Indoor localization method comparison: Fingerprinting and Trilateration algorithm

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Abstract

Enhanced Positioning Systems (EPS) are able to supplement Global Positioning Systems (GPS) in indoor environments where GPS cannot work because of disrupted or weak signals. Most EPS are Wifi-based because Wifi is a common technology available in many indoor environments and is deployed in cost effective manner. Fingerprinting and Trilateration are the two general methods used for calculating position with Wifi-based EPS. This paper will briefly introduce these two methods, summarize their common ground and differences, and compare the strengths and weaknesses of each.

Background and Relevance

As GPS becomes a routine tool for navigation and wayfinding more and more mobile handled devices (smartphones and PDAs) are integrating GPS. However, an important and well-known limitation of GPS is that it cannot work inside buildings because of the weak signal's inability to penetrate building material. EPS is an important supplement for GPS in indoor environments where GPS cannot work. Most EPS are Wifi-based because Wifi is a common and accessible technology that provides the basic information necessary for indoor positioning without requiring additional hardware. In the case of Wifi-based indoor localization, the fingerprinting method based on Wifi singnal strength observations is often employed (Mok & Retscher, 2007). An alternate method is the trilateration algorithm which is also implemented in GPS; trilateration uses distance to surrounding Access Points which, in the case of Wifi routers, is derived from signal strength values.

Methods Comparison

Fingerprinting can be generally divided into two phases: an offline phase and an online phase. The offline phase involves building the signal strength database and creating the signal strength map. After creating an accurate database of Access Point (AP) locations, reference points are chosen. Evenly spreading these reference points in the experimental area improves the accuracy and reliability of the locations derived from fingerprinting. The received signal strength from every visible AP is included in the database for each reference point. After measuring the received signal strength from each visible AP, the mean value of the signal strength and the distribution of signal strength of each reference point will be calculated and stored in the database. During the online phase, both deterministic and probabilistic methods can be employed as a positioning algorithm (Zhou, 2006). The former chooses the reference point in the database whose signal strength has the minimum difference from the received signal strength of the device as the most probable location; the latter chooses the most likely location of the device in database as the most probable location.

The trilateration algorithm does not need an offline phase like fingerprinting. However, trilateration still needs an accurate AP location database, including accurate Access Point coordinates and the unique Media Access Control (MAC) address for each AP. During active measurement, after calculating average signal strength for each visible AP, the system uses this value as an approximation for distance to trilaterate the device's location. It is of considerable importance that the general relationship between signal strength and distance may vary from different networks of APs, so it is practical and necessary to recalculate the general relationship when the network of Access Points change. This also suggests that trilateration benefits from the use of a common or small set of AP models. The common ground of the two methods is the need for an accurate database of AP locations and the dense and consistent wireless signal.

The differences between the two methods lead to some strengths and weaknesses. From a cost perspective, compared with trilateration algorithm, using fingerprinting consumes more time and labor during the collection of signal strength data and a huge volume of data needs to be stored as fingerprinting depends on a pre-existing signal strength database for all reference points. For a reasonably sized building, the offline phase of fingerprinting could take over 100 hours (Bahl & Padmanabhan, 2000). Positional accuracy with a fingerprinting algorithm is positively associated with the density of reference points in the database. The trilateration technique, on the other hand, includes as a database creation process but without collecting signal strength data.

From the perspective of adaptability, the trilateration technique performs better than fingerprinting. When a router is installed or removed in the environment, the trilateration technique only needs to add that new record to the database (with its accurate location and MAC address) or delete the existing record in the database; the fingerprinting technique, on the other hand, signal strength data needs to be recollected for every reference point within range of that new or removed router.

From the perspective of signal strength, fingerprinting takes into account the attenuation because the actual signal strength at each reference point is collected (which integrates the presence of obstructions between device and routers). Trilateration, on the other hand, collects signal strength values in real time and converts them to distances, taking no account of possible obstructions. The distance used for trilateration will be same for common received signal strength whether a signal is passing through walls or travelling through an obstruction-free space. To reduce this effect, a correction factor should be added to revise the average of the signal strengths for the non-line-of-sight router signals, if it can distinguish occluded from non-occluded signals.

From the perspective of accuracy, the calculating accuracy of fingerprinting will be greatly affected by the density of the reference points. When the database granularity achieves 5 feet, the corresponding average distance error could be 21.7 feet (6.62 meters) (Prasithsangaree, Krishnamurthy, & Chrysanthis, 2002). In Wireless indoor tracking system, a history-based tracking algorithm helps improving the accuracy to 3.89 meters for quickly moving device (Zhou, 2006). When calculating position with trilateration algorithm, distance conversion error becomes the largest error source, usually Kalman

Filter and Particle Filter are applied to trilateration algorithm to improve the accuracy, which ranges from 2 to 6 meters depending on various kinds of systems.

Conclusions

Both fingerprinting and trilateration use estimated wireless signal strength to determining the location. However, each determines position in different ways. Fingerprinting requires a detailed signal strength database for each reference point that can be compared with received signal strength in the field; the use of this method needs to balance the accuracy and time-commitment for collecting data when creating signal strength database. The trilateration technique is more flexible as the system calculates device location in real-time and the system is more adaptable to environmental change than fingerprinting. In real-world use, trilateration needs a correction factor to reduce the effect of attenuation; fingerprinting, on the other hand, already considers attenuation in the database creation process, which leads to a better accuracy in the signal strength data for calculation.

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