy logic into CSP. We can model constraints as fuzzy sets over a particular domain. This leads to the fuzzy constraint satisfaction problem (FCS). Fargier and Lang (1993) interpret the degree of satisfaction of a constraint as the membership degree of its domain value on the fuzzy set that represents it. In order to obtain the global satisfaction degree, we need to aggregate the values of each constraint. For the aggregation operator, we use fuzzy logic operators: t-norms, t-conorms, and fuzzy negation.

Priority is generally viewed as the importance level of an object among others, and it is often used in real time systems. PFCSp is actually a