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Received signal strength based least squares lateration algorithm for indoor localization☆

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ABSTRACT

Following the success of accurate location estimation for outdoor environments, locating targets in indoor environments has become an important research area. Accurate location estimation of targets for indoor environments has the potential for the development of many different applications such as public safety, social networking, information and mapping services. However, the GPS (Global Positioning System) technology used for outdoor environments is not applicable to indoor environments, making accurate location estimation a challenging issue for indoor environments. In this paper, we propose a received signal strength based least squares lateration algorithm which uses the existing infrastructure. By employing redundancy in the number of access points and applying least squares approximations to the received signal strength values, the lateration algorithm increases the accuracy of location estimations. The usage of the existing infrastructure makes the proposed algorithm low cost when compared to other positioning algorithms which need very precise high cost components.

1. Introduction

Knowledge of the location information of a target has become a steadily increasing necessity in a variety of areas with the development of new types of applications after the implementation of the GPS [1]. GPS has become an essential component for the global information infrastructure, since critical positioning capabilities for commercial, military, and civil users can be provided with the GPS system. Some of the common areas that use GPS include mapping, aviation, environment, agriculture, and timing. For example, by using the precise timing data from the atomic clocks of the GPS satellites, wireless networks are able to synchronize all their base stations. On the other hand, in a completely different area, precision agriculture has led the farmers to become more efficient and productive. With GPS, farmers can navigate to specific locations in a field even in low visibility conditions, pest problem areas can be pinpointed for effective solutions, and the fields can be micromanaged.

Although GPS has proven to be a very successful solution for locating targets in outdoor environments, it is not capable of accurately determining locations inside buildings. The construction materials for buildings such as concrete walls or steel infrastructure blocks attenuate the signals coming from the satellites and consequently the signals cannot penetrate walls, roofs, and other objects. Thus, it becomes either very difficult or impossible to locate a target inside a building. Sensitive GPS chips can sometimes get signals from the satellites when they are inside a building, but typically the resulting location is not accurate enough to be useful.

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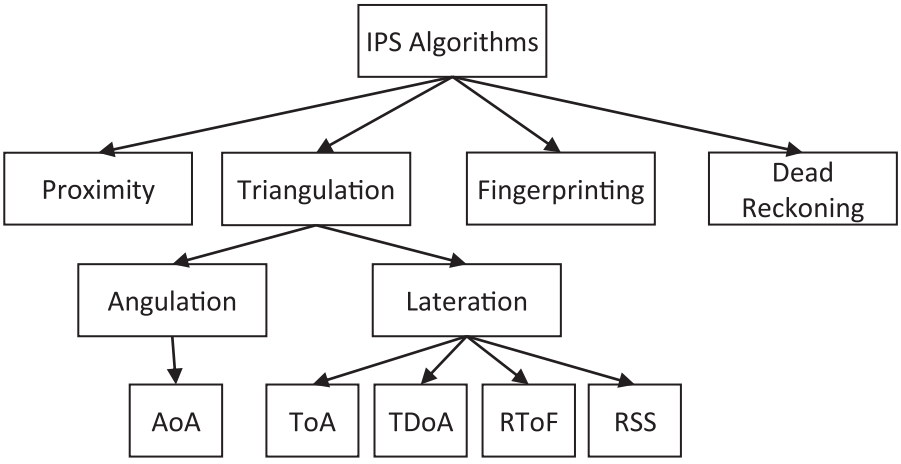

Fig. 1. Indoor positioning algorithms.

The unsuccessful nature of the GPS for locating targets in indoor environments has resulted in research efforts for the development of new technologies. An Indoor Positioning System (IPS) can be regarded as a solution of this problem, as IPS aims to locate people or objects inside buildings. In contrast to the GPS, the IPS can be used inside buildings and therefore it can be conveniently used for large buildings such as malls, airports, offices, schools, and hospitals.

With the successful implementation of the IPS, many different types of applications can be developed for indoor environments. For example, some of the applications that implement location information for indoor environments can be used for public safety, social networking, map services, and information services. With the help of an IPS system, guiding visitors and customers to their destinations at a mall or an airport will not only save time, but also increase customer satisfaction. Retailers in a mall will benefit greatly from the IPS for their sales related activities. Location based messaging will enable companies to tailor their messages to their customers' context and personalized offers will be delivered to their customers at the right place and right time. IPS will also provide security professionals a new and innovative way to locate and communicate with people inside buildings during emergency situations. By correctly determining the location of individuals inside buildings, the security operations can be significantly improved when an incident occurs. For example, during an emergency event such as an earthquake or a fire, having the knowledge of precisely how many people are inside an affected building and their exact locations will not only save time to reach the trapped people but will also be very critical as it can make a life or death difference. Adding the element of communication to the IPS will further reduce the risk in emergency situations, since those affected will be able to be guided and directed to safe areas.

In this paper, a Received Signal Strength (RSS) based least squares lateration algorithm which uses redundant access points is introduced. The proposed algorithm is tested and implemented at Kadir Has University, in Istanbul, Turkey. The significance of this algorithm is its ability to use the existing 802.11 infrastructure inside the buildings and mobile phones without any additional hardware requirements. Most of the other developed IPS algorithms briefly described in the next section require the installation of expensive hardware for indoor localization. However, our algorithm works with the already available RSS data obtained from the multiple access points. In our test bed at Kadir Has University, we were able to collect the RSS data coming from many different access points. In order to improve the accuracy of the localization for indoor environments, we have combined two different approaches: Using the least squares method and using the data obtained from multiple (more than three) access points. Our results have indicated that the accuracy of lateration can be significantly increased with our proposed algorithm.

The rest of this paper is organized as follows: Section 2 describes different techniques for locating targets in indoor environments and briefly introduces the most common IPS algorithms in literature. Section 3 introduces the RSS based least squares lateration algorithm by describing lateration, RSS to distance conversion, and least squares approximation. Section 4 describes the experimental set up and the accuracy results that have been obtained from pure lateration, least squares lateration, and least squares lateration with redundant access points. Our paper is completed by the conclusions made in Section 5.

2. Algorithms for indoor positioning systems

Location estimation algorithms for indoor environments use one of the four major estimation techniques illustrated in Fig. 1. These four algorithms can be classified as proximity, triangulation, fingerprinting, and dead reckoning. In this section, these algorithms and their different types are briefly described.

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