Towards Orientation-Aware Location Based Mobile Services

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Abstract

Within this paper we present an approach on how orientation sensors built into mobile devices can enable a new paradigm for mobile service discovery and use: In conjunction with 3D models of urban terrain, mobile devices can act as virtual pointers to services and information anchored at geographic locations such as buildings or landmarks. We outline a system architecture that enables this new form of orientation- and location-sensitive service discovery. We describe our experiences with a prototype device consisting of a plain, mass market mobile phone and a custom-built shell that houses a magnetic compass and a 2-axis tilt sensor. Concluding, we describe our ongoing research project that will apply the described concepts and technologies in practice.

1 Introduction

Location based mobile applications are gradually gaining importance in the consumer electronics and telecommunications market. The growing proliferation of increasingly powerful handheld computing devices and the availability of relatively low-cost, embeddable GPS receivers have made navigation applications for PDAs and smartphones a popular product. At the same time, mobile network operators are adopting location based services (LBS) as an increasingly important component of their service portfolio [15]. Typical examples of LBS offered today are direction finding services or yellow pages-like services (e.g. "Where is the next pharmacy?"). Despite the fact that the success of LBS has as yet been less than anticipated, user evaluations have shown that the demand for location aware information is high [10]: Since users potentially have access to their mobile device all the time, they expect it to be of particular value for accessing information about unfamiliar environments or locations; when looking for a specific service or in emergency situations; or for accessing the kind of information that may change while they are on the move: Examples are traffic information or train schedules with delay information.

We argue that location aware applications offer a real added benefit to the user – provided that they deliver information that is relevant, easy to find and well-focused. Our work is motivated by the assumption that a more natural and intuitive way of discovering and using location aware services is essential for meeting these criteria. It can not only play a key role for an improved awareness and an increased use of current LBS; it can also open up new possibilities and application areas for future mobile service ideas.

This paper is organized as follows: In section 2, we introduce the idea of "Point-to-Discover" – our concept of accessing information and mobile services by pointing at geographic locations with a handheld device – and develop a possible system architecture for a Point-to-Discover service platform. In section 3, we address two technical issues that are crucial for the feasibility of our concept: the accuracy limitations of current positioning methods and orientation sensors and the availability of three dimensional environment models. In section 4, we focus on a prototype of a Point-to-Discover-enabled mobile device we developed. We explain the hardware used and point to related work. Finally, in section 5, we present our ongoing research project, in which we will practically apply the technologies and concepts described in this paper.

2 Point-to-Discover

The advent of 3G technology and more complex mobile devices poses challenges to researchers and designers of mobile applications: The mobile interface is restricted to tiny displays and keypads; information retrieval on the fly is slowed down by bandwidth limitations and network latencies. In all described restrictions we expect advances, but whenever interface components increase in size, they challenge the mobile devices' mobility. For this reason we introduce a new user interface paradigm for how people can discover information on the go and use mobile services in the future, by combining orientation detection with accurate satellite positioning.

Today, users access mobile services and information through WAP menus or search engines, mobile operator portals or by simply entering a URL in their phone's browser. We envision a more natural method of discovering services and information: With the help of three-dimensional models of urban terrain, services can be 'anchored' virtually at geographic locations. Mobile phones function as pointing devices towards these services. For example, users could access the train schedule, get delay or estimated arrival time information or purchase tickets online by simply pointing their mobile phone towards a train station; or they might participate in a sweepstake by pointing at an advertisement billboard.

An early realization of a similar approach was presented by Wasinger et al [19]: They describe the implementation of a navigation application on a PocketPC PDA. The application uses GPS in conjunction with a magnetic compass and allows the user to indicate an area of interest on a two-dimensional map by pointing the device into a direction in the real world. The focus of their work, however, is primarily on multimodal and speech in- and output in the context of mobile navigation and exploration services.

We suggest to enhance the concept presented by Wasinger et al by adding the third dimension: Using the 3D orientation of the device – measured with a magnetic compass and a tilt sensor – and a 3D environment model rather than a 2D map, the system can determine the user's real perspective and specifically select the services that are available within the user's real field of view. Figure 1 portrays the architecture of a Point-to-Discover system as we envision it. Three domains constitute the system: The client domain consists of the user terminal running the necessary client software ("Point-to-Discover Browser"). The operator domain is formed by the Point-to-Discover service platform. The platform stores geo-referenced meta-data as well as geo-referenced links to content and processes the Point-to-Discover requests. It is important to mention that the actual content itself is not held in the operator domain. The operator domain merely provides the "lookup service" for the content offered by external providers over standard WWW infrastructure (3rd party domain). After the lookup, the client device will access the content directly from the 3rd party services, using the links received from the service platform.

