Chapter I
3SST Model:
A Three Step Spatio-Temporal Conceptual and Relational Data Model

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ABSTRACT

In order to represent spatio-temporal data, many conceptual models have been designed and a part of them have been implemented. This chapter describes an approach of the conceptual modeling of spatio-temporal data, called 3SST. Also, the spatio-temporal conceptual and relational data models obtained by following the proposed phases are presented. The 3SST data model is obtained by following three steps: the construction of an entity-relationship spatio-temporal model, the specification of the domain model and the design of a class diagram which includes the objects characteristic to a spatio-temporal application and other needed elements. The relational model of the 3SST conceptual model is the implementation of the conceptual 3SST data model on a relational database platform. Both models are characterized by generality in representing spatial, temporal and spatio-temporal data. The spatial objects can be represented as points or objects with shape and the evolution of the spatio-temporal objects can be implemented as discrete or continuous in time, on time instants or time intervals. More than that, different types of spatial, temporal, spatio-temporal and event-based queries can be performed on represented data. Therefore, the proposed 3SST relational model can be considered the core of a spatio-temporal data model.

1. INTRODUCTION

Spatio-temporal databases (STDB) deal with spatial objects that are changing over time and space. In other words, these objects are characterized by spatial and temporal attributes, yet these are not static objects. There are many domains where the spatio-temporal (ST) data is used: cadastral applications, military operations, weather systems, multimedia presentations, moving objects etc.

Spatial databases and temporal databases have been studied for many years (modeling, implementing, optimizing), but the surrounding reality showed us different applications which needed to combine the spatial and temporal domains. Thus, the two dimensions were both included into spatio-temporal databases. The first attempts consisted in adding one dimension to the other: including temporal data into a spatial database or adding spatial attributes to the temporal objects. Later, other models joined space and time into one unified spatio-temporal view (Worboys, 1994).

Following these different approaches in perceiving ST data, modeling techniques and database models, many conceptual models have been designed and concrete applications have been implemented. Some of the models represent space and evolving spatial objects organized in time-stamped layers (see the Snapshot Model – Langran & Chrisman, 1988). One layer contains the state of a geographic distribution at a moment of time, but there are no explicit temporal connections between layers. Another class of spatio-temporal data models is represented by the Event-Oriented Models which record information about the events that led to spatio-temporal changes (see the Event-Oriented Spatio-Temporal Data Model (ESTDM) - Peuquet & Duan, 1995). Thus, event-oriented queries are supported and the evolution of an object has to be traced through the stored events.

Other spatio-temporal data models have been designed using and / or adapting conceptual data modeling techniques in order to satisfy some spatio-temporal requirements. Such a model is the STER model (the Spatio-Temporal Entity-Relationship Model - Tryfona & Jensen, 1999; Tryfona & Jensen, 2000) which extends the standard Entity-Relationship Model to include spatial and temporal characteristics. The entities may have spatial attributes of type point, line or region, while entities, attributes and relationships can be time-stamped using valid time, transaction time or bi-temporal data. The object-oriented data modeling technique is used in another paper (Price, Tryfona, & Jensen, 2000), where the Unified Modeling Language (UML) is extended to include attributes and methods of spatial and temporal nature (Spatio-Temporal UML - STUML).

An original approach is the Three-Domain Model (Yuan, 1999) which separates semantic domain from spatial and temporal domains. The advantage of this model arises from the independence of the three domains at semantic and behavioral level. There are links from semantic and temporal objects to spatial objects and from spatial and temporal objects to semantic objects. Assuming that a spatial object is located in time, there are no direct links from semantic to spatial domain. The particular case of objects without temporal measures is marked with a null time value. The ST data is organized within four relations: three relations that correspond to the three domains and a relation that links the semantic objects, the time elements and the spatial entities.

A parametric ST model is the Parametric k-Spaghetti (Chomicki & Revesz, 1997). The evolving spatial data can be of type point, line segment or region. One geometry element is represented by one or more triangles (degenerate in the case of points and line segments). Therefore the ST information is stored within tuples which contain the object's id, the parametric coordinates of one triangle and a valid time interval as timestamp. Though the structure of the relation is relatively simple, the represented information can capture the continuous evolution of spatial objects in time.

Moving Object Data Models have been developed to deal explicitly with continuously moving objects. The Moving Objects Spatio-Temporal data model (MOST) (Sistla, Wolfson, Chamberlain, & Dao, 1997; Wolfson, Xu, Chamberlain, & Jiang, 1998) introduces the notion of dynamic attribute represented as functions of time in order to denote an attribute that changes continuously. Another approach consists in modeling the continuous evolution of objects using the so-called