A survey of mobile guides

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ABSTRACT

In recent years, a large number of mobile guides have been proposed (and commercialised). In this paper we attempt to give a survey of the field. We select a set of systems that offer unique features or have been influential in the development of the field, and compare them according to several criteria. These criteria are derived from some key issues that mobile guides have to face. We conclude by pointing out future challenges in developing mobile (navigational) assistants.

1. INTRODUCTION

Mobile guides and navigational assistants have come a long way since the first research prototypes (e. g. [1]). At the moment, there are not only many different research projects working on the topic (some of which we will present in this paper), but there are also several commercial services available to mobile phone users and car drivers (e. g. [7]). Recent developments such as the emergence of ubiquitous computing [20] and the convergence of portable computing devices (such as Portable Digital Assistant (PDAs) and laptop computers), wireless communication (such as wireless LAN or the General Packet Radio Service (GPRS)) and localisation means (such as the Global Positioning System (GPS)) have further increased the pace of progress. The arrival of the new generation of mobile phones that provide a higher bandwidth and allow for a more precise localisation will most likely have a similar effect.

Therefore, we think that there is a need for a survey of systems providing mobile guidance. Due to the large number of available systems, we can only present a selection. We try to choose those systems that either offer unique features (such as resource adaptation) or have influenced the development of later systems. Before we compare the different systems, we first discuss various issues that mobile guides have to address. These issues then serve as a basis for the comparison, which constitutes the main contribution of the paper. We conclude on some remarks about what may be key challenges for future mobile guides.

2. ISSUES

Mobile guidance systems provide their users with location-based services (LBS) such as navigational assistance where and when they need them most. However, this convenience does come at a cost: A system aimed at supporting the user in situ requires some compromises compared to a stationary system such as a traditional desktop computer. On the one hand, the resources available in a mobile scenario are severely restricted – which will most likely be the case for the foreseeable future as well. This does not only concern technical resources such as bandwidth, storage capacity, display size, and computational power but also cognitive resources, e. g. when the user is performing a secondary task. The latter is more frequent in the mobile scenario due to the user moving around and the situation changing continuously.

On the other hand, situational factors gain importance compared to a stationary setup, where the situation is more or less static (the user sitting in front of her computer). The affordances of the environment, for example, strongly influence the way, in which the user interacts with a device: If she is riding a fast car, navigational instructions will differ from those given to a slow-walking pedestrian. Furthermore, the user's abilities and properties can have a strong impact not only on the way the system best interacts with the user but also on what services a user requests. For example, a deaf user has little interest in acoustic directions, and a user that is pretty familiar with an area most likely does not appreciate elaborate explanations about known sites.

A key factor for determining the current situation is the position of the user. Unfortunately, there is no technology that can measure the current position precisely at all times. Electromagnetic devices such as electronic compasses or accelerometers suffer from interference by electromagnetic fields, the popular Global Position System (GPS) does not work properly inside buildings or in narrow alleys, and light-based systems such as infrared beacons require a tight infrastructure. Hence, mobile guides should be able to cope with positional information of varying quality.

This applies for information access in general: most systems assume a permanent and reliable connection to a server in order to work properly. However, especially wireless connections are prone to (temporary) outages. Therefore, it is desirable for mobile guides to function (to some degree) even if there is no connection or if information is partially unavailable.

A further challenge consists of designing situated interfaces that enable the user to access the services provided by a system in an intuitive way. Due to the limited resources of most mobile devices – e. g. in terms of display size, speech recognition, and computational power – this task is even more difficult than for stationary systems. Moreover, situational circumstances may impose additional constraints such as audio output being unfeasible in a church.

Generally, a mobile system suffers from severe resource restrictions while at the same time, it has to deal with a continuously changing situation of the user. This is one of the main future challenges in designing mobile guides.

