Chapter XXXV
Supporting Location-Based Services in Spatial Network Databases

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INTRODUCTION

Location-based services (LBSs) utilize consumer electronics, mobile communications, positioning technology, and traditional map information to provide mobile users with new kinds of online services. Examples include location-sensitive information services that identify points of interest that are in some sense nearest and of interest to their users and that offer travel directions to their users. Data management is a core aspect of the provisioning of LBSs. The diversity and complexity of LBSs demand novel and advanced data management techniques.

The scenario of network-constrained movement is of particular interest to LBSs as a large amount of users of LBSs are car drivers and mobile users moving in vehicles. We term the transportation networks where LBS users are moving as spatial networks. The databases that manage the spatial network data as well as other relevant data are termed spatial network databases (SNDBs). Data management in SNDBs poses novel challenges to the database research community. Specifically, most existing discussions on spatial databases assume that objects can move arbitrarily in Euclidean space. The fundamental difference between network-constrained space and the Euclidean space is that the distance of two objects cannot be computed by their coordinates but by the shortest path on the network (Jensen, Kolář, Pedersen, & Timko, 2003). This makes it difficult to extend the existing data models, indexing structures, and query processing techniques from spatial databases to SNDBs.

This article summarizes existing efforts from the database community to support LBSs in spatial networks. The focus of discussion is on the data models, data structures, and query processing techniques in SNDBs. An example application framework is presented to illustrate the relationship of these topics. Challenges and future trends are also addressed.

BACKGROUND

Due to the natural similarity between spatial networks and graphs, the study of SNDBs can be traced back to the study of graph models in databases (Gyssens, Paredaens, & Gucht, 1990). The graph models discussed in these works cannot be directly used for LBSs and many real-world aspects of networks, such as U-turns (U-turn means a complete reversal of travel direction) and one-way roads, are not considered. There are also past studies on shortest-path computation in large urban transportation networks (Shekhar, Kohli, & Coyle, 1993). Assuming that network data are stored in disk pages, these papers are focused on techniques that optimize the amount of disk accesses in the shortest-path search.

In the study of LBSs, spatial networks have several distinct differences from graphs. Specifically, the study of graph concentrates on the links between graph nodes, while in spatial networks, positions of nodes are of equal importance to links. Second, as an important element in LBSs, data on points of interest are represented in spatial networks using linear referencing. Next, data modeling of spatial networks often needs to consider the pragmatic constraints in real-world road networks, such as U-turns and one-way roads, which are not very common in the study of graphs. The study of moving-object databases is also relevant to our discussion as users of LBSs are often modeled as moving objects in networks.

We proceed to discuss relevant works in three categories, that is, data modeling of spatial networks and network-constrained moving objects, data structures of spatial networks, and spatial and spatiotemporal query processing in spatial networks.

Data Modeling of Spatial Networks and Network-Constrained Moving Objects

Vazirgiannis and Wolfson (2001) first considered modeling and querying for moving objects in road networks. In this paper, the network model is basically an undirected graph, with nodes representing road junctions and edges representing roads between these junctions. The paper also considers trajectories as basic elements to represent moving objects in databases.

The paper by Hage, Jensen, Pedersen, Speičys, and Timko (2003) presents an industrial study on the data modeling of spatial networks for supporting LBSs. The paper presents four interrelated representations of the road networks. The kilometer-post representation provides a convenient and precise way of relating a location in the physical world with a location stored in a database. The link-node representation is based on the mathematical graph model. The geographical representation contains the geographical coordinates of the roads. The segment representation models the network as a collection of polyline segments that intersect at road intersections. Other representations of the network can be mapped to and from the segment representation, which ensures that all these representations are interrelated and locations in one representation can be transformed to another in very convenient ways.

Next, the paper by Speičys, Jensen, and Kligys (2003) describes a formalized model that incorporates the ideas described in Hage et al. (2003). This paper proposes the 2-D representation and the graph representation, both of which are similar to a graph while the 2-D representation is focused on capturing the detail of road network properties and the graph representation is used to support efficient computations. This paper also proposes the connection matrix (also the co-edge relationship in the graph representation) to reflect the real-world situations on road junctions where turning from one road to another is restricted. On top of the network, there are data points and query points, which serve as basic elements of LBSs.

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