Tell Me Your Needs: Assistance for Public Transport Users

Bernd Ludwig (*), Martin Hacker (+), Richard Schaller (+), Bjoern Zenker (*)
*Chair for AI +Embedded Systems Institute
University of Erlangen-Nuremberg
Haberstr. 2, D-91058 Erlangen
ludwig,martin.hacker,richard.schaller,
bjoern.zenker@cs.fau.de

Alexei V. Ivanov, Giuseppe Riccardi
Department of Information Engineering and Computer Science
University of Trento
I-38050 Povo di Trento
riccardi,ivanov@disi.unitn.it

ABSTRACT
Providing navigation assistance to users is a complex task generally consisting of two phases: planning a tour (phase one) and supporting the user during the tour (phase two). In the first phase, users interface to databases via constrained or natural language interaction to acquire prior knowledge such as bus schedules etc. In the second phase, often unexpected external events, such as delays or accidents, happen, user preferences change, or new needs arise. This requires machine intelligence to support users in the navigation real-time task, update information and trip replanning. To provide assistance in phase two, a navigation system must monitor external events, detect anomalies of the current situation compared to the plan built in the first phase, and provide assistance when the plan has become unfeasible. In this paper we present a prototypical mobile speech-controlled navigation system that provides assistance in both phases. The system was designed based on implications from an analysis of real user assistance needs investigated in a diary study that underlines the vital importance of assistance in phase two.

Author Keywords
mobile navigation, replanning, plan execution monitoring

ACM Classification Keywords
H.5.1 Information Interfaces and Presentation: Multimedia Information Systems; H.5.2 Information Interfaces and Presentation: User Interfaces

General Terms
Algorithms, Experimentation, Human Factors, Languages

INTRODUCTION
With the availability of GPS enabled smart phones and mobile devices constantly growing, more and more applications provide location based services to their users. Many of them compute suggestions for points of interest (POI) and therefore fall in the class of recommender systems ([2, 4]).

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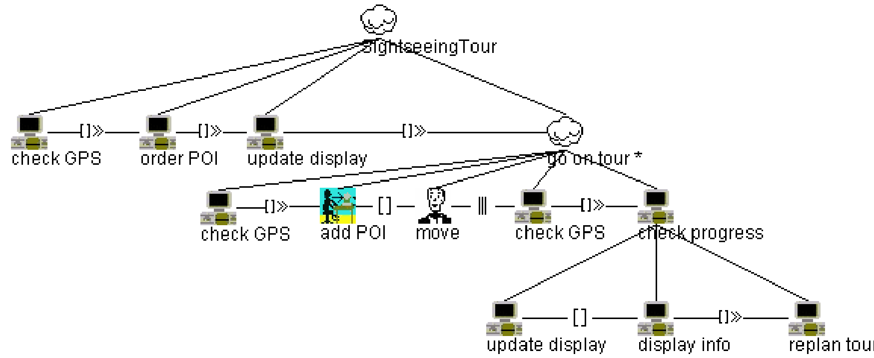
However, people, tourists and residents (with a bunch of every day affairs) often need further assistance: they have to complete a task involving of a series of POI. In order to implement this requirement in an application, we need to consider some implications for the recommendation algorithm: Firstly, as it has to provide a solution for the user's task, it should not recommend just individual POIs, but a set of them: *the computation of recommendations needs to be not only context-aware, but task-aware*. Secondly, assistance aims at providing support to users in executing the task (phase two). At any time, users may wish to start interacting with the system and modifying the tasks according to needs which came up while completing the task: *the computation of recommendations needs to be interactive* as well. When user communicate new needs, the system must adapt its solution (replanning). It is this kind of assistance that distinguishes systems that support the user in both phases from such that provide only recommendations in phase one.

In this paper we present our design methodology how we have developed systematically a navigation system of the type discussed above. As a first step we conducted a diary study to assess assistance needs of pedestrians and public transport (PT) users. The results of the survey were formalized using Concurrent Task Trees (CTT) in order to identify and understand which kinds of problems have to be solved for providing assistance. Building upon this analysis we could specify the necessary components of the hybrid system architecture and the requirements for the user interface.

