Poster Abstract: An Indoor-Outdoor Navigation Service for Subway Transportation Systems

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ABSTRACT

The proliferation of mobile computing has prompted navigation to be one of the most attractive and promising applications. Conventional designs of navigation systems mainly focus either indoor or outdoor navigation. However, people have a strong need for navigation from a large open indoor environment to an outdoor destination in real life. In this poster, we present a joint navigation system, named *ioNavi*. It can enable passengers to easily deploy indoor-outdoor navigation service for subway transportation systems in a crowdsourcing way, without comprehensive indoor localization systems. Any self-motivated passenger records and shares its individual walking trace and associated rich set of sensor readings, from a location inside a subway station to an uncertain outdoor destination within a given range, such as one kilometer. *ioNavi* further extracts navigation traces from shared individual traces, each of which is not necessary to be accurate and usable. A following subsequent user achieves indoor-outdoor navigation services by tracking a recommended navigation trace.

1. INTRODUCTION

Navigation services are highly attractive for each passenger to obtain the most convenient and shortest walking path from any indoor position inside a subway station to a nearby outdoor destination (e.g., a shopping mall) for subway transportation systems. This essential requirement, however, is not easy to be satisfied due to the following reasons. First, such subway stations suffer complicated indoor structures, especially for those interchange stations. Second, the passengers are unaware of the situation around each exit entrance of a subway station, especially when some exit entrances are on the road to other indoor buildings. The lack of necessary indoor-outdoor navigation not only brings a lot of trouble for the passengers but also considerably decreases the efficiency of subway transportation system.

Conventional methods are to make each passenger learn from the posted map, which provides coarse outdoor situation information around the subway station. The map information, however, is insufficient to meet the navigation demand of most passengers. Moreover, it is non-trivial for passengers to find an appropriate navigation path quickly and accurately by looking the map, especially for users with no sense of direction. Although mobile device applications, such as Subway Navigation [1], are recently developed, they just integrate the existing map information inside subway station into mobile devices. Thus, they also cannot realize the indoor-outdoor navigation automatically. Moreover, conventional designs of navigation systems mainly focus either indoor or outdoor navigation [2], no matter the joint navigation system from indoor to outdoor.

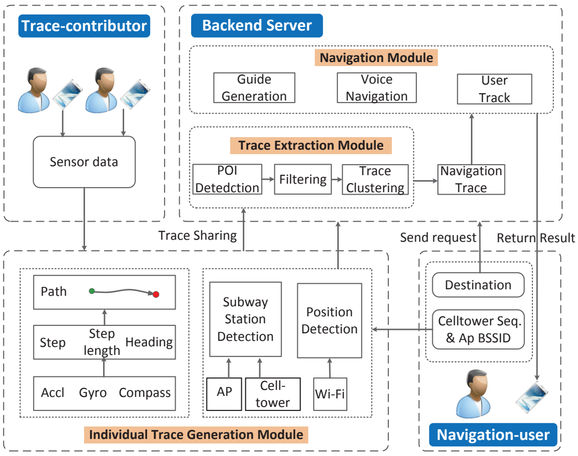

Figure 1: System architecture

In this poster, a joint navigation system is proposed, *ioNavi*, for subway transportation systems, which can be easily deployed in a crowdsourcing way without the support of comprehensive indoor localization systems. The *ioNavi* system consists three major components (Fig.1). (1) Each of trace-contributors makes its mobile device automatically record the walking trace and rich set of sensing data along the trace, from its beginning point in a subway station to an outdoor destination. A self-motivated contributor will report its individual walking traces to a backend server for upcoming usages. (2) The backend server continuously collects and processes such inaccurate individual traces, so as to derive more available navigation traces and expand the navigation area in both indoor and outdoor area. (3) A navigation-user will achieve a recommended navigation trace according to its coarse indoor position and an outdoor destination. Meanwhile, the user also contributes its actual walking trace and associated sensing data to the backend server.

2. CHALLENGES AND TECHNIQUES

The implementation of system, however, entails substan-

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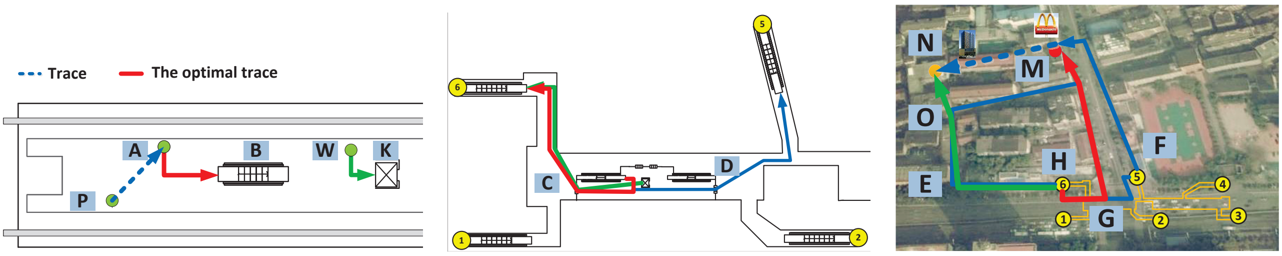

