Demo: FootPath – Accurate Map-based Indoor Navigation Using Smartphones

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***Abstract*—We present *FootPath*, a self-contained, map-based indoor navigation system. Using only the accelerometer and the compass readily available in modern smartphones we accurately localize a user on her route, and provide her with turn-by-turn instructions to her destination. To compensate for inaccuracies in step detection and heading estimation, we match the detected steps onto the expected route using sequence alignment algorithms from the field of bioinformatics. As our solution integrates well with OpenStreetMap, it allows painless and cost-efficient collaborative deployment, without the need for additional infrastructure.**

I. Introduction

While navigation systems for outdoor environments are readily available, navigation within buildings still poses a challenge. The main reason for this lies in the difficulty to obtain accurate position information in an easy to set-up way with minimal infrastructure and to create indoor maps.

Our approach to this problem is twofold: (1) We use simple step detection and step heading estimation. (2) We match detected steps onto the expected route from the source to the destination using sequence alignment algorithms. Instead of a more general localization problem, we solve the localization problem on a specified route. This allows us to compensate for inaccuracies and give the user accurate turn-by-turn directions.

To allow easy incremental deployment of our system, we integrate our system with OpenStreetMap [1], which already has rudimentary indoor support [2]. GPS, Pseudolites, UWB, WiFi access points, and RFID is avoided, making the system useful for protected environments like historical buildings and archaeological sites as well as hospitals, where additional RF gear might interfere with medical equipment.

A. Contributions

The main contributions of this paper are:

1) **Infrastructureless indoor navigation:** We use simple step detection and step heading detection, which we then map onto a route using sequence alignment algorithms. Additional infrastructure, like GPS, Pseudolites, UWB, WiFi access points, and RFID can be avoided.
2) **Localization on a route:** We know the route, the user intends to take. Using this knowledge, we reduce inaccuracy at corners opposed to further accumulating errors. Path matching is precise enough to allow for accurate indoor turn-by-turn directions.
3) **Easy incremental deployment:** Deploying the system for a new building simply consists of entering the floor plan into OpenStreetMap.

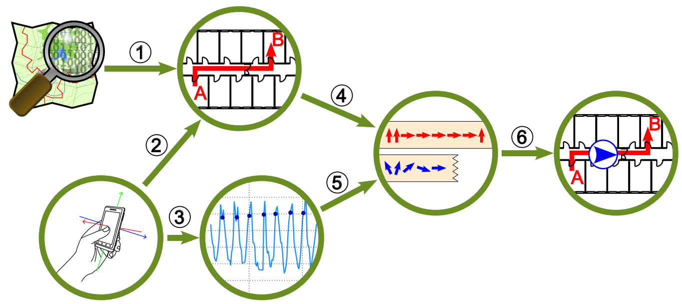

Fig. 1. Flow of information during navigation. (1) The application obtains map material from OSM. (2) The user selects her current position and her destination. The phone calculates the best route. (3) The mobile phone detects steps and directions. (4) The route is transformed into expected steps. (5) The detected steps are mapped onto the expected steps. (6) The user gets feedback about her position and her next way-points.

II. System Design

Figure 1 presents an overview of our system. We obtain map material from OpenStreetMap, this allows easy updating and incremental deployment on a global scale, see Section II-A. After the user selects her route, the accelerometer and compass of the user's phone are used to detect steps and step headings, see Section II-B. We then match these steps onto the map using a first fit and a sequence matching scheme, see Section II-C. Finally, we present the estimated position back to the user, together with turn-by-turn directions towards the destination, see Figure 3 for screen shots of our current prototype.

A. Generating Maps

OpenStreetMap [1] is an effort to create and distribute free geographic data, such as street maps, but also indoor maps of public buildings, albeit indoor support is still rudimentary [2]. OpenStreetMap allows wiki-style editing, thereby enabling everyone to contribute easily.