ASSISTANCE NEEDS ON PUBLIC TRANSPORT USAGE
In order to better understand the assistance and information needs of PT users, we conducted a pilot user study. For this step of requirements engineering, nine participants who use PT regularly for private and business purposes kept a diary about their trips within a period of two weeks. The diary contained a questionnaire for each one-way trip, collecting some general information about the trip and contextual factors. Furthermore, the subjects could record their assistance needs emerging on the trip (see Figure 1(a)). In order to capture as many requirements as possible, we asked the participants to record "any question or problem" they were concerned with on the trip. To allow for objective interpretations, we also collected as much background information as possible in the questionnaire. For a quantitative analysis of the user responses, we classified all recorded needs (i.e. the

Q1 Explain information or assistance need
Q2 Indicate reasons why you had this need
Q3 Where and when did it come up during the trip?
Q4 Indicate the relevance of a solution for this need: (very relevant – not relevant)
Q5 Does this need come up often? (just today – sometimes – often)
Q6 Could you find a solution? If not, please indicate why.
Q7 If you found a solution was it hard to find (hard – easy) and satisfactory (satisfactory – not satisfactory)? Why?

(a) Questionnaire used in the user survey



(b) Concurrent task tree for the task of organizing and executing a tour consisting of a set of POI. The task is hierarchically decomposed in phase one (`check GPS` ⟩⟩ `order POI` ⟩⟩ `update display`) and phase two `go on tour` (see the text for more details).

Figure 1. Requirements engineering based on a diary study and the resulting task analysis

Pa	arrival time of a certain means of public transport
Pc	live information about public transport connection or line
Pd	departure time of a certain means of public transport
Pd+	departure time under additional external constraints
Pg	geographic information about PT facilities, e.g. bus stop
Pl	duration of a trip
F	solution how to organize a foot walk without using PT
F+	as above under additional constraints mentioned explicitly
T	solution how to organize a trip using public transport
T+	as above under additional constraints mentioned explicitly
fee	information about the price of a trip or how to acquire a ticket
n.a.	other type of information or no information need involved
?	requested information out of the public transport domain

Table 1. The tags used to label the collected data.

information retrieval need	**type**	?	Pa	Pc	Pd	Pd+	Pg	Pl	fee	n.a.
	abs.	11	4	16	9	2	3	1	4	32
	rel. (%)	13	5	19	11	2	5	1	5	39

find solution for a task	**type**	?	F	F+	T	T+	n.a.
	abs.	1	2	5	6	17	51
	rel. (%)	1	2.7	6	7.3	21	62

verify own proposal for a solution	**type**	Pc	T	T+	n.a.
	abs.	4	1	3	74
	rel. (%)	5	1	4	90

verify information from external sources	**type**	Pc	n.a.
	abs.	2	80
	rel. (%)	2	98

describe external circumstances	**type**	Pc	n.a.
	abs.	1	81
	rel. (%)	1	99

Table 2. Information needs registered by users in the diary study

answers to the questions in Fig. 1(a)) according to the type of missing information that underlies the assistance need using the schema in Table 1.

From the collected data we observe that people need support in *deciding* about a sequence of actions to complete complex tasks: Table 2 indicates that a large portion of requests concerns usual information retrieval tasks with a given set of search parameters – most of them concerned with departure and arrival times of trains, busses, trams, and subways: 35 out of 82 diary entries involved an information retrieval assistance need resulting from a lack of such information (see the information types Pa, Pc, Pd, Pd+, Pg, Pl). 19% addressed information about live data on PT, such as *current delays* or *extraordinary changes of stops*. Obviously, people are unsure about the information necessary to decide how to complete a task. Even more interesting is that the need to *find solution for a task* is involved in 38% of all diary entries. In these cases, users did not know how to solve a PT task or – even more complicated – how to integrate a PT trip into a more complex task as one step of a solution. Examples of such problems are: *The recommended bus is late. Should I wait for the next one or should I start walking towards the train station? Whatever, I still have to find a cash machine as I need some money urgently.* In this example, assistance requires problem solving: a solution starting in the current situation consists of multiple steps to be executed in a certain order. Moreover, often from the diary entries it can be concluded that assistance to the user requires updating the recommendation to new needs or changes in the current situation: While executing a part of the solution for a complex task, this process is often interrupted by tasks resulting from new information needs. An example for this is the following problem recorded in the diaries: *Is it possible to buy something in the shop over there quickly without missing my bus?* In this example, the new need *to buy something in the shop over there* is communicated. In order to provide assistance in such a case, an assistance system must be capable to *replan* a solution for a complex task comprising both the interrupted (*take a bus*) and the interrupting task (*buy something*).

