

Chapter XIX

Challenges and Critical Issues for Temporal GIS Research and Technologies

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ABSTRACT

Temporal Geographic Information Systems (GIS) technology has been a top research subject since late the 1980s. Langran's Time in Geographic Information Systems (Langran, 1992) sets the first milestone in research that addresses the integration of temporal information and functions into GIS frameworks. Since then, numerous monographs, books, edited collections, and conference proceedings have been devoted to related subjects. There is no shortage of publications in academic journals or trade magazines on new approaches to temporal data handling in GIS, or on conceptual and technical advances in spatiotemporal representation, reasoning, database management, and modeling. However, there is not yet a full-scale, comprehensive temporal GIS available. Most temporal GIS technologies developed so far are either still in the research phase (e.g., TEMPEST developed by Peuquet and colleagues at Pennsylvania State University in the United States) or with an emphasis on mapping (e.g., STEMgis developed by Discovery Software in the United Kingdom).

INTRODUCTION

Dynamics are central to the understanding of physical and human geographies. In a large part, temporal GIS development is motivated by the need to address the dynamic nature of the world. Most, if not all, temporal GIS technologies focus on visualization and animation techniques to communicate spatiotemporal information. Like maps for spatial data, visualization and animation provide an excellent means to inspect and identify changes in space and time. Nevertheless, recognizing spatiotemporal distribution and change is only one step towards an understanding of dynamics in geographic domains. The expectation of a temporal GIS goes beyond visual inspection. It demands a comprehensive suite of data management, analysis, and modeling functions to enable transformation of spatiotemporal data to information that summarizes environmental dynamics, social dynamics, and their interactions.

Extensive literature exists on the conceptual and technological challenges in developing a temporal GIS, such as books (Christakos et al. 2002; Peuquet, 2002; Wachowicz, 1999), collections (Egenhofer & Golledge, 1998; Frank et al. 2000), and articles (Dragicevic et al. 2001; López 2005; O'Sullivan, 2005; Peuquet, 2001; Shaw, Ladner & Abdelguerfi, 2002; Worboys & Hornsby, 2004; Yuan et al. 2004). Readers are advised to consult these and many other spatiotemporal publications for details. This chapter highlights the critical issues and major research challenges for conceptual and technological developments in temporal GIS.

CRITICAL ISSUES

What constitutes a temporal GIS needs to be addressed from three perspectives: (1) database representation and management; (2) analysis and modeling; and (3) geovisualization and commu-

nication. There were at least four commercial "temporal GIS" available in 2005: DataLink; STEMgis; TerraSeer, and Temporal Analyst for ArcGIS. In addition, there are many open-source software for spatiotemporal visualization and analysis, such as STAR, UrbanSim, SLEUTH and ArcHydro. ¹However, most of these systems were designed for certain application domains and only address the three temporal GIS aspects based on their identified applications. Building upon all of the recent conceptual and technological advances in temporal GIS, researchers are now well positioned to examine the big picture of temporal GIS development, address critical issues from all three perspectives, and envision the next generation of spatiotemporal information technologies.

Database Representation and Management

Issues in spatiotemporal data modeling are discussed in depth in the literature, see for example Langran (1992); Peuquet (2001); Peuquet & Duan (1995); Raper, 2000). There is an apparent parallel between the GIS and database research communities in the strategies of incorporating time into respective databases (Yuan, 1999). Both communities commonly adopt time-stamp approaches to attach temporal data to individual tables (Gadia & Vaishnav, 1985) or layers (Beller et al. 1991); to individual tuples (Snodgrass & Ahn, 1986) or spatial objects (Langran & Chrisman, 1988); or to individual values (Gadia & Yeung, 1988) or spatiotemporal atoms (Worboys, 1994). Figures 1 and 2 summarize the time-stamp approaches in both communities. Beyond the time-stamp approaches, researchers advocate for activity-event- or process-based approaches to integrate spatial and temporal data (Kwan, 2004; Peuquet & Duan, 1995; Raper & Livingstone, 1995; Shaw & Wang, 2000; Worboys, 2005; Yuan, 2001b). These are just a few samples of spatiotemporal data models proposed in the wealth of GIS lit-

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