G-Loc: Indoor Localization Leveraging Gradient-based Fingerprint Map

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***Abstract*—In this paper, we propose G-Loc which leverages the gradient-based fingerprint map in localization. G-Loc firstly builds a gradient-based map ($Gmap$) by comparing RSSI values at nearby positions and runs an online extended particle filter to localize the user/device. With the robust Gmap, G-Loc can be more adaptive to the time-variant RSSI and effectively reduces the overhead in fingerprint map calibration. We fully implemented G-Loc and conducted extensive experiments. In an office building with both stable and highly dynamic WiFi signals, G-Loc achieved an 80 percentile accuracy of $4.1m$ and $5.1m$, respectively.**

I. Introduction

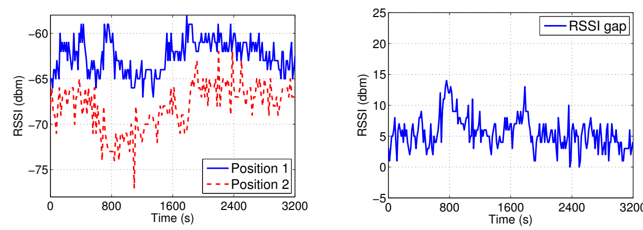
Among different branches of indoor localization researches, RSSI-based fingerprinting attracts the most attention. They localize the user/device through a comparison of RF signal strengths with a pre-established location-specific fingerprint map. However, due to the time-variant wireless signal strength, fingerprint map in such kind of systems needs to be periodically calibrated. In addition, existing WiFi routers can dynamically change their transmit power and the absolute RSSI measurements vary among devices, which further weaken the effectiveness of existing fingerprint-based systems. Motivated by these challenges, lots of researches have been done to enhance the efficiency of WiFi fingerprinting approaches. Although these works made an important step forward in improving the stability of WiFi based indoor localization system, they still suffer from high complexity and low accuracy. In this paper, we propose G-Loc, which utilizes the novel gradient-based fingerprint map to localize the user. The basic rationale behind G-Loc is that gradient-based fingerprint map is more stable and tolerable for signal strength variances than existing absolute value-based fingerprint map.

II. Measurement and Observation

Before proposing our main design, we first present some measurements and observation results of indoor WiFi signals, which serve as the basis of G-Loc.

A. Temporal Variation of Wi-Fi Signal

We firstly conduct experiments to verify the impact of the change of transmit power. Two smartphones are put on different tables with a distance of $4m$ apart in an office environment, and continuously scan and record the WiFi RSSI for hours. RSSI of one scanned AP is shown in Figure 1(a). From Figure 1(a) we can see the fluctuations of RSSI caused by the adaptive transmit power adjustment [4]. Due to the existence of such unpredictable temporal variations of RSSI, localization performance of absolute value-based fingerprinting approaches will be easily influenced. However in Figure 1(b), we find the RSSI gap between two smartphones remains positive and relatively stable.

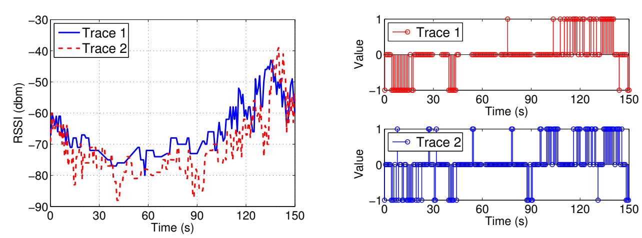


(a) Absolute RSSI value (b) RSSI gap

Fig. 1. Temporal variation of WiFi signal

B. Spatial-temporal Variation of WiFi Signal

We further examine the spatial-temporal variation of WiFi signal in this part. In this experiment, one user carries a smartphone and walks along a pre-defined path in an office environment at different times of the day. The smartphone keeps recording the WiFi RSSI during user walking and we plot the RSSI to examine the difference among various traces.



(a) Absolute RSSI value (b) Gradient-based map

Fig. 2. Local disturbance of WiFi signal

From Figure 2(a) we can see that there exists a shift between two RSSI curves. This is because the AP slightly increases its transmit power to cover a larger area in the morning when few connections has been established (Trace 1). In fact, the gap in between two curves reflects the temporal variation of RSSI at a fixed location (as shown in Figure 1(a)).

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Although the absolute RSSI values vary in two traces, we can see the trends of the RSSI are similar. In Figure 2(b), we use a sliding window to calculate the gradient of absolute RSSI values. Specifically, if the difference of RSSI values at two ends of the window is larger than a threshold $\pm\delta$ (e.g. 5 dbm), we generate an output of ± 1. As shown in Figure 2(b), gradient-based maps of two traces are almost identical and much more stable in both spatial and temporal domains.

