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Chapter XX

Issues in Spatiotemporal Data Modeling

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Recent interest in spatiotemporal data modeling comes from Multimedia Information Retrieval and Geographic Information System communities. Early reviews of spatiotemporal research were biased towards geographic and cartographic applications and representational concerns. In this paper, we move beyond implementability considerations to highlight a range of fundamental research issues relevant to spatiotemporal data modeling such as conceptual space, time, and data models. An evaluation of recent research with respect to these issues and comparison of work from different research communities provides a framework for understanding the current state of spatiotemporal research and indicating priorities for future work.

INTRODUCTION

Recent interest in spatiotemporal data modeling comes from Multimedia Information Retrieval (MIR) and Geographic Information System (GIS) applications, which manage data with spatial and/or temporal properties. Although an extensive literature for spatial and for temporal databases is already available, current efforts seek to integrate the two in a consistent framework and understand the semantics of spatiotemporal data. Early reviews of spatiotemporal research were biased towards representational and implementation concerns of geographic and cartographic applications (Al-Taha, 1993; Langran, 1993). Later work in image and video databases focused on processing techniques and retrieval using the extracted low-level features such as color or using text annotations (Aslandogan, 1999). However, there has been increasing recognition of the need for conceptual data models to support retrieval and manipulation of spatiotemporal data at a higher semantic level.

Although both GIS and MIR are essentially examples of multimedia information systems, the two communities have remained fairly distinct and the authors are not aware of any comprehensive reviews of spatiotemporal data research that compare work from both research communities. These communities have overlapping concerns in the representation and modeling of both spatiotemporal data and the contents of individual and sequential images or video frames. In this chapter, we review recent efforts from both communities to develop spatiotemporal data models. Spatial, temporal, data modeling, and representation issues are discussed only insofar as they are relevant to understanding current research in spatiotemporal data models. The objectives of this chapter are to:

1. highlight fundamental research issues relevant to spatiotemporal data modeling, concentrating on higher-level models based on data semantics rather than representational models based on data storage or access;
2. compare GIS and MIR perspectives on spatiotemporal modeling;
3. review current research efforts in this area from both research communities, evaluating the work with respect to the research issues and differing application perspectives as described; and
4. assess the current state of spatiotemporal research in terms of recent trends and future priorities.

ISSUES IN SPATIOTEMPORAL DATA MODELING

The term *spatiotemporal data* is used to refer both to *temporal changes in spatial properties* and *variation of thematic (i.e. alphanumeric) attributes across time and space*. These two types of data have traditionally been referred to as temporal changes in *spatial objects* (e.g. changed land-deed boundaries or object position changes in a video), and *spatial attributes* (e.g. changed soil acidity depending on location and time) respectively. We use the terms *spatiotemporal* objects and *spatiotemporal* attributes respectively. This generally corresponds to an object- versus a field-based view of space, i.e. separate objects with spatial properties versus thematic attributes whose values vary continuously across a spatial field. A spatial object is most often represented using vectors to approximate boundaries and a spatial attribute by a grid of spatial locations associated with thematic attribute values. An application may be concerned with either or both data types: this is likely to influence the underlying model of space and representations employed. A further distinction can be made based on the view of time and change processes. Depending on the application domain, time may be viewed as continuous or discrete and data recorded at regular or irregular intervals. Change processes are related to the integration of space and time, i.e. temporal changes in data having spatial properties. In some cases, the spatiotemporal data to be managed represents discrete, instantaneous changes or *events*. Other phenomena such as moving objects or spatial attributes are better represented as a process of continuous change. A final consideration when comparing research proposals is the data model used to organize and manage the data. We consider alternative models for data; space; time; integrated space/time, change processes; and data manipulation in the following sections.