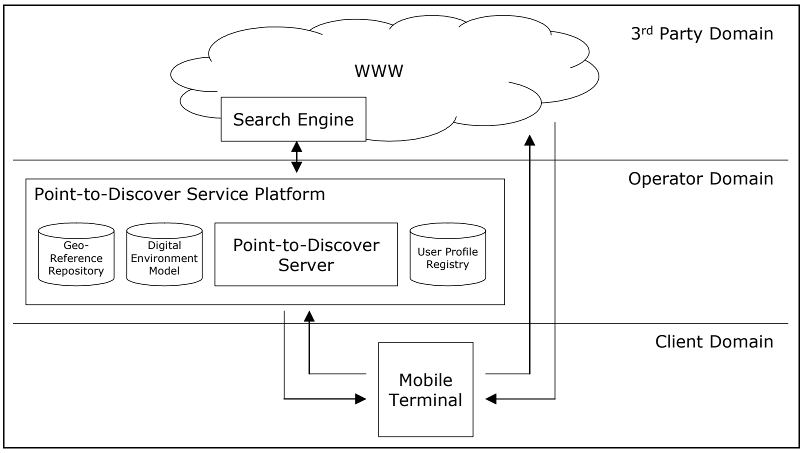

Figure 1. Point-to-Discover service platform architecture and usage scenario

The Point-to-Discover service platform consists of a digital environment model, the geo-reference repository, the actual Point-to-Discover server and (optionally) a user profile registry. The service platform can – but need not necessarily be – hosted and maintained by a mobile network operator. When the user points at an object in the real world and triggers a request, the mobile phone transmits its position and orientation sensor readings to the Point-to-Discover server. The server queries the digital environment model and identifies the area of interest that is indicated by the pointing ray (defined by the position coordinates and the orientation vector). With the estimated area as a parameter, the server queries the geo-reference repository.

The geo-reference repository is a database that holds a list of geo-referenced links to 3rd party content and services. These links are maintained by the platform operator and therefore allow placement of specially promoted, branded services (such as e.g. the sweepstake linked to the advertisement billboard mentioned in the example above). Optionally, a user profile (stored in the user profile registry) can help to tailor the service selection towards the personalized preferences of the user before the list of service links is returned to the device. In addition to the user profile, the platform might take further external parameters into consideration: Time of day, time of year or the weather at the current location are just a few examples of context parameters that might help to match the service selection better towards the user's current situation.

Additionally, the geo-reference repository also stores geo-referenced meta-data, such as street or landmark names. The Point-to-Discover server can use this meta-data to generate a refined search query for an Internet search engine. That way, the user can obtain information about a landmark (e.g. a particular building of historical relevance) from the World Wide Web without the need to type; and even without the need to know the name of the landmark he or she is pointing at.

3 Technological Requirements

For the successful implementation of a Point-to-Discover service platform as described above, two factors are critical: First, there are considerable accuracy constraints on both positioning and orientation detection that influence the quality of service selection. Second, the Point-to-Discover principle heavily depends on the availability of sufficiently accurate 3D environment models. In this section, we therefore first address the factors that lead to accuracy degradation. Secondly, we want to point out the relationship between our digital environment model and geo-reference repository components and Geographic Information Systems (GIS).

Selection Quality

Two sources of error influence the service selection process: The positioning error and the error introduced by the orientation sensors. Depending on the positioning method, positioning accuracy in the range of several 10 meters can be achieved in urban environment (see [17] for a comparison of different technologies). If we assume that the Point-to-Discover concept is required to identify an object with a radius r, at a distance d, the overall error is given by

$$e = e_P + d \tan(\alpha) \equiv r$$

with e_p being the positioning error and alpha being the angular error as illustrated in Figure 2. If we require to identify an object with a radius r=2.5 meters, at a distance of d=100 meters, the currently deployed terrestrial range based localization technologies are inadequate. The necessary positioning accuracy we would need to achieve is at least 5 meters, with no angular error. Assuming differential code phase GPS, which reaches an accuracy of $e_p \approx 1$ meter, we require a more reasonable angular error of ~1°.

