ABSTRACT

Research in temporal database management has viewed temporal dynamics from a structural perspective, posing extensions to the entity-relationship (E-R) model to represent the state history of time-dependent attributes and relationships. We argue that temporal dynamics are semantic rather than structural and that the existing constructs in the E-R model are sufficient to represent them. Practitioners have long used E-R models without temporal extensions to design systems with rich support for temporality by modeling both things and events as entities — a practice that is consistent with the original presentation of the E-R model. This approach supports methodologies that leverage narrative and human cognitive processing capabilities in the development and verification of data models. Furthermore it maintains modeling parsimony and facilitates the representation of causality — why a particular state exists.

Keywords: conceptual modeling, entity-relationship models, temporal databases, temporal data models, time semantics, event representation

INTRODUCTION

Numerous authors recognize the importance of representing the temporal, or time-dependent, aspects of business data. These include Dey, Barron, and Storey (1995), Ozsoyoglu and Snodgrass (1995), Etzion, Jajodia, and Sripada (1998), Gregersen and Jensen (1999), Snodgrass (2000), and March and Allen (2003). Managers frequently must know not only the most current data but also historical data. They require facts such as:

- a specific customer’s account balance on a specific date (e.g., on the date that customer was refused additional credit) and the transaction history that led to that balance;
- the length of time an employee has been at his or her current salary level and the history of salary reviews and salary changes; and
the last date on which a stock-out was experienced for a specific inventory item and the history of sales and purchases for that item.

Business systems increasingly require support for temporality. In a seminal book on temporal database research, theory, and implementation, Tansel et al. (1993) state the motivating assumption of temporal database research as follows: “Conventional databases were designed to capture the most recent data, that is, current data. As new values become available through updates, the existing data values are removed from the database. Such databases capture a snapshot of reality. Although conventional databases serve some applications well, they are insufficient for those in which past and/or future data are also required. What is needed is a database that fully supports the storage and querying of information that varies over time” (preface). Depending on the domain of interest, simply representing time-varying information may not be sufficient to meaningfully reconstruct its history. It may be necessary to represent the causes of those variations.

Numerous extensions to the relational model and relational databases have been posed seeking to better manage the temporal nature of business information. These include the notion of temporal functional dependency (Wang et al., 1997), techniques to facilitate temporal queries (Dean, 1989; Gadia and Yeung, 1988), extensions to the relational model and relational algebra (Gadia, 1988; McKenzie and Snodgrass, 1987), and indexing algorithms to support temporal queries (Kouramajian et al., 1994; Kumar et al., 1998). The complexity added by these extensions immediately suggests a need for temporal support at the conceptual level. Over a dozen temporal entity-relationship (E-R) models have been proposed (Gregersen and Jensen, 1999; Dey et al., 1995). These extend the E-R model by adding syntactic constructs and changing the fundamental definitions of existing constructs. They are based on the assumption that, “The E-R model can at best represent a ‘snapshot’ of the real world at any point in time; it does not contain specific constructs to model the dynamic aspects of the real world. As a result, the E-R model is an inadequate tool for temporal database design” (Dey et al., 1995, p. 306).

Temporality has arisen as a major problem in data representations not because of limitations to the E-R or relational models but because database design approaches have viewed data models as representing only a snapshot of the world at a point in time and recommend ignoring the temporal aspects of the application during initial data modeling (Snodgrass, 2000). Temporality is addressed in a post hoc, structural manner by identifying “temporal attributes” in a snapshot model and using a temporal DBMS to maintain state history for those attributes.

We contend that a data model should not be so viewed nor should the temporal aspects of an application be left to post hoc analysis. A data model represents the semantics necessary to support a specific application’s purpose. If that purpose includes temporality, then the temporal nature of the data must be represented in the data model. Time is an integral part of the semantics of most business systems and should not be treated as a simple structural addition. Its semantics should be modeled. Furthermore, merely representing the state history of temporal attributes is often semantically deficient. It may be necessary to identify and
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