3. COMPARISON

There are already too many mobile guides – either commercial ones or research prototypes – to list them all in this paper. Therefore, we will focus on the ones that have some unique features, or that introduced a specific feature. For example, there are several EU funded projects such as CRUMPET (creation of user-friendly mobile services personalised for tourism) [15] or PEACH (personal experience with active cultural heritage) [14] that aim at building navigational assistant systems. In addition, further projects are continuously initiated such as the new Special Research Centre "Umgebungsmodelle für kontextbezogene Systeme" (environment models for context-aware systems) [17, 8], and virtually every car-manufacturer nowadays offers more or less sophisticated car navigation systems. Our goal in deciding which systems to review here was to select a representative subset of all projects and systems concerned with situated interaction on spatial topics.

Therefore, we focussed on systems that offer unique services (such as the transparent transition between indoor and outdoor usage) or that have been influential throughout the field such as the Cyberguide project, which was on of the first mobile guides: Abowd et al. [1] developed a system that provides maps and information services about certain indoor and outdoor locations. All maps and information were stored on the mobile device. Indoor positioning relied on infrared beacons, and GPS was used outdoors. The second project in our overview is the GUIDE project [5]. The system provides information about the city of Lancaster. The mobile component was connected wirelessly to an information server. Based on the current WLAN access point the guide senses the position and provides guidance and information services through a browser-based interface. The Hippie/HIPS project [13] has been concerned with the development of an exhibition guide, which provides guidance and information services. The guide senses infrared beacons installed near all exhibits. From these observations about the visitor's journey through the exhibition the systems creates a user profile and suggests interesting exhibits augmenting them with background information.

The CyberAssist project at the CyberAssist Research Center (CARC) [4] pursues the ambitious goal of designing devices and techniques to enable a human user to access a variety of location-based services through a simple and unified interface. An innovative battery-less device called Cobit ('compact battery-less interaction terminal') uses small solar panels for energy *and* data transmission [12]. TellMaris is a prototype for a mobile tourist guide that was developed at Nokia Research Center [10, 11]. It is one of the first mobile systems that combine three-dimensional graphics with two-dimensional maps and that run on a mobile device (a mobile phone). The first prototype was developed for the city of Tønsberg, Norway to help boat tourists in finding locations of interest (e. g. hotels). During summer 2002, a first exploratory field test was conducted with a small number of volunteers (see [11]).

The LoL@ (local location assistant) system [2, 16] is a mobile tourist guide for the city of Vienna designed for the next generation of mobile phone networks, the Universal Mobile Telecommunications System (UMTS). It was developed at the Forschungszentrum Telekommunikation Wien and is currently undergoing empirical evaluation. Baus et al. [3] developed a hybrid pedestrian navigation system in the project REAL, which provides guidance and information services. Their system helps the user to find locations by generating graphical route descriptions. Information about the users' position in the environment results from a combination of GPS/compass positioning outdoors and the use of infrared transmitters (beacons) inside buildings. The system has the ability to adapt the graphical presentations according to various technical as well as cognitive resource restrictions. Within the SmartKom framework, where a multi-modal dialogue system allows for speech, gestures, and mimic interaction [18], a mobile communication assistant is currently under development. The mobile assistant offers information and navigation services using GSM/UMTS for communication and GPS for positioning purposes. The information presentations combines maps, natural language and an anthropomorphic presentation agent. The Deep Map [9] project at the European Media Lab in Heidelberg aimed at building a tourist guide for the city of Heidelberg. Aside from providing several services related to space, it is the first system to provide a sophisticated multi-layered approach for the determination of the user's current position.

3.1 Basic features

Table 1 lists the aforementioned systems, and compares them along several criteria. In this table, entries in round brackets indicate that the corresponding functionality is either severely limited or not realised yet. (For example, CyberAssist does not yet provide guidance.) The symbols ⊕ and ⊖ stand for 'does apply' respectively 'does not apply'. Deep Map, for example, takes into account the task the user is performing, while SmartKom does not. We compared all systems along several dimensions. From the table, we can see that some systems such as SmartKom or GUIDE do indeed offer a number of different services, while some are fairly limited in this regard (e. g. TellMaris).

