The previous chapter focused on the analysis of the spatial features of static objects such as stores, cities, or states, where by static we mean that the spatial features of these objects do not change (or change exceptionally) across time. However, there is a wide range of applications that require the analysis of the so-called moving objects, that is, objects that continuously change their position in space and time. This is called mobility data analysis.

The interest in mobility data analysis has expanded dramatically with the availability of embedded positioning devices like GPS. With these devices, traffic data, for example, can be captured as a collection of sequences of positioning signals transmitted by the cars’ GPS along their itineraries. Since such sequences can be very long, they are often processed by dividing them in segments. For instance, the movement of a car can be segmented with respect to the duration of the time intervals in which it stops at a certain location. These segments of movement are called trajectories, and they are the unit of interest in the analysis of movement data. Trajectory analysis can be applied, for example, in traffic management, which requires to monitor and analyze traffic flows to capture their characteristics. Other applications aim at tracking the position of the users of social networks recorded by the electronic devices they carry, like smartphones or tablets, in order to analyze their behavior. As we have seen throughout this book, data warehouses and OLAP techniques have been successfully used for transforming detailed data into valuable knowledge for decision-making purposes. Extending data warehouses to cope with trajectory data leads to trajectory data warehouses, which we study in this chapter.

We start this chapter in Sect. 12.1 motivating mobility data analysis. Then, in Sect. 12.2, we define temporal types, which provide a way to represent at a conceptual level values that evolve in time, while in Sect. 12.3 we give a possible implementation for these types in PostGIS. In Sect. 12.4, we present the Northwind trajectory data warehouse. Finally, Sect. 12.5 is devoted to querying trajectory data warehouses.
12.1 Mobility Data Analysis

Nowadays, with the massification of positioning devices such as GPS, we are able to collect huge amounts of mobility data, which may be extremely valuable in many application areas. A typical application scenario is the analysis of the activities carried out by tourists in a city. During their stay, tourists visit museums, parks, and several different attractions. They also consume many services like accommodation, restaurants, shops, and so on. From the point of view of an analyst, these tourist places and services are denoted places of interest. A tourist trajectory consists in moving from one place of interest to another, stopping for some time at some of them. Data about these trajectories can be collected and analyzed, for example, to optimize the offer of services or to plan tourist itineraries within the city. As another example, large industrial cities with high car ownership rates are suffering a decrease in their air quality. Normally, stations are located at different points in these cities in order to measure air quality at regular time intervals. It is not hard to guess that the techniques that we have studied in this book can be very useful for understanding and analyzing the evolution of the quality of the air and the effects of corrective measures that the governments may take to keep pollution below certain limits. For example, we can analyze the trajectories followed by cars, trucks, and buses and correlate them with the air quality measures. Or we can study the population being exposed to heavy pollution loads and when this occurs.

In Chap. 11, we have studied how the spatial features of objects can be represented in databases and data warehouses. Although these spatial features can change in time, these changes are typically considered as discrete. For example, a parcel can be merged with another one at a certain instant. Similarly, the borders of a state or a country can change in time. In this chapter, we are interested in objects whose spatial features change continuously in time. These are called moving objects. While we will deal with moving points in this chapter, many applications must also deal with moving regions, for example, to monitor the trajectory of polluting clouds, or stains in sea bodies, as in our previous example. Trajectories can be represented in a continuous or a discrete way. A continuous trajectory is composed of the movement track of an object, occurring within a certain interval, enriched with interpolation functions that allow us to compute, with a reasonable degree of confidence, the spatiotemporal position of the moving object for any instant in this interval. On the other hand, a discrete trajectory is composed of the finite sequence of spatiotemporal positions in a certain interval. The main difference between a discrete and a continuous trajectory is that in the former there is no plausible interpolation function between two points. As a typical example, consider the case of a web site