Chapter 91
On Predicting the Future Locations of Moving Objects: The State of the Art

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ABSTRACT

The pervasiveness of mobile devices and location-based services produces as side effects an increasing volume of mobility data, which in turn creates the opportunity for a novel generation of analysis methods of movement behaviors. In this chapter, the authors focus on the problem of predicting future locations aimed at predicting with a certain accuracy the next location of a moving object. In particular, they provide a classification of the proposals in the literature addressing that problem. Then the authors preset the data mining method WhereNext and finally discuss possible improvements of that method.

INTRODUCTION

In the last years, we have witnessed a considerable increase of the number of mobile devices used by the people and an extensive use of wireless communication, such as Bluetooth, Wi-Fi and GPRS. The mobile devices often, are equipped with positioning sensors that utilize Global Positioning System (GPS) to accurately provide the location of a device. Therefore, nowadays, the movement of people or vehicles within a given area can be observed from the digital traces left behind by the personal or vehicular mobile devices, and collected by the wireless network infrastructures. For instance, mobile phones leave positioning logs, which specify their localization at each moment they are connected to the GSM network; analogously, GPS-equipped portable devices can record their latitude-longitude position at each moment they are exposed to a GPS satellite, and transmit their trajectories to a collecting server. The pervasiveness of ubiquitous technologies guarantees that there will be an increasing availability of large amount of data pertaining to individual trajectories, with increasing localization precision.

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Knowledge about the positions of mobile objects has led to location-based services and applications, which need to know the approximate position of a mobile user in order to operate. Examples of such services are navigational services, traffic management and location-based advertising. In a typical scenario, a moving object periodically informs the positioning framework of its current location. Due to the unreliable nature of mobile devices and the limitations of the positioning systems, the location of a mobile object is often unknown for a long period of time. In such cases, a method to predict the possible next location of a moving object is required in order to anticipate or pre-fetch possible services in the next location. A hot topic in mobility management research field is *location prediction*. Location prediction can be defined as the prediction of the next locations where the mobile user is traveling between the cells of a personal communications services (PCS) network or a GSM network. The predicted movement can then be used to increase the efficiency of PCSs. By using the predicted movement, the system can effectively allocate resources to the most probable-to-move cells instead of blindly allocating excessive resources in the cell-neighborhood of a mobile user. Effective allocation of resources to mobile users would improve resource utilization and reduce the latency in accessing the resources.

Problem Statement

The Location Prediction task is composed of two main steps: a) learning a prediction model by observing historical movement data; and b) applying the prediction model for forecasting the next location visited by a specific user. More formally we can define the location prediction problem as follows:

Definition 1 (Location Prediction Problem): *Given a set of mobility data describing the user movements, first we want to learn a model called predictor P. Then, for any new trajectory t of a moving object o we want to apply the predictor P for forecasting the next location that the moving object o probably will visit.*

Several proposals in the literature have addressed this interesting problem. The strong interest is due to the fact that this task enables novel applications in a wide range of scenarios.

APPLICATIONS

The ability to predict future locations, which will be visited by people, enables a rich set of novel pervasive applications and systems. In general the knowledge about the mobile objects positions fosters location-based services and applications, which need to know the approximate position of a mobile user in order to provide their functionality.

In the following we discuss examples of applications where the location prediction could help to improve a service:

- **Location-Based Advertising**: Embedding a location prediction system in a service such as Groupon, Foursquare and Facebook Places may provide location-aware sponsored advertisements together with search results that are relevant to the predicted user movement patterns. As an example, it is possible to offer discounts at shops or restaurants near to user or his followed path.

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