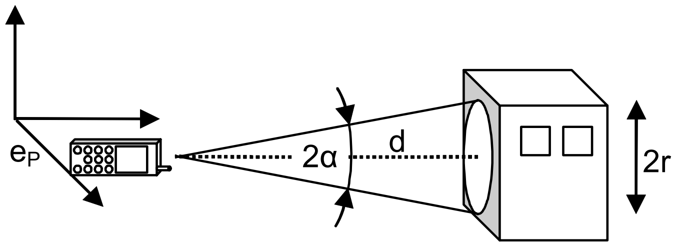

Figure 2. Angular error.

3D Environment Models

The capabilities of the digital environment model and the geo-reference repository which are part of our Point-to-Discover service platform are closely related to the capabilities of Geographic Information Systems (GIS). Until recently, GIS were mainly restricted to modeling the world in two dimensions due to the high computational effort required for three-dimensional data manipulation and display and, in particular, the complexity involved with gathering three-dimensional environment data. More recent methods such as automatic or semi-automatic building reconstruction from high-resolution aerial imagery and/or LIDAR (LIght Detection And Ranging) scans, however, make gathering of large-scale three-dimensional environment data feasible [13], [9]. Further techniques, for instance combining aerial imagery with ground-level 3D laser scans and/or geo-referenced photographs [7], [11] even aim at automatically reconstructing detailed textured 3D models of urban environment. We argue that these advances in the area of 3D environment modeling indicate that sufficiently accurate large-scale data will indeed be readily available to enable the Point-to-Discover principle. In fact, our platform's digital environment model/geo-reference repository components can be implemented using commercial off-the-shelf 3D GIS, which are already available from a number of vendors and are e.g. being used by mobile network operators for network planning purposes.

4 Orientation-Aware Mobile Devices

Based on an ordinary mass-market Java-enabled mobile phone, we developed a prototype for a Point-to-Discover-enabled client device. The phone has a custom-built shell attached to its back that houses a three-axis tilt compensated compass module purchased from a commercial vendor.

The module essentially combines a magnetic compass with a 2-axis tilt sensor on a single chip, mounted to a 2.5 by 4.5 cm printed circuit board. The sensor module is connected to the phone via the serial port.

Magnetic Compass

The magnetic compass detects the heading of the device by measuring the direction of the earth's magnetic field. Unlike GPS-based methods, which derive the heading from the sequence of the most recent position fixes, this solution also works for stationary users. Magnetic compasses do not require extensive computational power, nor do they need any prior knowledge about the environment – both of which is the case for approaches based on optical image recognition ([12], [18]). First mobile phone models with comparable embedded magnetic compass sensors are already being introduced by handset manufacturers (e.g. Nokia model 5140). The compass used in our prototype device can reliably resolve <0.07mGauss. Compared to the typical magnetic fields in the x- and y- horizontal plane, which are in the range of 200 mGauss (more at the equator, less near the poles), it achieves a theoretical resolution of 0.02°. This resolution is practically superposed by magnetic sensor errors, variations of the earth's magnetic field, nearby ferrous materials, A/D converter resolution errors and temperature effects (as discussed for instance in [5]), summing up to a total accuracy of about 1-3° and 0.1° resolution.

Tilt Sensor

The 2-axis tilt sensor detects the mobile phone's pitch and roll angles (compare Figure 3) by measuring the acceleration that is exerted on a small mass (or heated gas) by the earth's gravitational field. The mechanic principle of the sensor makes it particularly robust against external influence, such as electrical interference or magnetic fields. Compared to gyroscopes or electrolytic fluid based sensors, no rotating or pendulous parts are required, allowing smaller structures and higher resonant frequencies. The operating frequencies of such sensors easily achieve several 100Hz, thereby allowing the detection of fast user movements.