(a) Traces on floor one (b) Traces on floor two (c) Outdoor traces

Figure 2: Traces from subway station positions to outdoor destinations.

tial challenges which require practical solutions to cope with.

First, both trace-contributors and navigation-users should start with detecting whether or not they locate in a subway station and which subway station before executing the *ioNavi* system. In the case of a wrong detection of the subway station, each shared indoor-outdoor trace is not only unusable but also consumes unnecessary energy due to record the trace via a mobile device. Moreover, such wrong traces will directly misguide the following navigation-users. In this work, motivated by the fact that each subway station has been covered by distinguishing Access Points (AP) and signal strength of the cell-towers, we design a dedicated method using such identifiable metrics to detect the subway station. Thus, all of trace-contributors and navigation-users trigger the *ioNavi* system only when necessary.

Second, although trace-contributors instantly report their indoor-outdoor traces to the backend server, such individual traces could not be directly shared with the following users. The root cause is the lack of accurate locations and measurements during the indoor-outdoor trace and the fact that the observed walking path sometimes cannot reflect the planed walking path due to the interference of the crowd. Accordingly, the backend server has to extract useful traces from mass of disorganized traces so as to share with navigation-users. In this work, we combine the point of interest detection, dead reckoning, and trace clustering to realize the trace extraction by the backend server.

Finally, a navigation-user may naturally find multiple navigation traces from the backend server. The key challenge is how can the backend server derive and recommend an optimal navigation trace with the shortest walking distance. In this work, we utilize both historical knowledge and latest information to accurately derive the optimal trace for each navigation request. On the contrary, it is possible that none of extracted trace at the backend server involves the current position of a navigation-user. To solve this problem, we recommend the trace, whose starting point is closest to the current position of the navigation-user. After the end of navigation, the user also contributes its actual walking trace and associated sensing data to the backend server. That is, each navigation-user can further act as a trace-contributor.

3. PERFORMANCE EVALUATION

Evaluation methodology and scenarios. The *ioNavi* prototype is implemented on different android phones, including Galaxy S4, MI3, and Nubia Z5. All of such mobile phones are equipped with the inertial sensors (accelerometers, compasses, and gyroscopes), light sensor, Wi-Fi module, GPS module, and GSM module. In this poster, we conduct the experiments from the *Yingbin Road* station and expand to the whole subway line 2 in Changsha, China.

Navigation Performance. To evaluate the navigation performance, we consider four contributed traces from the indoor position A in the *Yingbin Road* subway station to the outdoor destination M, i.e., $McDonald's$. As shown in Fig.2, there exist three blue traces and one red trace from A to M. The red trace is the optimal one.

Five volunteers participate in this experiment. Note that, they are not aware of the navigation routes at the beginning, and only know that the destination is $McDonald's$. The navigation performance is evaluated under three situations.

There exist many traces from the user's starting point to the destination. There exist four traces from A to M in Fig.2. The red trace is the optimal one among them in terms of the walking distance and time. In this experiment, they start with inputting the destination as the $McDonald's$ and the starting point as A. Then, *ioNavi* returns the recommended walking traces to their mobile phones. We find that all of navigation-users can successfully reach the destination along the provided trace. This experiment confirms that *ioNavi* can recommend an optimal navigation trace, when there exists many traces from the user's starting point to the destination.

None of shared traces starts at the user's current position but at least one shared trace ends at the user's destination. As shown in Fig.2, none of those shared traces starts at the P and ends at the destination M. After any volunteer queries the $McDonald's$, the system return a blue dash trace from P to A as the first stage and another trace from the A to the destination M. According to such two stage traces, all volunteers can successfully reach the destination M.

None of shared traces meets the user's navigation requirement, but the user's starting point and destination point are involved by some shared traces. In Fig.2, the trace-contributor shared two traces, $A \to M$ and $W \to N$ (green line). In our experiment, *ioNavi* navigates volunteers walking from A to N. Obviously, none of shared traces meets such navigation requirements. However, *ioNavi* can derive out a new trace, which can guide volunteers successfully reach the destination, i.e., $A \to B \to C \to H \to E \to O \to N$.

4. REFERENCES

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