# Demo Abstract: Indoor Navigation Leveraging Gradient WiFi Signals

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## ABSTRACT

In this demo, we propose I-Navi, an Indoor Navigation system which leverages the gradient WiFi signal. To be more adaptive to time-variant RSSI and enrich information dimension, I-Navi exploits a three-step backward gradient binary method. Meanwhile, we adopt a lightweight online dynamic time warping (DTW) algorithm to achieve real-time navigation. We fully implemented I-Navi on smartphones and conducted extensive experiments in a five-story campus building and a newly opened two-floor shopping mall with a 90% accuracy of 2m and 3.2m achieved at two places.

## CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing**;

## KEYWORDS

Indoor navigation, Leader-Follower structure, DTW

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## 1 INTRODUCTION

There is a growing demand of indoor navigation in many typical scenarios like parking lots, airport terminals, office buildings, etc. Numerous approaches have been proposed in the area of indoor navigation leveraging WiFi signal. However, some existing APs (Access Point) can dynamically change their transmission power and the absolute RSSI measurements vary among devices [1]. Motivated by these challenges, we present I-Navi, an indoor navigation system exploiting gradient property of WiFi signals. In order to reduce the impact of WiFi signal's limited two dimension information, we adopt a three-step back gradient method to enrich the information density and improve the algorithm robustness. During navigation, a lightweight online DTW algorithm is applied to calculate an optimal match between two WiFi sequences which may vary in length. In short, main contributions of this demo are summarized as follows:

- We propose I-Navi, leveraging gradient WiFi signals to provide easy-to-deployed navigation service without map plans.
- We design a three-step backward gradient binary method to solve the problem of temporal variation, device diversity and limited information of WiFi signals. A synchronization algorithm based on DTW is adopted to match signals, making the real-time navigation a reality.
- We conduct extensive experiments in an office building and a big shopping mall with 90% accuracy of 2m and 3.2m, respectively.

## 2 MOTIVATION

Thanks to widely deployed WiFi APs in modern buildings, WiFi RSSI-based indoor navigation has drawn significant attention among different branches of researches. However, RSSI changes over time due to AP's dynamic transmission power. Meanwhile, WiFi RSSI can be easily influenced by environmental factors. Device diversity is another issue that adversely influences the performance of navigation as RSSI variation is observed among different devices. To solve these problems, I-Navi borrows the gradient idea to be more adaptive to time-variant RSSI, and achieves a robust and accuracy system. In addition, I-Navi enriches the information density from WiFi signals by using a novel three-step backward gradient binary method. Finally, as the amount of information increases, the requirement of computing capability will also increase. Taking this factor into considering, I-Navi adopts a modified online DTW algorithm to synchronize the signal matching procedure, which turns I-Navi into a plug-and-play system with fast computing.

## 3 SYSTEM DESIGN

In this section, we present a system design of I-Navi.

### 3.1 System Architecture

I-Navi adopts a Leader-Follower framework which consists of three main modules: trace data collection and processing module, data packing and sharing, navigation module. Fig. 1 shows the system architecture.

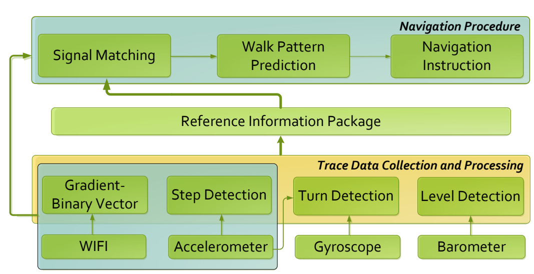


**Figure 1: System Architecture.**

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In I-Navi, leader walks a path with a smartphone. While walking, sensors on smartphone collect WiFi signal and motion information. I-Navi aligns motion data with WiFi information according to timestamps and packs them to generate a reference data package, which will be uploaded to the server. In navigation phase, follower searches for a path and downloads a reference data package. After downloading, I-Navi starts to collect the surrounding WiFi and track follower's movement. A real-time signal matching is performed at the same time, then follower just needs to follow the motion instructions (e.g., go straight, upstairs) to the destination.

