Chapter 1.29
Indexing Mobile Objects:
An Overview of Contemporary Solutions

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ABSTRACT

Mobile computing emerged as a new application area due to recent advances in communication and positioning technology. As David Lomet (2002) notices, a substantial part of the conducted work refers to keeping track of the position of moving objects (automobiles, people, etc.) at any point in time. This information is very critical for decision making, and, since objects' locations may change with relatively high frequency, this calls for providing fast access to object location information, thus rendering the indexing of moving objects a very interesting as well as crucial part of the area. In this chapter we present an overview on advances made in databases during the last few years in the area of mobile object indexing, and discuss issues that remain open or, probably, are interesting for related applications.

INTRODUCTION

During the last years, a significant increase in the volume and the diversity of the data which are stored in database management systems has happened. Among them, spatio-temporal data is one of the most fast developing categories. This phenomenon can be easily explained since there is a flurry of application development concerning continuously evolving spatial objects in several areas. To name a few, mobile communication systems, military equipment in (digital) battlefields, air traffic, taxis, truck and boat fleets, and natural phenomena (e.g., hurricanes) all generate data whose spatial components are constantly changing.

In the standard database context, data remains unchanged unless an update is explicitly stated; for example, the phone number in an employee's record remains the same unless it is explicitly updated. If this assumption was employed to continuously moving objects, then highly frequent updates should be performed. Otherwise, the database would be inaccurate and thus query outputs would be obsolete and unreliable.

In order to capture continuous movement and, additionally, spare unnecessary updates, it is widely accepted to store moving object positions as time-dependent functions, which results in updates triggered only by function parameter changes. For example, when objects follow linear movement, the parameters could be the position and the velocity vector of each object at the particular time the function (and therefore the object) is registered to the database. Usually, the moving objects are considered responsible for updating the database about alterations of their movement.

The following paragraphs present a comprehensive review on the various indexing proposals for accommodating moving objects in database systems, so that complex queries about their location in the past, the present, or the future can be served. The more elementary problem of location management, which asks for storing and querying the location of mobile objects based on the underlying network architecture, is surveyed in Pitoura and Samaras (2001). The works of Agarwal, Guibas, et al. (2002), Wolfson (2002), and Lomet (2002) discuss various aspects of modeling and manipulating motion, while the "lower level" subject of organizing (indexing) data for efficient broadcasting in wireless mobile computing is treated in Chen, Wu, and Yu (2003) and Shivakumar and Venkatasubramanian (1996); the interested reader could consult all these references for a wider introduction.

DEFINITIONS AND BACKGROUND

The indexes developed to accommodate moving objects can be classified into two broad categories:

(a) those optimizing queries about past states of movement, the so-called *historical queries*, and
(b) those designed to answer queries about future positions of the moving objects, which are termed *future* or *predictive queries*.

This categorization is not strict since there are structures enabling queries about both past and future positions. One can also group the indexes based upon whether the object trajectories are indexed or the objects themselves. However, in this study, we have chosen the classification according to whether the proposals are *practical* ones (that is, they have been actually implemented and experimentally investigated in realistic environments) or *theoretical* ones, which aim mainly at indicating the inherent complexity of the problem since their adoption to real applications is problematic because of the hidden constants or the involvement they exhibit, and, thus, their use is avoided.

Moving Object Representation

Since the size or the shape of a moving object is unimportant compared to the significance of its position as time evolves, its representation is directly related only to time and location. On the other hand, the way this spatiotemporal information is registered depends on the kind of the processing needed, namely, the postprocessing of recorded data and the exploration of current and future data location.

In the first case, object trajectories must be maintained. This means that one has the complete knowledge of location at any past time instance. Obviously, this is impossible, not only for storage limitations but also due to the nature of the underlying application; for instance, communication frameworks, like Global Positioning System (GPS) equipment, generate discrete location data. Therefore, trajectories must be calculated by