III. Architecture Overview

G-Loc consists of two main modules, namely map construction and G-Loc engine. Figure 3 shows G-Loc architecture.

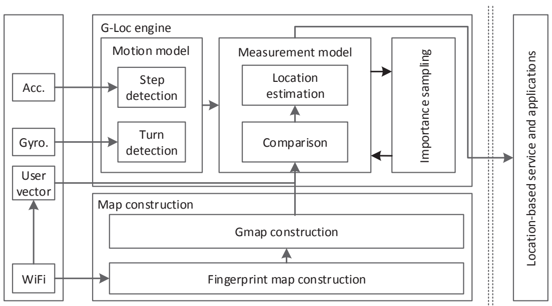


Fig. 3. G-Loc architecture

Gmap is constructed by comparing RSSI values at nearby positions. To build $Gmap$, we firstly build map construction module which automatically collects and builds RSSI fingerprint map during user walking. We use length parameter l and threshold parameter δ to help the construction of $Gmap$. Specifically, we extract RSSI values collected at neighbor locations separated by l in the RSSI fingerprint map and compare the difference between RSSI values and δ to decide the corresponding values in $Gmap$. If the difference is larger than $\pm\delta$ (e.g.5 dbm), we denote the output as ± 1. Otherwise the output is 0.

Based on $Gmap$, G-Loc engine estimates user location by leveraging an Extended Particle Filter (EPF). During user walking, EPF calculates the similarity of RSSI gradient values between user measurements and $Gmap$. Based on the similarity, EPF updates weights of particles and further estimates user location. In G-Loc engine, we also adopt accelerometer and gyroscope to detect user steps and turns to help improve the movement of particles.

IV. Implementation and Evaluation

We fully implement G-Loc on Android platform including a Samsung P7510 Tablet and a Samsung I9100 smartphone. Figure 4 shows a screenshot of G-Loc application on P7510.

The performance of G-Loc is evaluated in environment with both relatively stable and highly dynamic WiFi signals. We use Radar [5], a WiFi fingerprinting method which finds the nearest neighbors in signal-space, as a benchmark.

As shown in Figure 5(a), G-Loc and Radar achieve comparable performance in terms of localization error, both in meter-level accuracy in static environment. The 80 percentile accuracy of G-Loc and Radar are $4.1m$ and $4.8m$ respectively.

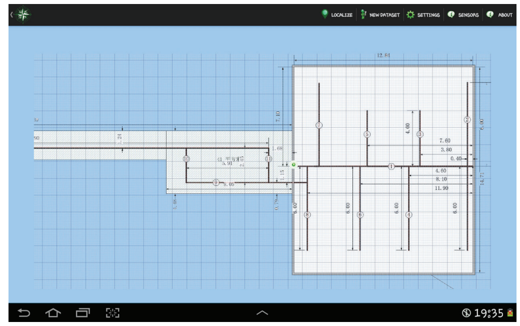
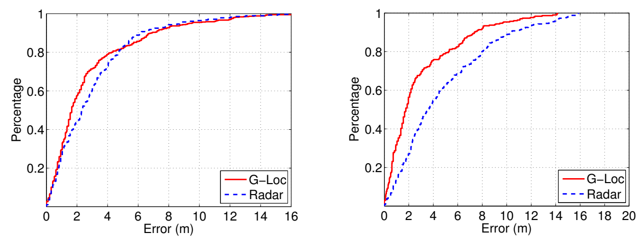


Fig. 4. Screenshot of a running G-Loc application

However, G-Loc is more robust in highly dynamic environment due to the use of gradient-based fingerprint map. In Figure 5(b), the 80 percentile accuracy of Radar is $8m$, which has a 40% performance degradation compared with results in static environment. However for G-Loc, the performance degradation of the 80 percentile accuracy is less than 20% and 80 percentile accuracy is less than 5m.



(a) Static environment (b) Dynamic environment

Fig. 5. CDF of localization accuracy

V. Conclusion

In this paper, we propose G-Loc, an indoor localization system based on gradient fingerprint map. We firstly present several observation results examining the indoor WiFi signal and then present the system design of G-Loc based on the robust gradient-based RSSI map. G-Loc is fully implemented on off-the-shelf smartphones and evaluated in various typical indoor environments with highly dynamic WiFi signals. Compared with legacy fingerprinting methods, G-Loc is more robust to the time-variant indoor wireless signals and could effectively reduce the cost of calibration of the fingerprint map.

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