Two major conclusions can be drawn from these results: Firstly, at any point of time, the interface must allow the user to express new needs and to require assistance in solving tasks related to these needs. The task trees for an application contain all activities and sequences of these activities. A flexible user interface allows users to refer to any activity

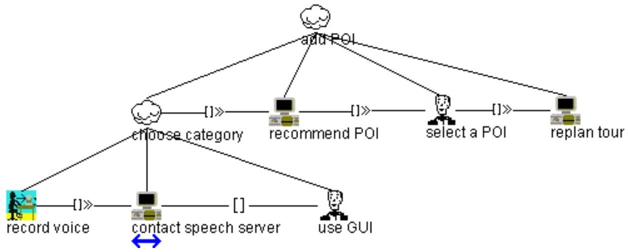


Figure 2. CTT for the task to communicate a new assistance need

at any time in order to express a need. The system must find the activities necessary to satisfy the identified need (planning a solution). Secondly, modifications of a solution are required when external events not foreseen in phase one prevent parts of the solution from being executed (replanning).

TASK ANALYSES TO MODEL ASSISTANCE

As the second step of our design methodology we performed a task analysis by constructing Concurrent Task Trees (CTT, see [5]). Due to space constraints, we just discuss the CTT for `SightseeingTour` in Figure 1(b): For executing this task, it is preassumed that the user has already selected a set of POI in phase one (see Figure 3(a) and (b)). The task is solved by recommending an order in which all POI can be visited with minimal effort to get from one to the next. This order depends on the current position of the user (see tasks `check GPS` and `order POI`). Finally, the route is displayed (`update display`) on the mobile device (see Figure 3(c)). This concludes phase one. In phase two, the task progress depends on live information gathered while the user is on tour: The phase two task `go on tour` iterates until all POI have been visited or the user explicitly abandons sight seeing. Users may visit the POI in the recommended order, but they can also deviate arbitrarily from it: in this case, the tour will be replanned by computing an optimal order for the remaining POI.

As far as the interaction between user and system is concerned, at any point of time during a tour users can activate the context menu of the application in order to communicate a change of their intentions: According to the Concurrent Task Tree in Figure 2, they can ask for a recommendation of nearby POI either by speech input (`record voice`) or by using the GUI (`use GUI`). The fact that there are always two modalities for input at the user's disposal, is important for the reliability of the user interface. Whenever it is too difficult to pronounce e.g. the name of a POI, the user can select it from a list on the screen. Anyway, in order to successfully complete the task, it is necessary to replan the tour: the selected POI is added to the list of POI in the tour as the next POI to visit. This strategy of replanning is based on the simplifying assumption that a communicated change of the user's intentions must have an immediate impact as the user communicates an urgent assistance need.

IMPLEMENTATION

As the third step of our design methodology, on the basis of the CTT discussed above, we implemented the interface that allows users to express their information needs in spoken language as well as using the GUI. The system is implemented as an Android application following the client-server paradigm: while the time-critical replanning for small, local problems is done on the mobile phone, the generation of complete tours and speech recognition run on the server. In order to transmit speech data from the phone to the server the application executes a phone call to a SIP phone number. The server propagates the signal to speech recognizers for English, German or Italian. The result is returned to the mobile application for further processing. Solutions for tasks are computed on the phone. The system continuously monitors the state of execution for the current solution and initiates replanning as to be discussed below.

Replanning As discussed in the previous section, in many cases when users require assistance they need support for solving a complex task in which a set of POI is involved: in particular, to solve the task it is necessary to visit each POI in the set once (Travelling Salesman Problem). An exact solution for this problem is computationally expensive. The problem becomes even harder if task constraints such as time tables, opening hours or limitations for the time available to complete the task have to be taken into account. In this case, it is necessary to drop some POI. This problem belongs to the class of Orienteering Problems [9], for which we implemented an approximative solution using a genetic algorithm and a constraint solver. Optimization is based on the minimization of the overall travel time, the most important criterion inferred from the user survey presented in [7]. To evaluate this algorithm, we implemented a prototypical assistance system for tourists in Trento[1]. It computes sightseeing tours across the Trento city center.