In terms of positioning, roughly half of the systems rely on GPS. Another large group uses light to determine the user's current position (either infrared or white light), e. g. beacons that send out IDs, which enable the corresponding receiver to look up the location in a table/database. Some systems have been designed from the beginning to support various sensors, i. e. they are adaptable with regard to the technology used to measure the user's position. Four systems (GUIDE, LOL@, REAL, and Deep Map) include some means of interacting with the user to determine her position. These capabilities range from simply clicking on designated alternative positions (REAL) over static list to choose from (GUIDE) to dynamic lists based on the last known position of the user (LOL@). Only Deep Map includes a sophisticated model based on position history, situational knowledge, and visibility (cf. [9]), which allows for the dynamic generation of interactions tailored to the current user and situation.

	Cyberguide	**Hippie HIPS**	**GUIDE**	**CyberAssist**	**TellMaris**	**LOL@**	**REAL**	**SmartKom**	**Deep Map**
Basic features									
Services	information, communication	guidance, information, (localisation), communication	guidance, information, reservation, communication	(shopping assistant), (ticketing assistant), (guidance), (spatial reminder), (disaster mitigation)	exploration	guidance, information, tour diary	guidance, (information)	guidance, localisation information map interaction	guidance information data collection, map interaction (reservation)
Positioning	GPS, adaptable	infrared beacons, compass	network cells, interaction	modulated light, adaptable	manually, (GPS)	GPS, adaptable	infrared beacons GPS compass, interaction	GPS, adaptable	GPS, adaptable, interaction
Situational factors									
User	⊖	⊕	presentation, content selection	envisioned	⊖	⊖	during tour tour planing	⊖	⊕
Context	⊖	⊖	presentation, content selection	(envisioned)	⊖	⊖	during tour planing	presentation	⊕
Task	⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊖	⊕
Adaptation capabilities									
Cognitive Resources	⊖	⊖	⊖	⊖	⊖	⊖	⊕	⊖	(⊖)
Technical Resources	⊖	⊖	⊖	⊖	⊖	⊖	⊕	⊖	(⊖)
Lack of information	⊖	⊖	local proxy/cache	⊖	⊖	⊖	⊖	robust	(⊕)
Position	⊖	two levels of precision: room vs. exhibit	simple interaction	⊖	synchronised manual navigation in 3D and 2D	communication of imprecision, interaction	communication of imprecision, simple interaction	⊖	communication of imprecision, inference, interaction
Interface and user interaction									
Language	English	English	multi-lingual	(Japanese)	English	English	German, English	dynamic, multi-lingual	dynamic, multi-lingual
Multi-modality	⊖	⊕	⊖	(envisioned)	⊖	⊕	⊕	⊕⊕	⊕
Evaluation	field test?	?	questionnaire	?	exploratory study	?	field test	?	field test
Architecture									
Type	interacting applications	client-server	client-server	multi-agent system	interacting applications	client-server	hybrid	multi-blackboard	multi-agent system
Interaction	proprietary	proprietary	proprietary object model	standard-based	proprietary object model	standard-based	proprietary	standard-based	standard-based

Table 1: Comparison of systems providing navigational assistance and related services (entries in brackets are not entirely realised, ⊕ and ⊖ provides the corresponding feature)

