Chapter XXXIV
Spatial Network Databases[1]

Michael Vassilakopoulos
University of Central Greece, Greece

INTRODUCTION

A Spatial Database is a database that offers spatial data types, a query language with spatial predicates, spatial indexing techniques, and efficient processing of spatial queries. All these fields have attracted the focus of researchers over the past 25 years. The main reason for studying spatial databases has been applications that emerged during this period, such as Geographical Information Systems, Computer-Aided Design, Very Large Scale Integration design, Multimedia Information Systems, and so forth.

In parallel, the field of temporal databases, databases that deal with the management of time-varying data, attracted the research community since numerous database applications (i.e., Banking, Personnel Management, Transportation Scheduling) involve the notion of time.

Since time and space are ubiquitous and in many cases related aspects of reality, the area of spatio-temporal databases, databases that simultaneously deal with the time and space aspects of data, also emerged. Technological advances that became accessible to the average user, such as accurate positioning systems (e.g., GPS), mobile computing, personal digital assistants with communication facilities, mobile and smart phones, and ubiquitous Internet terminals, made the development of applications about moving objects (an important kind of spatio-temporal data) possible. Such applications include vehicle navigation; tracking; and monitoring the positions of air, sea, or land-based equipment such as airplanes, fishing boats, and vehicles. In several of these applications, the objects move on predefined routes such as a transportation system, called a Spatial Network.

A Spatial Network is a collection of interconnected elements that have the shape of curves, or polylines, appearing in geographic applications (e.g., a railway network, an electricity network, a road network). A Spatial Network Database is a Spatial Database where the data modeled, stored, and queried are Spatial Network data. Queries mainly appearing in navigation

applications (e.g., find the route to the gas station that is closest to a traveling car) are the key motivation for the increased attention of the research community to Spatial Networks and Spatial Network Databases and Applications during last years. This chapter reviews the key aspects of Spatial Network Databases.

BACKGROUND

A Spatial Network can be considered a special kind of graph. A graph is a set of nodes and a set of edges connecting such nodes. Within this context, a Spatial Network is a graph in which the edges between nodes are constrained by the location of the nodes in space. Depending on the Spatial Network application, the graph can be directed (e.g., edges modeling one-way roads or gas distribution pipes) or not (e.g., edges modeling two-way roads or pedestrian streets), weighted (e.g., edges having a weight, such as speed limit or the number of lanes of a road), planar (e.g., a graph that can be drawn so edges do not intersect in the plane, such as a river network where river intersections correspond to graph nodes), or nonplanar (e.g., an electricity network where cables may intersect without an electrical junction between them). For example, in Figure 1, a part of a road network is depicted. The arrows indicate one-way roads. The filled circles indicate points of interest (e.g., gas stations A, B, and C), while the nonfilled circle represents the position of a motorist identified by q. The double-arrow symbol represents the permitted changes of direction at the related crossroad.

This graph-theoretic approach leads to a conceptual modeling of Spatial Networks that is independent of specific implementations and data management technologies (e.g., relational or object-oriented database management systems). By considering the representation of a Spatial Network graph through a specific data management technique, such as a set of interrelated tables or a collection of interreferenced objects, we reach a logical model, while the physical model of a Spatial Network describes the storage and indexing techniques used for the representation of the network.

The representation of a node of a Spatial Network may be enhanced by extra information (e.g., constraints or characteristics), such as permitted turns and changes of direction (e.g., the double-arrow symbol in Figure 1 that denotes the permitted changes of direction at the related crossroads); for example, in a navigation application. Similarly, an edge may be enhanced by extra information, such as (within a similar context) length, direction of movement (e.g., the roads with arrows in Figure 1), maximum allowed speed, and flow (traveling vehicle) capacity. Apart from representing the network itself, extra entities of several types may be modeled and represented in relation to the network (to its edges, in most cases). For example, static entities (points of interest) such as gas stations (e.g., the filled circles in Figure 1), stops of a train route, or tourist attractions; or moving/changing entities such as moving cars (represented by their current position) (e.g., the nonfilled circle in Figure 1) or their trajectory.

A Spatial Network Database, like any database, is useful when it enables answering of queries. The most interesting queries are those that refer not only to spatial characteristics of the network or the extra entities but also to the connectivity expressed

Figure 1. An example of a road network