Chapter 10

Extended Spatiotemporal UML: Motivations, Requirements, and Constructs

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This chapter presents a conceptual modeling language for spatiotemporal applications that offers built-in support for capturing spatially referenced, time-varying information. More specifically, the well-known object-oriented Unified Modeling Language (UML) is extended to capture the semantics of spatiotemporal data. The extension, Extended Spatiotemporal UML, maintains language clarity and simplicity by introducing a small base set of fundamental modeling constructs: spatial, temporal, and thematic. These constructs can then be combined and applied at attribute, attribute group, association, and/or class levels of the object-oriented model; where the attribute group is an additional construct introduced for attributes with the same spatiotemporal properties. A formal functional specification of the semantic modeling constructs and their symbolic combinations is given and an example is used to illustrate the simplicity and flexibility of this approach.

INTRODUCTION

Spatiotemporal applications have been the focus of considerable attention recently. The need for a temporal dimension in traditional spatial information systems and for high-level models useful for the conceptual design of the resulting spatiotemporal systems has become clear. Although having in common a need to manage spatial data and their

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changes over time, various spatiotemporal applications may manage different types of spatiotemporal data and may be based on very different models of space, time, and change. For example, the term spatiotemporal data is used to refer both to temporal changes in spatial extents, such as redrawing the boundaries of a voting precinct or land deed, and to changes in the value of thematic (i.e., alphanumeric) data across time or space, such as variation in soil acidity measurements depending on the measurement location and date. A spatiotemporal application may be concerned with either or both types of data. This, in turn, is likely to influence the underlying model of space employed, e.g., the two types of spatiotemporal data generally correspond to an object-versus-a field-based spatial model. For either type of spatiotemporal data, change may occur in discrete steps, e.g., changes in land deed boundaries, or in a continuous process, e.g., changes in the position of a moving object such as a car. Another type of spatiotemporal data is composite data whose components vary depending on time or location. An example is the minimum combination of equipment and wards required in a certain category of hospital (e.g., general, maternity, psychiatric), where the relevant regulations determining the applicable base standards vary by locality and time period.

A conceptual data modeling language for such applications should provide a clear, simple, and consistent notation to capture alternative semantics for time, space, and change processes. These include point- and interval-based time semantics; object- and field-based spatial models; and instantaneous, discrete, and continuous views of change processes. Multiple dimensions for time (e.g., valid, transaction) and space should also be supported.

Although there has been considerable work in conceptual data models for time and space separately, interest in providing an integrated spatiotemporal model is much more recent. Spatiotemporal data models are surveyed in Abraham (1999), including lower-level logical models (Claramunt, 1995; Langran, 1993; Pequet, 1995). Those models that deal with the integration of spatial, temporal, and thematic data at the conceptual level are the most relevant to this work and are reviewed here.

Several conceptual frameworks have been designed to integrate spatial, temporal, and thematic data based on Object-Oriented (OO) or Entity-Relationship (ER) data models that include a high-level query language capable of specifying spatiotemporal entity types. The data definition component of these query languages thus has some potential for use in modeling spatiotemporal applications.

Becker (1996) and Faria (1998) propose OO models based on extensions of ObjectStore and O2 respectively. Becker (1996) considers both object- and field-based spatial models, defining a hierarchy of elementary spatial classes with both geometric and parameterized thematic attributes. Temporal properties are incorporated by adding instant and interval timestamp keywords to the query
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