Chapter XXIX
Spatio-Temporal Indexing Techniques[1]

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INTRODUCTION

Time and space are ubiquitous aspects of reality. Temporal and Spatial information appear together in many everyday activities, and many information systems of modern life should be able to handle such information. For example, information systems for traffic control, fleet management, environmental management, military applications, local and public administration, and academic institutions need to manage information with spatial characteristics that changes over time, or in other words, Spatio-temporal Information. The need for Spatio-temporal applications has been strengthened by recent developments in mobile telephony technology, mobile computing, positioning technology, and the evolution of the World Wide Web.

Research and technology that aim at the development of Database Management Systems (DBMSs) that can handle Spatial, Temporal, and Spatio-temporal information have been developed over the last few decades. The embedding of spatio-temporal capabilities in DBMSs and GISs is a hot research area that will continue to attract researchers and the informatics industry in the years to come.

In spatio-temporal applications, many sorts of spatio-temporal information appear. For example, an area covered by an evolving storm, the changing population of the suburbs of a city, and the changing coastlines caused by ebb and tide. However, one sort of spatio-temporal information is quite common (and in some respects easier to study) and has attracted the most research efforts:

moving objects or points. For example, a moving vehicle, an aircraft, or a wandering animal.

One key issue for the development of an efficient Spatio-temporal DBMS (STDBMS) is the use of spatio-temporal access methods at the physical level of the DBMS. The efficient storage, retrieval, and querying of spatio-temporal information demands the use of specialized indexing techniques that minimize the cost during management of such information.

In this article, we report on the research efforts that have addressed the indexing of moving points and other spatio-temporal information. Moreover, we discuss the possible research trends within this area of rising importance.

BACKGROUND

The term Spatial Data refers to multidimensional data, like points, line segments, regions, polygons, volumes, or other kinds of geometric entities, while the term Temporal Data refers to data varying in the course of time. Since in database applications the amount of data that should be maintained is too large for main memory, external memory (hard disk) is considered as a storage means. Specialized access methods are used to index disk pages and in most cases have the form of a tree. Numerous indexing techniques have been proposed for the maintenance of Spatial and Temporal Data. Two good sources of related information are the survey by Guenther and Gaede (1998) and the survey by Saltzberg and Tsotras (1999) for spatial and temporal access methods, respectively.

During last years, several researchers have focused on spatio-temporal data (spatial data that vary in the course of time) and the related indexing methods for answering spatio-temporal queries. A spatio-temporal query is a query that retrieves data according to a set of spatial and temporal relationships. For example, "find the vehicles that will be in a distance of less than 5km from a specified point within the next 5 minutes". A number of recent short reviews that summarize such indexing techniques (especially, indexing of moving points) have already appeared in the literature. There are several ways for categorizing (several viewpoints, or classifications of) spatio-temporal access methods. In the rest of this section, we report on the approach followed by each of these reviews and on the material that the interested reader would find there.

In the book "Spatiotemporal Databases: the ChoroChronos Approach", that was authored within the ChoroChronos project and edited by Sellis et al. (2003), chapter 6 is entitled "Access Methods and Query Processing Techniques" and reviews spatio-temporal access methods that have appeared up to 2001. The main classification followed in this chapter is between methods belonging in the R-tree family and methods belonging in the Quadtree family. The principle guiding the hierarchical decomposition of data distinguishes between these two indexing approaches. The two fundamental principles, or hierarchies are:

- the data space hierarchy: a region containing data is split (when, for example, a maximum capacity is exceeded) to sub-regions in a way that depends on these data (for example, each of two sub-regions contains half of the data), and
- the embedding space hierarchy: a region containing data is split (when a certain criterion holds) to sub-regions in a predefined way (for example, a square region is always split in four quadrant sub-regions)

R-trees are data-driven, while Quadtrees are space-driven access methods.

The June 2002 (Vol.25 No.2) issue of the IEEE Data Engineering Bulletin (http://sites.computer.org/debull/A02june/issue1.htm) is devoted to "Indexing of Moving Objects" and is an excellent source of quite updated information. Pfoser (2002) reviews techniques that index the trajectories of