Poster Abstract: MaWi: A Hybrid Magnetic and Wi-Fi System for Scalable Indoor Localization

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***Abstract*—We present MaWi - a smart phone based scalable indoor localization system. Central to MaWi is a novel framework combining two self-contained but complementary localization techniques: Wi-Fi and Ambient Magnetic Field. Combining the two techniques, MaWi not only achieves a high localization accuracy, but also effectively reduces human labor in building fingerprint databases: to avoid war-driving, MaWi is designed to work with low quality fingerprint databases that can be efficiently built by only one person. Our experiments demonstrate that MaWi, with a fingerprint database as scarce as one data sample at each spot, outperforms the state-of-the-art proposals working on a richer fingerprint database.**

Keywords*—*Indoor Localization, Mobile Sensing

I. Introduction

As increasing urbanization forces people to stay more often at indoor environments, locating and navigating people in complex constructions (e.g., airports and shopping malls) becomes a crucial problem. Furthermore, government and business also benefit from accurate user location information in precise information pushing. Luckily, rapid spread of high performance smart phones and wide 3G/Wi-Fi network access have caused an explosion of mobile sensing applications. Since smart phone has become an indispensable device in people's daily life, an indoor localization service through smart phone sensing can be handily deployed without extensive efforts.

To address the challenge of indoor localization, many systems have been proposed in recent years [1], [2]. However, smart phone based systems achieving both scalable and high accuracy are still missing. On one hand, while high accuracy has been achieved by some fingerprint-based (or empirical) systems [1], they share the common prerequisite to entail heavy labor in building fingerprint database (a set of spots with associated signal fingerprints). Such a laborious spot survey process hinders the scalability in deployment. On the other hand, model-based systems [2] avoid the spot survey by using propagation model to infer distances and trilateration to locate users. Unfortunately, these systems have relatively low accuracy.

Because spot survey (deemed necessary for achieving high accuracy) hampers scalable deployments, recent proposals [3] suggest to distribute the intensive labors through crowd-sourcing, in which fingerprint databases are collected opportunistically by a large population. Whereas these technologies may have potential to make large deployment possible, opportunistic spot survey cannot warrant fingerprint quality: insufficient samples at a given spot and low density in sampled spots are both potential problems.

In this work, we propose MaWi, a smart phone based indoor localization system using Magnetic field and Wi-Fi as fingerprints. The two fingerprints are used in a "duet" manner such that they complement each other. Through this smart combination, MaWi achieves a scalable deployment due to its low demand on the fingerprint database, while getting very competitive localization accuracy compared to state-of-the-art systems. Furthermore, MaWi is light-weight as it requires no dedicate devices or adaption of existing infrastructure. Finally, MaWi is friendly for widely deploying because it uses a smart phone as both the survey device and the localization client.

II. Wi-Fi Signal and Ambient Magnetic Field

On one hand, Wi-Fi fingerprint as a vector of RSSs (Receive Signal Strength) from detectable APs, easily measured by normal smart phone, is not temporally stable. Our experiment in an 800 m^2 office area (Figure 1) shows that Wi-Fi fingerprint is more suitable to be used in discriminating large areas instead of close-by locations (Figure 2(a)). On the other hand, Geomagnetic Field, "twisted" indoor by building structures and forms unique *ambient magnetic field*, exists ubiquitously [4]. We find that geomagnetic field's temporal stability makes it good at differentiating close-by location (Fig. 2(b)). Basing on our observation, we propose a Revised Particle Filter that combines geomagnetic field and Wi-Fi fingerprint together to localize people in high accuracy.

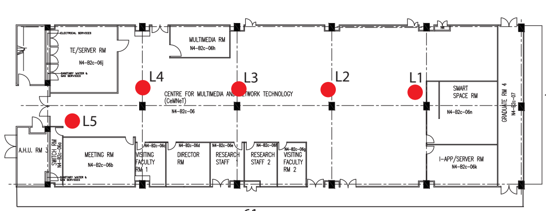
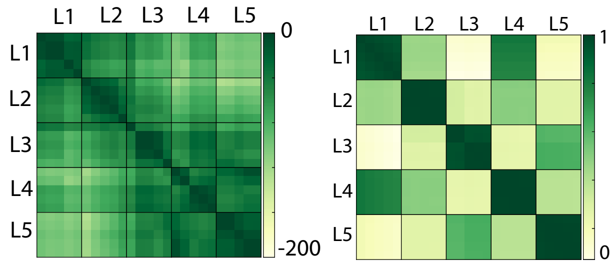


Fig. 1. Test region for fingerprint studies.

III. MaWi System Design

As illustrated in Figure 3, MaWi has two types of user: Surveyor who supplies fingerprint data, and Strayer who needs self-locating. Fingerprints from surveyor are labeled by Fingerprint Labeling Module, and then stored into Fingerprint Databases. On receiving a localization request, Revised Particle Filter draws fingerprints from databases and estimates a strayer's location based on on-line fingerprints.