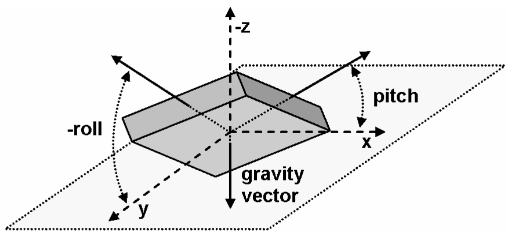

Figure 3. Tilt angle definitions.

Similar to the heading error, the tilt error of the sensor used in our prototype is less than 1°, resulting from temperature effects and measurement noise [1]. The acceleration sensor reaches maximum sensitivity when held normal to the gravitational field (parallel to the earth's surface). Since the tilt sensor used in our prototype is based on a single acceleration sensor for each axis, the resolution therefore decreases for tilt/roll angles above 60°. Consistent resolution of 1° for the entire range from 0 to 360° can be achieved by combining the measurements of 2 sensors arranged perpendicularly [1].

Related Work

Hinckley et al [8] demonstrated how tilt sensor data can be exploited locally on a PDA device. His experiments were aimed at proving that orientation detection can be used beneficially as a novel input modality that makes single-handed operation more natural and intuitive. Examples from his experiments include the activation of screen-scrolling by tilting the device or the activation of the PDA's voice recording functionality by holding it to the mouth and ear like a phone. Hinckley's experiments also included discussions and measurements of error probabilities and false-positive detection for certain gestures, such as the voice-recording activation gesture. Similarly, Eslambolchilar and Murray-Smith [6] implemented tilt-controlled zooming and scrolling on a PDA device. Their test users found that tilt-based single hand control was an intuitive solution to the problem of navigating large documents on small displays. We implemented a number of applications that also use the orientation of the device for single-handed input. One example is an experimental concept user interface with tilt-controlled slide-in menus. Another example is a dexterity game where the user must guide a ball through a maze without dropping it into holes in the maze floor. A photo of the device prototype, together with pictures of both applications is shown in Figure 4.

Figure 4. Device prototype and demonstrator applications

Due to an obvious potential for mobile entertainment and gaming (which has already turned into an important revenue channel for mobile network operators, with an estimated market worth $1.2 billion by the year 2006 [3]) and the possibilities for novel input modalities like gesture recognition, handset manufacturers have recently announced a number of mobile phone models which will be equipped with comparable tilt or acceleration sensors. Similar plug-in sensors for PocketPC PDAs are also available commercially.

5 Creative Histories Mobile Viewer

In addition to the local application of orientation awareness, as described in the previous section, we also aim to demonstrate the technical feasibility of the full Point-to-Discover concept in a practical setting: The objective of the "Creative Histories" project [2], [16] is to create a high-quality three-dimensional model of a cultural heritage site. The area being re-created is a square in downtown Vienna, Austria: the Josefsplatz. The virtual 3D model of the Josefsplatz is thereby not just confined to its current constructional state. Rather, it encompasses the constructional state in different historical stages throughout history: Users of the system will be able to navigate through the model in real-time and virtually move back and forth in time. A second objective of the project is to associate a virtual information space with the 3D model: Users can quickly and intuitively retrieve different types of historical information and media (such as textual information, historic images, photos or audio and video documents) related to certain locations, such as buildings or landmarks on the square.

Based on the device prototype introduced above, we are implementing a client application for a mobile smartphone device. With this application, the phone acts as a "real-world navigation tool" to the Creative Histories system: The user's field of view on the square is continuously determined by the on-device GPS and orientation sensors. By downloading appropriate chunks of 3D geometry and suitable textures from the geometry server, the mobile device can render a live simulation of what the user's view looked like in a different historical epoch – the screen acts as an interactive "window to the past". The application also indicates when there's additional information available for a certain building or object. The user can access the information by pointing the device towards the real-world object and selecting it in the 3D simulation [4].

Figure 5 shows a view of the Josefsplatz together with an emulator screenshot from an early version of the viewer application, which features a yet untextured environment model. As can be seen, the application implements the Point-to-Discover metaphor described earlier: Using positioning and orientation detection, the mobile phone functions as pointing device in the virtual 3D model of the real world. Furthermore, the application extends the basic principle by also representing the 3D model itself visually on the screen.

