Chapter 38
Modern Navigation Systems and Related Spatial Query

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ABSTRACT

With the availability and accuracy of satellite-based positioning systems and the growing computational power of mobile devices, recent research and commercial products of navigation systems are focusing on incorporating real-time information for supporting various applications. In addition, for routing purposes, navigation systems implement many algorithms related to path finding (e.g., shortest path search algorithms). This chapter presents the foundation and state-of-the-art development of navigation systems and reviews several spatial query related algorithms.

INTRODUCTION

Navigation systems have been of growing interest in both industry and academia in recent years. The foundation of navigation systems is based on the concept of utilizing radio time signals sent from some wide-range transmitters to enable mobile receivers to determine their exact geographic location. Based on this precise location, mobile receivers are able to perform location-based services (Shekhar, et al 2004). With the availability and accuracy of satellite-based positioning systems and the growing computational power of mobile devices, recent research, and commercial products of navigation systems are focusing on incorporating real-time information for supporting various applications. In addition, for routing purposes navigation systems implement many algorithms related to path finding (e.g., shortest path search algorithms). An increasing number of useful applications are implemented based on these fundamental algorithms.

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MODERN NAVIGATION SYSTEMS

A navigation system is an integration of position and orientation devices, computation devices, communication hardware and software for guiding the movement of objects (e.g., people, vehicles, etc.) from one location to another. In general, the infrastructure of navigation systems can be classified into two subsystems: positioning signal transmission systems and positioning signal receivers. The positioning signal transmission system allows the signal receiver to determine its location (longitude, latitude, and altitude) using timing signals. Positioning signal receivers range from hand-held devices, cellular phones, to car-based devices. These devices typically include some storage of map data and the computing capabilities of spatial operations, such as calculating directions. Additionally, in some novel geoinformatics applications, the receiver also relies on some server components for various services, such as real-time traffic information. In such a scenario, a server infrastructure is introduced which includes a Web server, a spatial database server, and an application server to provide these services. The signal receiver communicates with the server via wired or wireless networking infrastructures.

Positioning Signal Transmission Systems

Positioning signal transmitters, such as satellites and base stations, broadcast precise timing signals by radio to receivers, allowing them to determine exact geographic locations and then dynamically display and update their current position on digital maps. As of 2006, the Global Positioning System (GPS) is the only fully functional satellite-based positioning signal transmission system.

Global Positioning System

The invention of GPS has had a huge influence on modern navigation systems. GPS was developed by the U.S. Department of Defense in the mid-1980s. Since it became fully functional in 1994, GPS has acted as the backbone of modern navigation systems around the world.

The GPS consists of a constellation of 24 satellites in circular orbits at an altitude of 20,200 kilometers (Leick, 1995). Each satellite circles the Earth twice a day. Furthermore, there are six orbital planes with four satellites in each plane. The orbits were designed so that at least four satellites are always within line-of-sight from most places on the earth (Langley, 1991). The trajectory of the satellites is measured by five monitoring stations around the world (Ascension Island, Colorado Springs, Diego Garcia, Hawaii, and Kwajalein). The master control station, at Schriever Air Force Base, processes the monitoring information and updates the onboard atomic clocks and the ephemeris of satellites through monitoring stations (El-Rabbany, 2002).

Each GPS satellite repeatedly broadcasts radio signals traveling by line-of-sight, meaning that they will pass through air but will not penetrate most solid objects. GPS signals contain three pieces of information (Hofmann-Wellenhof et al, 1994): a pseudo random sequence, ephemeris data, and almanac data. The pseudo random sequence identifies which satellite is transmitting the signal. Ephemeris data allows the GPS receiver to determine the location of GPS satellites at any time throughout the day. Almanac data consists of information about the satellite status and current time from the onboard atomic clock of the satellite.

The GPS receiver calculates its location based on GPS signals using the principle of trilateration (Kennedy, 2002). First, the GPS receiver calculates its distance to a GPS satellite based on the timing signal transmission delay from the satellite to the receiver multiplied by the speed of radio signals. After measuring its distance to at least four satellites, the GPS receiver calculates its current position at the intersection of four abstract spheres, one around each satellite, with a radius of the distance from the satellite to the GPS receiver.

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