(a) Confusion matrix of Wi-Fi fingerprint for five locations (b) Confusion matrix of magnetic field fingerprint for five locations

Fig. 2. Wi-Fi locational discrimination.

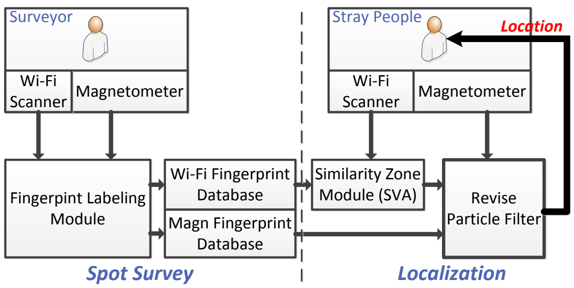


Fig. 3. System architecture.

Conventionally, high accuracy localization approaches (e.g., Horus [1]) require a rich fingerprint database which could takes days even with the collaboration of multiple surveyors. To enable a scalable deployment, MaWi has a simple spot survey mechanism. A surveyor indicates the trace he/she will take to collect fingerprint before survey starts. During the survey, smart phone records the fingerprints while surveyor walks. Assuming surveyor walking in uniform speed, MaWi uniformly arranges along the trace all the survey spots associated with fingerprints. Wi-Fi fingerprints are collected at 0.33 Hz, which is the highest frequency achievable by normal smart phones. Magnetometer records ambient magnetic field at 5 Hz. With a normal human walking speed of 1 m/s, Wi-Fi and magnetic field is recorded every 3 m and 0.2 m respectively.

Because MaWi has very loose requirements on fingerprint databases that it work with, it is compatible with legacy databases generated for other indoor localization approaches, such as [1], [3]. Furthermore, MaWi's spot survey can be further enhanced (hence being more time efficient) through crowd-sourcing.

MaWi offers two working modes of localization: server-side and client-side. MaWi chooses the client-side mode with priority to avoid network delay in continuous localization by default, but users can change it to server-side mode if computation becomes a bottleneck.

IV. Evaluation

We deploy MaWi in three test sites: an office area, a library , and a shopping mall, and we develop an Android application as the MaWi client (interface illustrated in Figure 4).

We show a real localization process on our MaWi client for five seconds in Figure 4. User stands still during the whole procedure at the lower side of the library (indicated by the particle at the 5-th second).

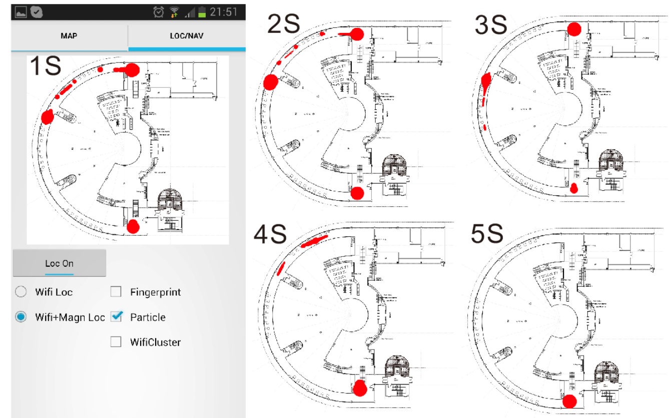


Fig. 4. MaWi localization on a client. Sizes of red dots denote particles' weights, and time sequence is indicated at the upper-left corner of each figure. Obviously, the weight eventually concentrates at a single particle, which happens to be the user's ground truth location.

We count the time we need to build a fingerprint database that can satisfy the requirement of MaWi. We employ only one surveyor holding smart phone to walk around the deployment area, while recording the fingerprints of both Wi-Fi and magnetic field at passed location. The results show that even for a large area of 22500 m^2, we only need no more than 1 hour to get a usable database for localization.

We compare MaWi working on low quality database with Horus [1] working on richer ones in Figure 5. Even when sample number increases to 100 (5 minutes survey time) at each survey spot, Horus's performance is still worse than MaWi.

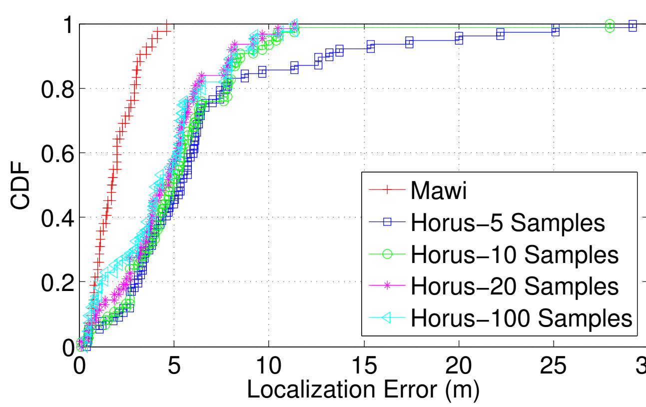


Fig. 5. Localization accuracy comparison between MaWi, and Horus (with rich fingerprint database)

References

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