Opportunities for Leveraging Context in Pedestrian Navigation

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Abstract. Pedestrian navigation systems (PNS) need to incorporate contextual information to achieve a benefit for the user. However, most PNS do not incorporate this information. To study context in PNS we created the PNS ROSE. First we present the pedestrian navigation system ROSE which recommends context-aware events, context-aware routes and allows point-to-point navigation by means of mixed mode transportation. Secondly we discuss a field study of using ROSE in the city of Munich and derive implications for incorporation of context in PNS and describe our current research for adding support for more contextual factors.

1 Introduction

Pedestrian navigation systems (PNS) provide point-to-point navigation for users: given a starting point and an ordered list of destinations, the navigation system computes a shortest path between subsequent points and guides the users from one point to the next in the list. State of the art navigation systems are able to retrieve the current position of the user automatically via localisation technologies, such as the well known GPS. Thus, there is no need for the user to enter his current position. However there are many additional contextual factors, that can be taken into account to further improve user experience and satisfaction. We are currently extending the pedestrian navigation system ROSE [1] to address more of these factors.

This paper first gives a short overview on context aware navigation and recommendation and then afterwards we will introduce the ROSE system itself. In sections 4 and 5 we discuss the results of a user study concluded among 75 heterogeneous participants and a self experiment for identifying and measuring contextual factors. The following sections describe future extensions to ROSE for incorporating these findings, namely group recommendations in section 6 and adaptive routing in section 7. A short summary concludes this paper.

2 State of the Art

[2] discusses a context aware recommender system for mobile tourist applications named COMPASS. An early context aware navigation system can be seen in [3]. Dynamic Tour Guide [4] is a tour planning system for tourists which supports replanning of tours if the old tour turns out to be impossible to follow anymore. This can happen if a tourist visited one sight for a too long time. As contextual factors the system uses the available time for a tour, the opening hours of a sight and the current GPS Position of the user. In contrast to our System, PECITAS [5] is a mobile personalisable navigation system, which does not include recommendation of events or locations and routes are restricted to one starting point and one destination point only. For user adaptation, PECITAS generates multiple routes by using different heuristics (e.g. fastest route, or not taking any bus) and ranks them according to user preferences (walking preferences, number of bus changes, arrival at destination, sightseeing).

Compared to these systems, the unique features of ROSE are routing to multiple destinations, recommendation of events and POIs, and support of public transport based on live data.

3 Overview of the ROSE System

3.1 Sample Session

In this section, we present a short overview of the current implementation of ROSE and its client-server architecture. In a sample session we demonstrate how ROSE is used in practice. ROSE is a combination of a recommendation and a routing system for mobile devices. First, to get a recommendation, where to go or what to do, the user enters a query, like 'pizza', into his mobile phone (see 1, *left*). The recommender then generates a list of suggestions based on the user input and the user's preferences. In this example it would likely be a list of restaurants which serve food according to the users preference (see 1, *right*). After the user has chosen one of the presented options, the system calculates a route from the current location to the selected goal. Figure (see 2, *right*) shows a route overview from the users current point to his chosen destination.

3.2 The ROSE System

Context Aware Recommendation In the field of context aware recommender systems we developed a system that incooperators location and time context to suggest better results to the user. We select the time context as "now" so that the user will always find recent events and will never experience that an already past event is suggested for visitation. If the user wants to include events far in the future or browse already past events he can do that by adjusting the date parameter.

In location based services the users current GPS-location is provided to the system. That helps the user to find events nearby. If a user is in, for example,