The popularity of OpenStreetMap allows us to make use of a variety of tools, e.g. JOSM [3], to create and extend maps incrementally. The OpenStreetMap community has already mapped the vicinity of our building in great detail, easing our task to integrate our indoor maps, which we derived from floor plans with outdoor footpaths and streets. To create a map for a new environment, we only need floor plans which we

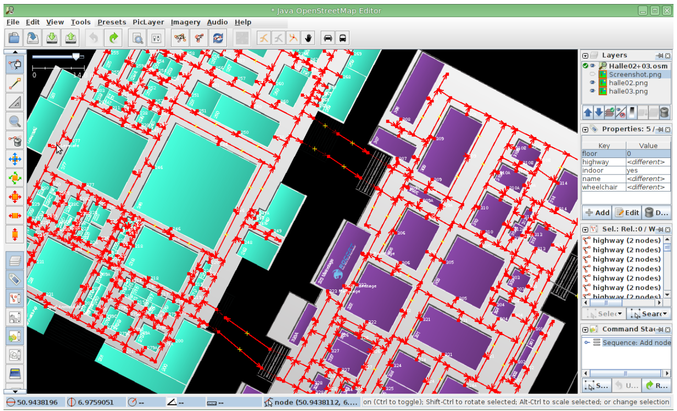

Fig. 2. A map for a trade fair in Cologne, Germany. The map covers an area of $20000m^2$ with more than 150 exhibitors. The total time needed to create the map was under three hours.

load into JOSM as layers, correctly align them to the vicinity and then corresponding to the floor plans create our map data.

B. Step Detection

Modern smartphones are typically equipped with an accelerometer and a compass. We make use of this fact and directly use them for our step detection and step heading estimation. We detect steps from a characteristic regular pattern produced by each contact of the heel with the ground during each step.

C. Path Matching

Upon detection of a step, we trigger path matching. We propose two strategies for matching detected steps onto expected steps from a map: (1) First Fit and (2) Best Fit. The best fit corresponds to a position on the route, which is in turn used for user feedback, see Figure 3.

First Fit makes use of the assumption that the user's detected step heading corresponds directly to the direction of the edge the user is currently located on. Upon each detected step with a corresponding step heading, we try to match this heading to the direction of the current edge and move along this edge. If this is not the case, we either wait for a limited number of steps until we obtain a step that matches the edge, or after the predefined number of unmatched steps, use a lookahead to find the best match of all previously unmatched steps to a location further along the path.

Best Fit adapts sequence alignment algorithms [4] from the field of bioinformatics, to align the detected steps with the expected steps extracted from a map. Here, the goal is to return the location that results with the best matching of expected steps up to that location and all detected steps. This is done by calculating all possible matchings of detected steps to the path and returning the location with the least penalty. The penalty for each location indicates how many steps would have to be added, deleted, or changed from the detected steps to match them along the path up to the given location. Thus, the fewer changes are needed, the better the resulting match is. We describe this approach in more detail in [5].

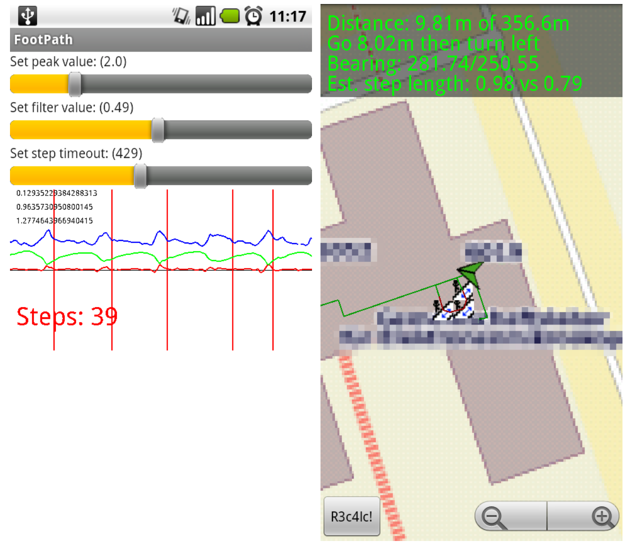

Fig. 3. Screenshots of the calibration screen and during navigation.

III. Demonstration Overview

We have deployed *FootPath* at the buildings for computer science at the RWTH Aachen. We created maps for three interconnected buildings and labeled doors to rooms according to their respective names using existing floor plans. Also, we created a map for a trade-fair in two hours. The map covers an area of $20000m^2$ with more than 150 exhibitors, see Figure 2. With this map we successfully navigated across the environment.

At the IPIN conference we intend to present how to create a map of the environment such that conference attendees can test our navigation system during the conference using a smartphone. As the matching algorithm is very robust with respect to step length variations, recalibration to different users is not necessary.

FootPath does depend on specific paths a user has to follow. If the user does not follow that path, for instance in an wide open space, there will be additional inaccuracies. However, due to the robustness of the matching algorithms, *FootPath* is still useable.

FootPath is an easy to set up, infrastructureless solution for indoor navigation, which deals with challenges such as inaccuracies from sensors, or movements of the user. This demonstration shows the feasibility of our algorithms for infrastructureless indoor navigation.

References

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