Calibration-Free Localizations and Applications on U-Care Cloud

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ABSTRACT

The key technique of the location-based service (LBS) is localization which is a kind of techniques for determining the location of mobile users (MU). One of the most common techniques for the location estimation of mobile users (MU) is the radio frequency (RF) site survey. The main idea of the technique is to build a signal strength model, called a radio map, in the off-line phase and to estimate the location of an MU by finding the best match from the radio map in the on-line phase. However, when signal strength values vary frequently due to the characteristics of environmental dynamics, the radio map will quickly become outdated, and recalibration requires considerable manual effort. A good positioning technique should be able to adapt to a dynamically changing environment. In this paper, the authors describe the design and implementation of a positioning system which can provide low-cost, but highly adaptable and precise positioning in the context of changeable radio environments. Instead of constructing a radio map, the authors use reference points (RP) installed in the localization area to continuously monitor changes in the environment. The authors then employ the minimum mean square error (MMSE) method to estimate the location of the MU. Experimental results show that the average error distance is about 3 meters. The positioning system has been implemented as a subsystem of the U-care project in the Chang Gung Health and Culture Village. From the results of questionnaire made by residents, the authors find that the most satisfaction system in the U-care project is the positioning and rescuing system because it can locate the exact position of a resident in need of emergency.

Keyword: Localization, Minimum Mean Square Error, Received Signal Strength, Reference Points, Wireless Networks

DOI: 10.4018/jghpc.2013070106
1. INTRODUCTION

Thanks to tremendous advances in wireless access techniques and mobile computing devices, intense interest has developed in location-based services. These technologies have made the dream of communication anytime and anywhere possible. People using a mobile device can surf the web as well as talk with their friends while they are moving all over the world. One of the most popular applications is the location-based service (LBS), such as geographical navigation for tourists or vehicles, advertising messages for local potential customers, 911 emergency services for subscribers, etc. The rapidly expanding demand for indoor/outdoor location-based services (LBS) has created a great need for high-precision location estimation techniques. In wireless networks, the most common technique used in location estimation is the RF site survey (Bahl & Padmanabhan, 2000; Youssef & Agrawala, 2004; Yin, Yang, & Ni, 2005; Youssef & Agrawala, 2005; Haeberlen, Flannery, Ladd, Rudys, Wallach, & Kavraki, 2004; Madigan, Elnahrawy, Martin, Ju, Krishnan, & Krishnakumar, 2005). As shown in Figure 1, the procedures of this technique are usually divided into an off-line phase and an on-line phase. The off-line phase is also called the training phase. Its objective is to construct a radio map by measuring the received signal strengths (RSSs) transmitted from access points (APs) at every location and recording the relation between each location and its measured RSSs. In the on-line phase, the location of mobile users (MU) is estimated through finding the best match of the RSSs between those measured from an MU and those recorded in the radio map.

The most famous system using RF site survey is RADAR (Bahl & Padmanabhan, 2000). The positioning method used in the on-line phase mainly uses Euclidean distance to calculate the RSS difference between the MU measurements and prior data from the radio map. The Euclidean distance at a given location can be calculated by the equation

$$ \sqrt{\sum_{i=1}^{k} (SS_i - SS_i')^2} $$

where $k$, $SS_i$, and $SS_i'$ respectively represent the number of APs, the $i^{th}$ AP’s RSS measured by MU, and the $i^{th}$ AP’s RSS recorded in the radio map. The positioning location is then calculated by averaging the $k$ APs with the $k$ minimum Euclidean distances.

Reference (Lim, Kung, Hou, & Luo, 2006) mentions that RSSs will vary frequently due to a number of factors such as multi-path fading, temperature and humidity variations, object relocations, and the presence of moving objects. Thus, the radio map will quickly become outdated and the accuracy of location estimations cannot be assured. As a result, frequent renewal calibrations are required to maintain up-to-date RSSs on the radio map, which incurs considerable labor cost.

Figure 1. RF site survey procedures
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