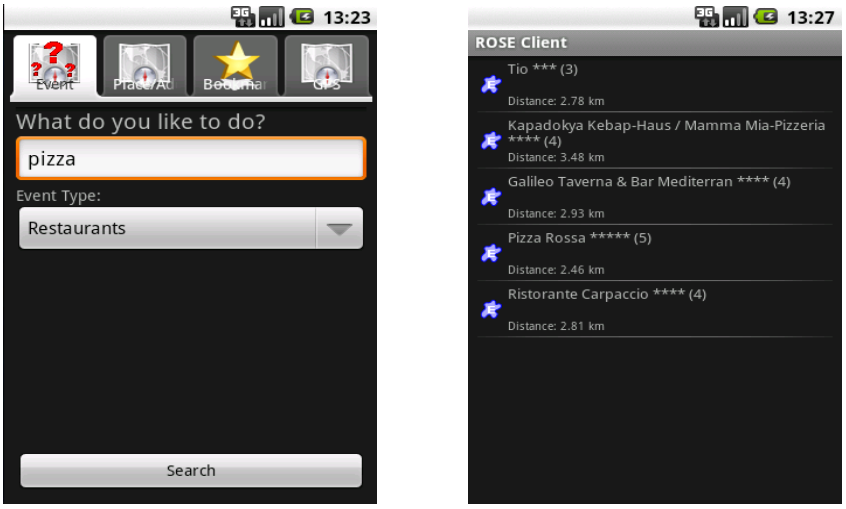

Fig. 1. *left:* Query, *right:* List of recommendations

Munich his motivation to travel to Nuremberg is very small to vistit for example the opening of a new museum. So we provide the user with a radius to enable him to find all desired events within his current position plus his chosen maximum radius.

We plan further to our already existing recommendation to display all results depending on distance to the users current location so he will always find events and points of interest closer to his location first and will be less on the move in between points of interest. This approach is similar to the one taken from the Magitti Mobile Leisure Guide [6].

Navigation To ease the traveling, public transportation is also considered. The system calculates a route from the user's current position to the nearest public transport option, which means of transportation to take, where to change transportation and how to walk from the last stop to the goal location.

Figure 2 shows, how the route is displayed on a map on the mobile phone. If the route includes public transport, the next possible departure time is shown and the user is informed, whether he has to hurry to catch a bus or reach his goal in time. As map data OpenStreetMap is used.

System Architecture To address the limitations of mobile devices like limited computational power and slow and expensive internet access, we constructed a client server-architecture: expensive calculations are conducted on the server and the transferred amount of data is minimized. The ROSE system consists of the ROSE server, a J2EE application which integrates different services from multiple service providers and offers them as RESTful web services to the ROSE client.

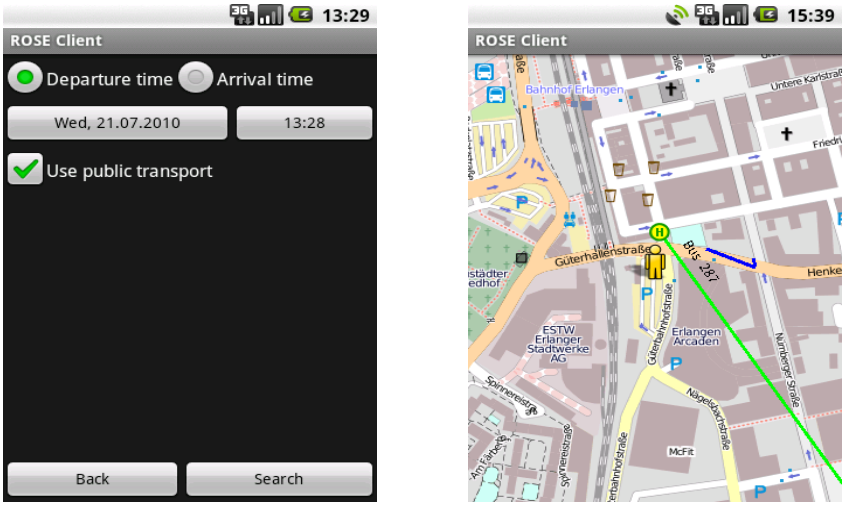

Fig. 2. *left:* Options for route generation, *right:* Route overview

At the moment, we are developing two prototypes of the client, one running on J2ME enabled mobile phones with GPS receiver and one on Google Android.

Routes, timetables, and live public transport data is obtained via VPN (Virtual Private Network) from a local public transport company.

On the client side, different localization services are integrated to cover a large number of devices and to allow navigation in various locations. As the start and end of a journey are often in buildings, and to support navigation also in subways a suitable indoor localization technique is needed. Therefore, we incorporate the Fraunhofer WiFi-localization module [7].

4 User Preferences

To evaluate the question, which preferences people have when getting event recommendations or navigation suggestions, we conducted a survey among 75 visitors. Participants had to rate how important different criteria are for them, ranging on a scale form 0 (unimportant) to 5 (irresistible). Figures 3 and 4 show the average for every criteria.