3.2 Situational factors

The consideration of situational factors is another relevant feature for systems aimed at real-world use. We therefore compared all systems in terms of whether they take into account user- and context-related information. (Due to its fundamental importance, we do not subsume the user's current position under context but rather consider it a 'basic feature' of a system.) Additionally, we analysed how they handle the impact of the user's current task. Roughly half of the reviewed systems includes user-related information but they differ greatly in how this information is included. Hippie contains a sophisticated user-model, which is continuously updated, and which is used throughout the entire system. GUIDE as well as REAL rely on a static user-model that is used to adapt the generated presentations and their content in the former case. In the later case it only affects tour planning. Deep Map currently also uses a static user model. This comparison is nearly mirrored in the case of contextual information and its inclusion into the systems. GUIDE as well as REAL take into account contextual information for specific tasks: presentation and content selection in the former case and during tour planning in the later case. SmartKom distinguishes three 'scenarios', which are used to adapt the presentation accordingly. Deep Map currently relies on a small static contextual model but considers contextual information on all stages of computation. Deep Map is also the only system that takes into account the task the user is currently performing, e. g. in object evaluation.

3.3 Adaptation capabilities

A further very relevant feature set for real-world applications is their ability to adapt to changes in their physical and virtual environment. Resource limitations on the cognitive and technical side fall into that category. REAL is the only system that can dynamically adapt to the varying availability of resources. Although most other systems have been optimised for mobile use, they are – at most – resource-adapted (following Wahlster and Tack's taxonomy [19]). Another common problem in real-world applications lies in the lack of relevant information: often, information (such as situational factors or database entries for world objects) is only partially available or not at all. In this case, a system should gracefully degrade instead of abruptly failing. Only GUIDE, SmartKom, and Deep Map incorporate this feature. GUIDE can handle network outages – which result in the unavailability of the central database – by relying on a scaled-down local version. SmartKom has been designed to be robust against such events: although it does not compensate for it, it is able to inform the user about the event and to continue to function properly. Deep Map can handle the loss of network connection in a similar way as GUIDE does. While the underlying model is designed to handle the lack of relevant information, this part of it has not yet been implemented.

Since knowledge about the user's current position is a central factor in determining her current situation, it is highly important for a real-world application to be able to adapt to varying quality of positional information. Consequently, all but three of the systems reviewed in this chapter provide some means to address this issue. Cyberguide, CyberAssist, and SmartKom currently do not dispose of adaptation mechanisms. Hippie distinguishes two levels of granularity: either the room is known, which the user is currently located in, or the exhibit that she is facing. TellMaris entirely relies on manual navigation (although later versions will employ GPS), and can therefore operate independently of the user's current position. GUIDE provides a means to select the current position from a (static) list of sights. LOL@ goes one step further by dynamically generating a list of street names based on the last known position, but it can also communicate the imprecision of a position to the user. To do so, it displays the current position on the map as a circle, which grows with imprecision. REAL relies on the same metaphor, and also provides some simple means of interaction: clicking on certain highlighted spots on the map allows the user to specify her current position more precisely.

While most systems provide one or more means to address varying quality of positional information, only GUIDE, LOL@, and REAL allow for some limited interaction to cope with this problem. Deep Map goes beyond this in several ways: on the one hand, it provides a sophisticated algorithm for dynamic interaction that is optimised for speed and minimal interaction. On the other hand, these interactions are not tied to a specific modus. Furthermore, it can employ induced frames of reference to address the (partial) lack or imprecision of positional information [9].

3.4 Interface and user interaction

The interface of a system and the available means of interaction are the parts of the system that are most apparent to its user, and that therefore greatly influences her perception of the system. Hence, we included a comparison in terms of support of natural language and multi-modality in our review. Most systems are statically tied to one language; GUIDE and REAL allow for several different languages, but are still static. Only SmartKom and Deep Map support dynamic multi-lingual interaction by introducing a semantic layer that encodes interactions in a way that is independent of the actual target language. While Deep Map relies on the preverbal message [9], SmartKom goes a step further by employing a full plan-based mechanism and sophisticated language processing features. The same is true in terms of multi-modality, since SmartKom has been specifically designed to account for various modalities such as speech, gestures, and mimic expressions. While Deep Map could (due to the preverbal message) in principle support a comparable range of modalities, its current implementation is limited to verbal/textual input and pointing (which also applies to Hippie, LOL@, and REAL).