Figure 5. Creative Histories mobile viewer application (untextured model)

6 Acknowledgements

Project Creative Histories is funded by the WWTF (Wiener Wissenschafts-, Forschungs- und Technologiefonds) funding programme. It is a collaborative research project of the Austrian National Library, the Austrian Research Institute for Artificial Intelligence (OFAI), the Research Center for Virtual Reality and Visualization, Ltd. (VrVis), and the Telecommunications Research Center Vienna (ftw.).

7 References

[1] *"Accelerometer fundamentals"*, memsic application note, AN-00MX-001, http://www.memsic.com/

[2] *"Creative Histories – The Josefsplatz Experience"* project homepage. http://www.josefsplatz.info/

[3] *"Sega, AT&T Wireless Push Mobile Gaming."* Wireless News Factor Press release, http://www.wirelessnewsfactor.com/perl/story/19673.html

[4] Baillie, L., Kunczier, H., Anegg, H., *"Rolling, Rotating and Imagining in a Virtual Mobile World."* 7th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI 05), Salzburg, Austria, September 19-22, 2005.

[5] Caruso, M., *"Applications of Magnetic Sensors for Low Cost Compass Systems."* Honeywell SSEC, http://www.magneticsensors.com/

[6] Eslambolchilar, P., Murray-Smith. R. *"Tilt-Based Automatic Zooming and Scaling in Mobile Devices – A State-Space Implementation."* Proceedings of the Mobile HCI conference (Mobile HCI'2004), Glasgow, Scotland, September, 13-16, 2004. Springer-Verlag, Heidelberg, 2004, 120-131.

[7] Frueh, C., Zakhor, A., *"Constructing 3D City Models by Merging Ground-Based and Airborne Views."* IEEE Computer Graphics and Applications, Vol. 23, no. 6, pp. 52-61, November/December 2003.

[8] Hinckley, K., Pierce, J., Sinclair, M., Horvitz, E. *"Sensing Techniques for Mobile Interaction"*, 13th ACM Symposium on User Interface Software and Technology, San Diego, California, USA, 2000.

[9] Hu, J., You, S., Neumann, U., Park, K. K. *"Building Modeling from LIDAR and Aerial Imagery."* ASPRS'04, Denver, Colorado, USA. May 23-28, 2004.

[10] Kaasinen, E., *"User Needs for Location-Aware Mobile Services."* Personal and Ubiquitous Computing, Volume 7, Issue 1, May 2003.

[11] Karner, K., Bauer, J., Klaus, A., Schindler, K., *"MetropoGIS: a city information system."*, IEEE Conference on Image Processing (ICIP'02), Rochester, USA, 2002

[12] López de Ipiña, D., Mendonça, P. R. S., Hopper, A., *"TRIP: A Low-Cost Vision-Based Location System for Ubiquitous Computing."* Personal and Ubiquitous Computing, Vol. 6, pp 206-219, Issue 3, May, 2002.

[13] Nevatia, R., Price, K., *"Automatic and Interactive Modeling of Buildings in Urban Environments from Aerial Images."* IEEE Conference on Image Processing (ICIP'02), Rochester, USA, 2002.

[14] Parkinson, B. W., Spilker Jr., J. J. (ed.), *"Global Positioning System: Theory and Applications"*, Vol. 2, American Institute of Aeronautics and Astronautics, Inc., 370 L'Enfant Promenade, SW, Washington, DC 20024-2518, 1996

[15] Rao, B., Minakakis, L., *"Evolution of Mobile Location-based Services."* Communications of the ACM. December 2003. Vol. 46, No. 12.

[16] Sormann, M., Reitinger, B., Bauer, J., Klaus, A., Karner, K., *"Fast and Detailed 3D Reconstruction of Cultural Heritage."* International Workshop on Vision Techniques applied to the Rehabilition of City Centres, 2004.

[17] Syrjärinne, J., *"Studies of Modern Techniques for Personal Positioning"*, Doctoral Thesis, Tampere University of Technology, March 2001.

[18] Ulrich, I., Nourbakhsh, I., *"Appearance-Based Place Recognition for Topological Localization."* IEEE International Conference on Robotics and Automation, San Francisco, USA, April, 2000, pp. 1023-1029.

[19] Wasinger, R., Stahl, C., Krüger, A., *"M3I in a Pedestrian Navigation & Exploration System"*. 5th International Symposium on Human Computer Interaction with Mobile Devices (MobileHCI 2003), Udine, Italy, September 8-11, 2003.