The results (see Figure 3) show that the participants have not given any criteria a significant preference. Out of this results we determine that only individual and situation adaptive criteria can help us in improving our routing. Our survey shows (see Figure 4), the most important fact is, that a recommended event suites the user needs as much as possible even if the trips are longer and more expensive. Furthermore it is of particular interest, that participants did value the recommendation by others the least. That can mean that collaborative filtering systems (an overview of collaborative filtering is given in [8]) are less helpful to improve recommendation performance.

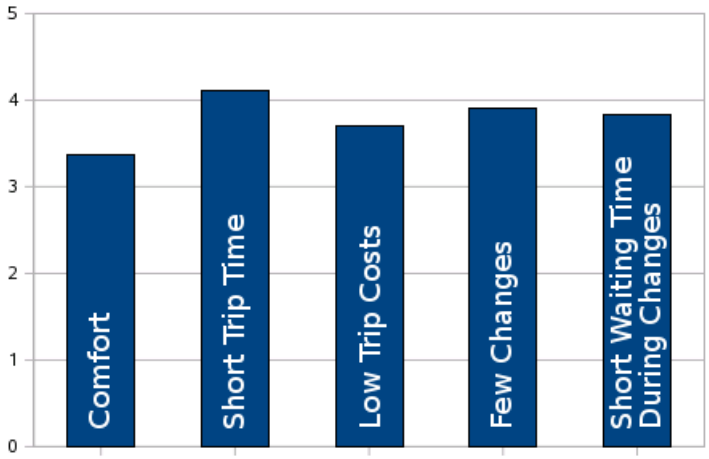

Fig. 3. Criteria for public transport routes

5 Contextual factors of large scale distributed events

On Lange Nacht der Wissenschaften ("Long Night of Science") [1] current scientific results have been presented to the interested audience at different places of the Metropolitan Area of Nuremberg/Fürth/Erlangen throughout the night.

Visitors easily get overstrained by the vast amount of offered events. Thus, lots of visitors plan their evening at Lange Nacht der Wissenschaften in advance. ROSE shall simplify this cumbersome planning process by recommending complete journeys for this event.

To further explore contextual factors in the ROSE system we conducted a self-experiment at Lange Nacht der Musik ("Long Night of Music") in Munich. This event is similar to Lange Nacht der Wissenschaften, having music events instead of science events in various places like theaters and bars across Munich downtown, which are all connected by public transport and additional buses specific for this event. We have been a team of four people using two mobile phones with ROSE clients besides traditional information (e.g. event list, city map, public transport map) to plan the evening and navigate from event to event. Our experiences concerning context will be described here.

We faced difficulties finding extra shuttle services stations which were temporary set up only for the Long Night of Music. One solution to this problem would be to also show these temporary bus stops on the map in the ROSE client.

Another problem we encountered was that it was sometimes necessary to arrive several minutes before the begin of the event to get a seat. A system for planning routes for these events should consider this contextual factor. Also we had events which have been already closed because not enough visitors came to

[1] http://www.nacht-der-wissenschaften.de/

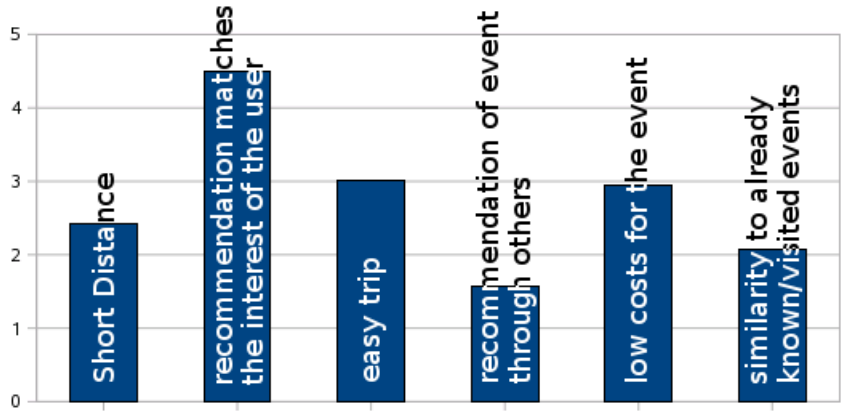

Fig. 4. Criteria for recommendations

see them. Therefore we need a more sophisticated approach to replanning which will be covered in section 7.