User Interface At any point of time, users can tell the system about changes in their preferences (see Fig. 3(a)). For the natural language understanding component we use the system described in [3]. After shaking their mobile phone, users can start speaking (e.g. "I would like to eat something in a restaurant.") or push a button. A list of possible locations is presented. Next, users can choose a destination that matches the query. Now, the route is replanned with the chosen location being the next sub-goal[2] (Figure 3(c)). Note that as a consequence the ordering of POI may be rearranged as the system always tries to minimize the overall trip length.

Evaluation Although the system has been successfully tested by staff members[3], the evaluation of the usability is still an ongoing work. In the next evaluation step the system will be used as a tool for collecting more data about the users' assistance needs. Test persons will be able to record their needs using the application instead of the paper questionnaire from the pilot study. In this way, we expect to gain additional data about the users' needs and feedback about the application which we can exploit for evaluation purposes.

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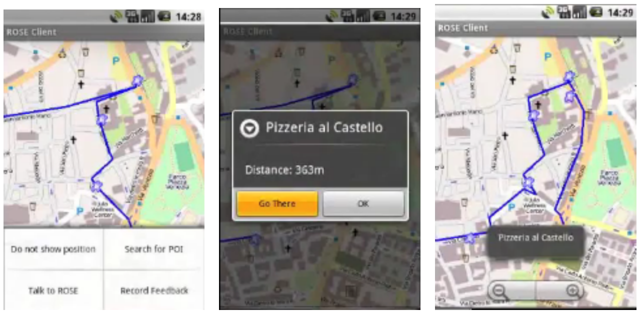
[2]Our next version allows to place the new goal anywhere in the list.

[3]for a demo video see `http://www.rose-mobil.de/aktuelles.php`.



a) b) c)

Figure 3. Screenshots illustrating the task of adding a POI to the tour.

RELATED WORK

The work on Cyberguide [1] started the research on mobile tourist guides and gave initial contributions to the design of these systems. The proposed model implements spatial awareness of the mobile device and history tracking, but it lacks the recommendation function. A more sophisticated mobile context-aware city guide is COMPASS [8]. The authors use context both as a soft and hard criterion for recommendations. This work focusses on the system architecture and the user study, evaluating the usefulness of a context-aware guide, whereas the recommendation step is described briefly. City Guide [6] is a mobile information system that has been evaluated extensively in a user survey. The system features a planner for a tour comprising a set of user-selected POI. The field study in which the system has been tested demonstrates the high acceptance of such information systems. In contrast to our system, City Guide does not support assistance for PT and the recommendation of POI. The systems presented so far lack the capability to provide assistance with PT connections. In this field numerous applications are available, e.g. a German web portal[4] lists more than 40 applications for Germany. However, almost all applications are proprietary developments of local PT providers. Most of them offer the same information also available from a PC at home and only a few of them take the current position into account. Moreover, the applications are not compatible. Therefore, a user needs at least one application for each city. Finally, the applications neither support phase two nor do they recommend solutions for complex tasks. As a consequence, they cannot replan a solution for a task in order to react on information obtained during the trip.

CONCLUSIONS AND FUTURE WORK

From our analysis of the state of the art we conclude that research about methodologies and system architecture for assistance in phase two is still at the beginning. Our system indicates that it is feasible to build assistance systems supporting complex tasks from the perspective of the user. This can be achieved by integrating different problem solving algorithms in a hybrid system architecture. This approach from the system designer perspective needs to be complemented by a user centered approach: using e.g. CTT one can specify how all the components work together towards a solution of a task that can satisfy the assistance needs of the user. We are aware of the fact that the system for Trento does not completely cover all the assistance needs entailed in our diary study. Therefore, we do not consider the system as sufficient proof of concept for assistance in phase two. Its benefit, however, is that we are now able to conduct user studies in which test persons will use the phone to report their needs. To analyze the performance of the genetic algorithm on the mobile, we are working on a system that computes tours on the phone. Our focus for future work lies in the conditional dependencies between recommending POI at a certain step of a solution for a task and planning the steps of the solution. This amounts to modelling explicitly the effects not just of actions as steps of the solution, but also of decisions on the planning process. For this purpose, the genetic algorithm will be combined with planning techniques.

[4] `http://www.fahrplanauskunftssysteme.de`

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