# Poster: Online Map Matching for Passive Indoor Positioning Systems

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## ABSTRACT

Passive indoor positioning systems (PIPS) enable non-invasive tracking of mobile devices (e.g., smartphones, Wi-Fi tags) using enterprise network infrastructure. This empowers operators of large airports and retail facilities to optimize cost-intensive resource allocation as well as to provide location-based services to their customers such as geo-fencing and proximity marketing. However, existing PIPS often generate noisy location estimates due to unpredictable interference and attenuation of wireless signals in indoor environments. To address this problem, we propose a novel map matching approach that uses a floor map to constrain location estimates to possible paths a mobile user can take.

## 1. INTRODUCTION

Figure 1 describes the online map matching problem. PIPS such as Cisco's Hyperlocation [1] use signal strength and angle of arrival of Wi-Fi signals to track these devices. Map matching for such PIPS is challenging because of four reasons. First, location estimates are noisy. The mean error can range from 3 to 7 m. Second, a floor map can contain many possible paths. Third, location estimates are temporally sparse due to the latency incurred in sampling Wi-Fi signal strengths from a user device and in the location estimation process. The time difference between two consecutive location estimates can vary by as much as four seconds. Fourth, the location estimates often lag the corresponding actual locations of the user device.

We propose a novel map matching approach that applies proximity and topological constraints to select path segments by modeling these constraints with a Hidden Markov Model. *Our main contribution is a new topological constraint based on our observation that a mobile user often takes a small number of turns between two consecutive locations that correspond to the location estimates generated by the system.*

To evaluate our work, we perform thirty experiments on two different building floors, with two participants, to collect location estimates and corresponding ground truth data. In each experiment, a participant walks on a floor for five minutes while holding a phone (iPhone 6S). Our results demonstrate improved map matching accuracy with our proposed constraint compared to travel time and travel distance constraints [2] on a floor having dense path segments. Our map matching approach aligns 50% of location estimates on correct path segments taken by mobile users and lagging the corresponding actual locations up to 7 m.

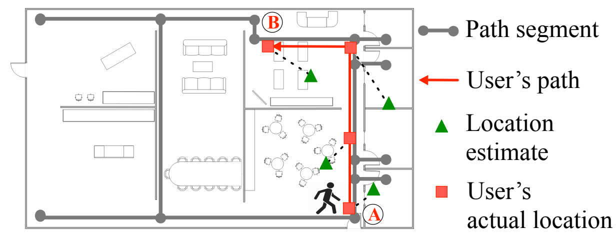


**Figure 1: A user walks from location A to location B on the floor map and is currently at B. Given the floor map composed of the path segments and the sequence of time-stamped location estimates, the map matching problem is to determine to which path segment the current location estimate must be aligned.**

We acknowledge that this result is not comparable with the accuracy of active indoor positioning systems in which a mobile device uses additional information such as fingerprint data and inertial sensor data to estimate the device locations. However, improving PIPS with a map matching technique brings two important benefits: low energy consumption at the user's mobile device and not encumbering every user with application installation on his/her device.

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## 2. REFERENCES

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[2] P. Newson and J. Krumm. Hidden Markov map matching through noise and sparseness. In *Proc. of the 17th ACM SIGSPATIAL*, pages 336–343, 2009.



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