INTRODUCTION

In traditional database development, databases have been constructed by mapping conceptual data models to logical data models of the target database management systems. For example, an Entity Set in an Entity-Relationship schema is often implemented as a Table in the corresponding relational DBMS. By modeling objects at the conceptual level, one derives benefits such as reduced costs, and increased system flexibility, system integration, and customer satisfaction (Moody, 1998). However, current data models cannot adequately model the semantics of micro-objects such as the Birth_Date attribute. As a result, micro-objects are often inadequately and
inaccurately represented and implemented.

A data model supports a set of constructs for modeling (i.e. meta-schema objects). Objects at the schema level are developed based on these constructs. Objects are defined through their dimensions. Dimensions are objects modeled through other constructs. For example, the Person object (modeled using the Entity Set construct) has the dimensions SS#, Name, and Birth_Date. These dimensions can be modeled using the Attribute construct. Birth_Date has the Date dimension, which is modeled using the Data Type construct.

Macro-constructs such as Entity Sets, Relations, and Object Sets can model highly visible, multi-dimensional objects (macro-objects). Many dimensions of macro-objects do not impact their fundamental semantics. For example, SS# is not crucial to the definition of Person, but is often contained in it. Micro-constructs such as Attributes and Data Types are used to model peripheral, low-dimensional objects (micro-objects). However, changes in the micro-object dimensions radically alter their semantics. For example, the BOOLEAN data type’s semantics change dramatically when the domain is increased from two (True, False) to three values (True, False, Null) (Date, 1986).

Most data models adopt a top-down approach for data modeling. Thus, research on the development of macro-constructs is fairly mature. For example, the Entity Set, Object Set, and Relation are macro-constructs that model the same objects in different data models. However, little research has addressed the development of adequate micro-constructs for data modeling. Almost every data model adopts the Attribute and Data Type as the only available micro-constructs. As a result, the following fundamental modeling issues remain unresolved:

- **Micro-Object Modeling:** Currently, the semantics of micro-objects cannot be modeled effectively. For example, an adequate data type for Gender has not been proposed (Chua, Chiang, & Lim, 1999), as the functions of traditional data types (e.g. STRING concatenation, INTEGER addition, BOOLEAN xor, SET union) are not appropriate.

- **Atomicity of Micro-Objects:** In many data models, it is important to identify the smallest independently manipulable (i.e. atomic) objects to resolve data integrity and redundancy issues (e.g. 1NF). However, it is often difficult to decompose non-atomic micro-objects (Date, 1990), as the interaction among micro-object dimensions obfuscates their atomicity. For example, dates can be represented as a composite attribute \{DAY, MONTH, YEAR\}, or as the data type DATE. DATE is non-atomic, since YEAR can be independently manipulated. However, the composite attribute representation cannot adequately express that the domain of DAY varies depending on the MONTH (e.g. while ‘March’ has only 31 days, ‘April’ has 30).

- **Best Representation:** There should be only one representation that best captures an application domain for every data model to remove ambiguity in model development. For example, in the relational data model, a relation in fifth normal form (5NF) is superior to one that is not in 5NF, since it has less redundancy. However, criteria to evaluate micro-object representations have not been established. For example, the abstract data type TREE can be represented using LISTS (e.g. LISP TREES), GRAPHs, or as a value and a set of TREES (e.g. left and right TREE).
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