It was particular difficult to find events which all group members were interested in. Therefore we printed out information about all events. Each of us rated the events separately, then we aggregated the scores (using arbitrary aggregation methods) and sorted them according their score. This operation was very cumbersome and lasted approximately one and a half hours. Therefore we conclude that there is a necessity for group recommendation support on mobile phones.

6 Group Recommendation

The problem of accounting to the various interests of group members introduces a new class of context parameters: the preferences, interests and goals *of other people* involved, when a user uses the system. We call these users *indirect users*, as they convey their interests to the system only over the user. Imagine two people who want to find a restaurant. Ansgar tells Betty, that he fancies Italian food. As Betty likes pizza, she uses this information to ask a recommender system, where there is a good Italian restaurant. In this scenario, Betty is the user and Ansgar is the indirect user.

This led us to conduct a preliminary user study, to find out, whether there exist indirect users in the ROSE scenario. We asked 12 people, with how many other people they normally go to different places. The result is shown in Table 6.

Although many people go shopping alone, they almost always go to restaurants and cultural events with one or more accompanying persons.

	alone	with companion	as a group
shopping	62.5%	29.2%	8.3%
restaurant	0.0%	25.0%	75.0%
cultural events	8.3%	45.8%	45.8%

Table 1. Out going behaviour of potential PNS users

As cultural events and restaurants are the most important goals of recommendation for ROSE, it can be clearly seen, that future systems need to incorporate besides non animated contextual factors human contextual factors of the other people involved.

To address this problem, we started research on group recommendation and routing for groups. We envision a distributed mobile system which helps groups of people to decide, what to do, where to go and how to go there: Every user can enter his interests and goals into his mobile device. The systems recommends events and places interesting to all users and helps them to arrive at an agreement, where to go. These two steps correspond to the scientific areas of group recommendation [9] and group support systems (GSS) [10]. Then, routes for each person are calculated with the respect to meeting the other persons as soon as possible and thus allowing a partial conjoint journey. This topic has, by best knowledge of the author, not yet been covered by research, nor exist systems to address this. We are currently working on this topic.

7 Adaptive Routing

For Lange Nacht der Wissenschaften in Nuremberg in October 2009 we developed a planning system for relieving the user from the burden of manually planning her trip. The user has to rate the events into 3 categories: no interest, some interest and must see. This rating is then used by the planning system to produce an optimal round trip in advance which is then printed out and taken along by the user. Both the travel duration between events and the visiting duration of the events are estimated values. Nevertheless the preplanned trips are feasible and small delays can be easily compensated. In fact we identified the opposite problem that some events have to be skipped because of different reasons:

- overcrowded events
- events with too few spectators ("nothing going on")
- events that do not meet user expectations
- cancelled events
- not yet opened or already closed events

The problem was even bigger on Lange Nacht der Musik in Munich in May 2010 where we were already warned by the organizer that preplanning might not be useful for music events. Therefore we decided to try it on our own and crafted

a plan for our round trip. During our trip we had to replan many times, mostly because of overcrowded or already closed events.

This let us to the conclusion that an adaptive routing system on a mobile device is needed which would easily replan a tour in case of a skipped event. In Munich we even faced another problem: The skipping of events wasted a lot of time because there were no alternatives around and thus overall travel time was nearly exceeding the overall visiting time at the events which is very frustrating for the visitor.

If replanning is such a common case during these round trips it should be considered right from the beginning before the first plan is presented to the user. Every event can be given a skipping probability and with this information an optimal adaptive route can be calculated which maximizes the total expected enjoyment under the assumption that a replanning takes place in case an event has to be skipped. A similar approach is well studied in the field of time-dependent stochastic shortest path problems were optimal adaptive routing algorithms were developed to calculate an optimal routing policy [11].

In fact humans can do something similar when planning round trips with high uncertainty: They should try to find an alternative nearby event for every event they plan to visit. If the planned event must be skipped they can switch to this alternative. Events that do not have alternatives should be left out right from the beginning. This strategy resembles a local repair process in contrast to our current research interest of a general global expected enjoyment maximization under the replanning assumption.

8 Conclusion and Future Work

There are several contextual factors which still have to be integrated in PNS. We identified various contextual factors in the area of PNS and suggested methods to include them in PNS. Because people visit most events and locations together, supporting groups of users will become one major challenge for future developments of PNS. As context changes continuously and highly probably, replanning has to be considered right from the beginning to calculate the maximum total expected enjoyment.

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