## 3.2 WiFi Signal Matching

Basic WiFi information includes MAC addresses and corresponding RSSI values. As validated in most systems, WiFi signal is time-variant. Therefore, I-Navi leverages RSSI gradient values by comparing RSSI values of the nearby scans. However, only RSSI gradient values and different MAC addresses are not enough to navigate. Hence, we enrich the information structure from two-dimension into four-dimension by introducing a novel method, three-step back gradient algorithm.

Specifically, for the same MAC address, I-Navi computes the RSSI gradient value $g$ by comparing the difference between RSSI values from two vicinity scans. In order to further reduce the computation, binary value $b$ is inferred to replace the RSSI gradient values by comparing $g$ with a threshold $\delta$. Furthermore, I-Navi proposes a novel three-step backward gradient binary method to enrich information density, which calculates the difference between RSSI binary values of the current scan and the previous three scans. Hence, the final WiFi information consists a MAC address set and three binary value sets, leading information into four-dimension.

## 3.3 Real-time Navigation

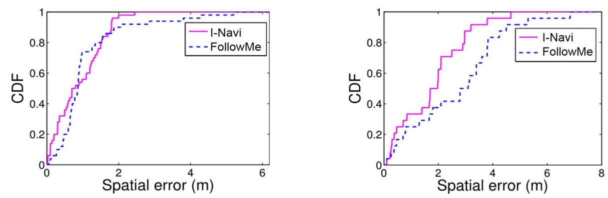
After signal processing, the system needs to estimate the user's location according to the relationship between the reference package and user's signal sequence. Instead of using compute-intensive techniques like particle filter, I-Navi adopts a modified online DTW algorithm to synchronize the gradient WiFi signals. After the user starts the system, the smartphone gets the WiFi information. Then DTW will calculate the similarity between reference and user's signal sequence by quantifying their gradient difference to find the best match, and provide navigation instruction according to the user motions from the reference package.

# 4 IMPLEMENT AND EVALUATION

We implement I-Navi on Android devices. A Dell Optiplex 390 is used as the remote server. Demo video of I-Navi can be found at https://youtu.be/RJVTDfvr_dM.

The performance of I-Navi is evaluated in a five-floor campus building and a two-floor shopping mall. We use FollowMe [2], a system exploits the geomagnetic field and natural walking patterns to navigate the users to the same destination taken by an earlier traveler, as a benchmark.

As shown in Fig. 2(a), I-Navi and FollowMe achieve comparable performance in terms of navigation error, both 90-percentile accuracy of 2m in campus building. Fig. 2(b) shows the system performance in a shopping mall. The 90 percentile accuracy of FollowMe is 4.5m whereas the accuracy of I-Navi is as low as 3.2m, indicating I-Navi is more adaptive to the complicated environments.




(a) Spatial error in office building (b) Spatial error in shopping mall

**Figure 2: Spatial error of two scenarios.**

We also evaluate the robustness of the system. Fig.3 shows the performance among different users. We let four volunteers test the performance in four different traces. The result shows that the accuracy of different person is very close, which indicates that the system is adaptive to different person.

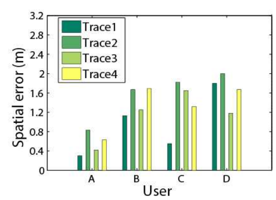



**Figure 3: Spatial error of difference person.**

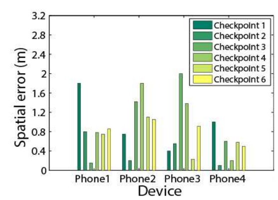



**Figure 4: Spatial error of difference device.**

Fig. 4 shows the performance of device diversity. We test the system accuracy at 6 check points with different smartphones, Samsung Note 4, S5, S6 and S7. The result shows that all spacial error is less than 2m, which means device diversity has little effect on the system.

# 5 CONCLUSIONS

In this paper, we present I-Navi, an indoor navigation system leverages the gradient-based WiFi signal. I-Navi is fully implemented on off-the-shelf smartphones and evaluated in various indoor environments. Compared with legacy indoor navigation system, I-Navi is more robust to the time-variant indoor wireless signals and has higher accuracy.

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