Maybe due to the fact that most systems still face many technical and interface issues, empirical evaluation of most systems is not yet a prime concern. From the literature, it seems that only a few systems have been evaluated to some degree. The GUIDE system was used with 'real' tourist visiting the city of Lancaster, which have been asked to rate their experience with the system. In [5] a small user study based on direct observation, audio recording and a time stamped log of user interactions is reported. In this study the majority of users appreciated the ability to use the system as a tour guide, a map or a guidebook. In their opinion location-aware navigation and information retrieval mechanisms were useful and reassuring and they trusted the information and navigational instructions provided by the system. Within the TellMaris project, a further study was reported [6], which investigated the usefulness of combined 3D/2D presentations with a limited number of participants and a limited prototype. 3D maps were received positively, although some users complained that they had difficulties in comparing the 2D and 3D maps provided by the system, which they attributed to some lack of correspondence between them. In the 3D map the user had the possibility to choose between a walking level (pedestrian view) and a flying level (birds-eye view). In the study, the flying mode was found much easier for navigational purposes.

Further user studies have been announced but, as far as we know, not been publicly reported yet. Most of the systems that we review in this paper apparently were either only analysed in field tests or not at all although most authors acknowledge the importance of empirical evaluation.

3.5 Architecture

Another point of practical importance is the architecture of a system. While not being directly apparent to the user, it has a serious impact on the system in terms of extensibility and adaptability. Hence, we compared all systems with respect to what type of architecture they are built on, and how interaction between different components is realised. Although all systems rely on a modular architecture, they do so in different ways. Hippie, GUIDE, and LOL@ are based on the client-server paradigm: a 'client' (i. e. a web browser) accesses a 'server' (i. e. a web server). While this approach allows for the easy addition of multiple clients, it highly depends on a reliable connection between client and server, which is not always a given (e. g. in wireless networks). In addition, the server is a single point of failure – making the systems relying on it is less robust than less centralised approaches. Cyberguide and TellMaris are built using interacting applications. Although this approach is more decentralised, it has some drawbacks: On the one hand applications may be specifically designed for a certain device/platform, which may hinder dynamic distribution. On the other hand, their interaction is often problematic because different programming languages may have to communicate and there is no standard on how to realise this. The architecture of REAL is a hybrid that combines a client-server approach with that of interacting applications, therefore inheriting the respective advantages and drawbacks. SmartKom relies on an approach that was originally developed in the Verbmobil project: Multiple blackboards are used to enable distributed applications to interoperate. While this approach allows for easy extension, interactions between various components are implicit and hard to track. Multi-agent systems address this issue by introducing an explicit message passing mechanism, and also include standardised look-up services. This enables systems relying on this approach (CyberAssist and Deep Map) to compensate for failures of certain components, to dynamically add or remove components, and to transparently relocate components to other platforms. In addition, multi-agent systems facilitate the encoding of contents using a standard language that is explicitly defined. Aside from CyberAssist and Deep Map, only LOL@ and SmartKom employ such an encoding scheme, while all other systems rely on a proprietary interaction language.

4. CONCLUSION

In this paper we attempted to give a survey of mobile guides. We selected a set of systems that offer unique features or have been influential in the development of the field, and compared them according to several criteria such as the services they provide, or their adaptation capabilities. These criteria were derived from some key issues that mobile guides have to face, e. g. the continuously changing situation of the user. None of the systems reviewed here addresses all the issues but some can already cope with a large subset.

In the future, mobile guides will have to take into account more and more situational factors in order to provide their users with a user-friendly experience. In addition, the adaptation to real-world problems such as network outages or the lack of precise positional information will greatly improve the usefulness of mobile guides. Another as yet unresolved issue is the type of architecture that is suitable for mobile guides, e. g. what are the benefits of a client-server approach compared to a multi-agent system? Closely related to this issue are the questions of how to represent the information contained in the system, how to best present it to the user, and how to facilitate the interaction between various services.

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