User Context Recognition for Navigation Systems in Public Transportation

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***Abstract*—Navigation systems have become ubiquitous in today's individual transport. They guide users to their destinations and adapt to both external traffic conditions and the user's preferences. In contrast, public transportation systems still lack well-engineered solutions to support user navigation. Navigation features may however significantly improve comfort for public transport users. For instance, passengers may be pointed to different transportation means if delays or congestions occur on the route to destination. Offering such a service requires the system to continuously ascertain the current location of a passenger. To perform location ascertainment in an efficient and reliable manner, we propose a novel framework to establish vehicle-to-passengers communication and adequately process the thereby collected data. Using this framework, we aim to recognize the route over which a passenger is traveling and consequently determine whether a dynamic adaptation of the route itself is required or not.**

I. Introduction and Motivation

The Global Positioning System (GPS) has recently become an ubiquitous presence in our daily business. One of its applications is the ability to guide people to a chosen destination in an outdoor scenario. We distinguish between public and individual transport, where in the latter case personal navigation systems guide users to their destinations and adapt to both external traffic conditions and the user's preferences. In contrast, public transportation systems are still lacking sophisticated support for the user navigation, although thanks to a wide distribution of personal mobile devices, e.g., smartphones, most of the passengers are equipped with suitable technology. The user navigation in public transportation is a desired feature for several reasons, including the ability to provide route informations for a commuter by a rapid recognition of the public vehicle which he is currently riding, notifications for tourists about getting into a wrong vehicle, or support pensioners on the road.

There is a main difference in public transportation over the individual transport in terms of using GPS for navigation. It is the fact that it is not about a simple finding of a short route to the desired destination, but to get a correct match between the user's position and suitable public means of transport. A public vehicle is suitable in terms of schedules, routes, and current delay informations. Furthermore, in addition to the user's preferences, public transportation navigation systems have to take real time information in to account, e.g., a bus can run late or a connecting train can be rescheduled or cancelled. We concentrate our research on deviations from the recommended route which are based on user's decisions, both intentional or not. However, adaptations triggered by traffic conditions require often an established coordination between different transportation companies.

A simple approach to this problem adapted from navigation in individual transport may rely on comparing GPS values between the user and the potential public vehicle to determine passengers current context. By *context*, we mean the information whether the user is currently in a public vehicle and if so, which vehicle. However, comparing coordinates would not provide a reliable result for user context due to the lack of signal in underground stations or the fact that several vehicles can be close to each other and thus produce identical results. Furthermore, since GPS tends to show inaccurate values particularly in urban scenarios, two devices can respond with different values although they are close together.

Therefore, relying on GPS is not sufficient to determine user's context. Since modern mobile devices are widely distributed and provide several sensors, e.g., accelerometer or gyroscope, their readings can be used for the given task. Recent work has shown the possibility to determine the user context by observing patterns provided by the accelerometer [1] or to identify whether a vehicle is currently leaving a station or is still waiting for the passengers [2].

Based on these observations and motivated by the challenge to provide a reliable user context recognition for public transportation, we propose a novel framework to establish vehicle-to-passengers communication and passengers and adequately process the thereby collected data. Using this framework, we aim to recognize the route over which a passenger is travelling and consequently determine whether a dynamic adaptation of the route itself is required or not. Therefore, sensor values from both vehicle's and the passenger's smartphone are combined in order to achieve the localization of the user at high accuracy.

II. Framework for Context Recognition

To determine passengers' context our framework analyses the user's environment by taking sensor readings from both the user's and vehicle's mobile device in to account. Therefore, we deploy smartphone in public vehicles and collect sensor readings, e.g., accelerometer, gyroscope, GPS, or a list with discovered WiFi networks. We especially interest in sensor readings from public transport in the user's range.

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In the final step, our framework compares this informations with those from the passenger's smartphone.

A crucial issue in this context is the specification of an adequate architecture for our system. A centralized solution may be viable for collecting sensor readings and building user context. Based on transmitted data, an algorithm provides a match between user and possible vehicle by comparing fingerprints for collected data. The communication to the server is based on the internet connection of the mobile phone provider, for which reasons this solution has a lot of drawbacks. It requires a stable link to the server and forces users to pay for the communication. Furthermore, the algorithm on a centralized server requires a rough knowledge about the user's current location and all potential vehicles in his range, to avoid a comparison between all uploaded sensor readings. In addition, transport companies may raise concerns over providing such informations to a third party.

