Positioning Methods and Technologies in Mobile and Pervasive Computing

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INTRODUCTION

The proliferation of wireless communication and mobile devices with sensing capabilities has given the rise of mobile and pervasive systems and services that offer novel opportunities for users behaving and acting in the environment. The range of services, often referred as location-based services (LBS) and context-aware services, have emerged in many different domains, such as personal navigation, mobile tourist guides, vehicle tracking, traffic monitoring, pervasive healthcare, emergency management, environment protection, analysis of animal behavior, etc. At the heart of these services lies the ability to sense and determine in real-time the location of mobile users.

With advances in sensor technologies and wireless communications, various positioning methods and systems have been developed over the past years. This article briefly reviews the state-of-the-art in the development of methods, technologies and systems for positioning and location data collection. These methods are classified and described according to their main characteristics. Examples of LBS applications that utilize appropriate positioning methods are given. Prominent research directions are categorized and discussed.

BACKGROUND

The core of any positioning method relies in the real-time measurement of one to several parameters, such as angles, distances, or distance differences (Hightower & Borriello, 2001). Measurement parameters reflect the location of a target object relative to a single point or several fixed points in the environment with known locations. Such parameters are measured using the physical characteristics of electromagnetic radio and infrared signals, as well as ultrasound signals, such as their travel time, velocity or attenuation. After the determination of the required parameters, the target object's location can be calculated using measurement results and the known locations of the fixed points.

There are four principal techniques and methods for location calculation and estimation:

- The proximity technique (Figure 1a) derives the location of a target object with respect to its vicinity to the location of known object(s). A target object receives the signal from a given node, so the location of the node or the cell identification defines the location of a target.

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- The triangulation technique uses the triangle geometry to compute locations of a target object. It is applied via lateration (actually trilateration) (Figure 1b), that uses distance measurements to points with known locations, or via angulation (sometimes also referred as triangulation) (Figure 1c), which measures angles relative to points with known arrangement. Since electromagnetic/ultrasound signals move with known and nearly constant speed, determination of the time difference between sending and receiving a signal enable computation of the spatial distance between a transmitter and a receiver. Known distances from three or more transmitters provide accurate positioning of the target object. For the angulation technique, antennas with direction capabilities are used. Given two or more directions from fixed locations to the same object, the location of the target object can be computed.
- Scene analysis techniques involve examination and matching a video/image or electromagnetic characteristics viewed/sensed from a target object. Analysis of electromagnetic "scene" sensed by a target object defined by electromagnetic signals and their strengths from different transmitters, provide the determination of location using a pattern matching, radio map technique. Using video cameras, a positioning system can detect significant patterns in a video data stream to determine the user's location. If users wear badges with certain labels, they can be detected in video images. At the other extreme are techniques involving the matching of perspective video images of the environment to 3D models stored in an image/video database.
- Dead reckoning techniques provide estimation of the location of a target object based on the last known location, assuming that the direction of motion and either the velocity of the target object or the traveled distance are known.

POSITIONING TECHNOLOGIES, SYSTEMS AND APPLICATIONS

Positioning technologies and systems based on one or more positioning techniques and methods possess different characteristics that determine their suitability for specific LBS applications.

Characteristics and Classification of Positioning Technologies

Positioning systems can be based on either an existing communication network, or a dedicated network/infrastructure that is only used to receive/transmit positioning signals. Mobile devices can be active when transmitting a signal themselves, or passive when just receiving a signal. The location can be determined in the mobile device itself, in the wireless network, or within dedicated positioning infrastructure.

Positioning systems differ in accuracy, precision, scope, the type of determined location: geometric or symbolic, and the cost. An estimated location is considered accurate if it corresponds, as much as possible, to the true location of a target object. Precision refers to the repeatability of the measurement and indicates how sharply a location can be defined for the sequence of

Figure 1. Location sensing techniques: a) Proximity; b) Trilateration; c) Angulation