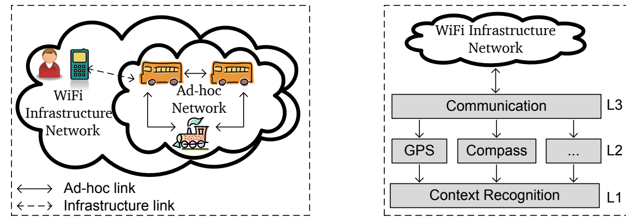
Due to these drawbacks and for privacy reasons, we decided to implement the evaluation part at the user's smartphone and to disclaim the usage of a centralized server. In the following, we describe the data collection subsystem and the layer architecture for the context recognition.

A. Data Collection Subsystem

For collecting sensor readings from vehicles and for providing this informations to a user, our approach requires two types of networks. The first one is a WiFi ad-hoc network for public vehicles, which broadcast their sensor readings. Received values are stored on the vehicle itself using a buffer of fixed length. Therefore, each public vehicle contains sensor values for all public means of transport in its range. To make collected informations available for the passengers, a WiFi infrastructure network is required which is spanned by the public vehicles. Hence, a passenger is able to connect to this network and to receive all sensor readings for public means of transport in his range. For a better understanding of our collection approach, we refer to the Figure 1a.

B. Layer Structure for Context Recognition

The framework's architecture which is implemented on the user's mobile device is depicted in Figure 1b and consists of three layers. The upper layer (L3), so called communication-layer, is responsible for the vehicle-to-user connection establishment and for retrieving collected sensor readings from vehicles in the user's range. The gathering process is triggered periodically and communicates transmitted data to the middle layer (L2). On this layer an individual fingerprint comparison for each sensor data row provided by both passenger and public vehicle takes place. The configuration of the middle layer depends on the sensor's availability on both the user's and vehicle's mobile device. Afterwards, for each sensor the lowest layer (L1) is informed with the calculated likelihood whether the passenger is inside the given vehicle according to the individual evaluation of the respective sensor. At this point all communicated decisions can be combined together by applying weights on it for making a final decision on the user current context.



(a) Communication for data collection (b) Architecture layers

Figure 1: Framework for Context Recognition

III. Outline of Future Work

After the presented conceptual work, the next steps will contain both the implementation and the collection of sensor values. Therefore, we plan to deploy mobile devices in multiple vehicles to gather sensor readings. For collecting data from android based mobile devices we will use the *funf* [3]. According to collected sensor values the evaluation part has to be implemented with respect to the observed data. Furthermore, we plan to investigate the impact of different means of transport on respective sensors. Our preliminary results show that accelerometer is more reliable for road traffic, since railway traffic fails to create measurable vibrations. Finally, we need to find effective sensor weightings and combinations for different means of transport.

IV. Conclusion

Within the scope of this extended abstract, we have presented a framework for user context recognition for navigation systems in public transportation. It allows to determine whether the passenger is still on the calculated route or a dynamic adaptation to the new context is necessary. By providing for this adaptive behaviour, our framework represents a first step towards the implementation of public transportation navigation systems.

References

[1] A. Ofstad, E. Nicholas, R. Szcodronski, and R. R. Choudhury, "AAMPL: Accelerometer Augmented Mobile Phone Localization," in *Proceedings of the first ACM international workshop on Mobile entity localization and tracking in GPS-less environments*, 2008, pp. 13–18.

[2] S.-T. Chang, Y.-C. Huang, and H.-Y. Wei, "Accelerometer-Assisted Power Efficient Wi-Fi Networking on Public Transpotation System," *SIGMOBILE Mobile Computing and Communications Review*, vol. 14, no. 1, pp. 16–18, 2010.

[3] N. Aharony, W. Pan, C. Ip, I. Khayal, and A. Pentland, "Social fMRI: Investigating and Shaping Social Mechanisms in the Real World," *Pervasive and Mobile Computing*, vol. 7, no. 6, pp. 643–659, 2011.