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A Resource-Adaptive Mobile Navigation System

Jörg Baus, Christian Kray, Antonio Krüger, Wolfgang Wahlster
Collaborative Research Center 378
University of Saarbrücken
PO-Box 151150
+49 681 302 4137
{baus, krüger}@cs.uni-sb.de
{kray, wahlster}@dfki.de

1 Abstract
The design of mobile navigation systems adapting to limited resources will be an important future challenge. Since several different means of transportation typically have to be combined in order to reach a destination, it must be ensured that the user interface reacts to the user's changing situation. In addition, the necessary change between different positioning techniques should remain unnoticed to the user of such a navigation system. This article presents a hybrid navigation system that adapts the presentation of route directions to different output devices and modalities. The system also takes into account the varying accuracy of positional information according to the technical resources available in the current situation.

1.1 Keywords
Mobile navigation, adaptive and intelligent user interfaces, resource management, location sensitivity

2 Introduction

While car navigation systems are already widely commercialized today, in the near future not only motorists will be guided through the use of a navigation assistance system. Recent progress in mobile computing has opened perspectives for pedestrian navigation systems. Mobile personal navigation systems will provide location sensitive information, which could be accessed at any place and any time. Since several different means of transportation have to be combined typically in order to reach a destination, it must be ensured that the user interface reacts to the user's changing situation. Changing the means of transportation implies that a personal ubiquitous navigation service must adapt smoothly to the associated situational context. The necessary change between different positioning technologies such as GPS or GSM/UMTS radio-cell based technologies in an outdoor scenario or the use of infrared bluetooth technologies in buildings should remain unnoticed to the user of such a navigation system. Furthermore, the system should adapt the presentation to different output devices and modalities and to the varying accuracy of positional information according to the technical resources available in the current situation.

3 Resource adaptive navigation
The REAL project aims at developing a resource-adaptive navigation system consisting of three major components. Firstly, an information booth that consists of an 3D-graphics workstation, where a virtual walk-through through the environment is shown by a virtual presenter, which uses complementary spatial utterances and meta-graphics. Secondly, an indoor navigation system has been build based on strong infrared transmitters mounted at the ceiling and small PDAs as presentation devices. These are used to display simple sketches of the environment received via infrared. The third component is an outdoor navigation system that uses a small laptop in combination with a head-mounted display. A GPS system determines the user's actual position and an electronic compass tracks the user's orientation.

All graphical way descriptions are generated from scratch according to the cognitive limitations of the user and the technical constraints of the output device. A single 3D-model of the environment is used to produce walkthroughs at the information booth and sketches for the mobile use. Adaptation services include the choice of camera perspective and path as well as the decision to include landmarks and interactive areas in the graphics. The REAL system tailors the presentations to a variety of technical limitations [1,6]. Besides the size, resolution and color capability of the display, the system takes into account the computational power of the used device (information booth, PDA, and wearable computer). A speciality of REAL is the ability to integrate two different approaches to location-sensitivity: *active* and *passive* location sensitivity.

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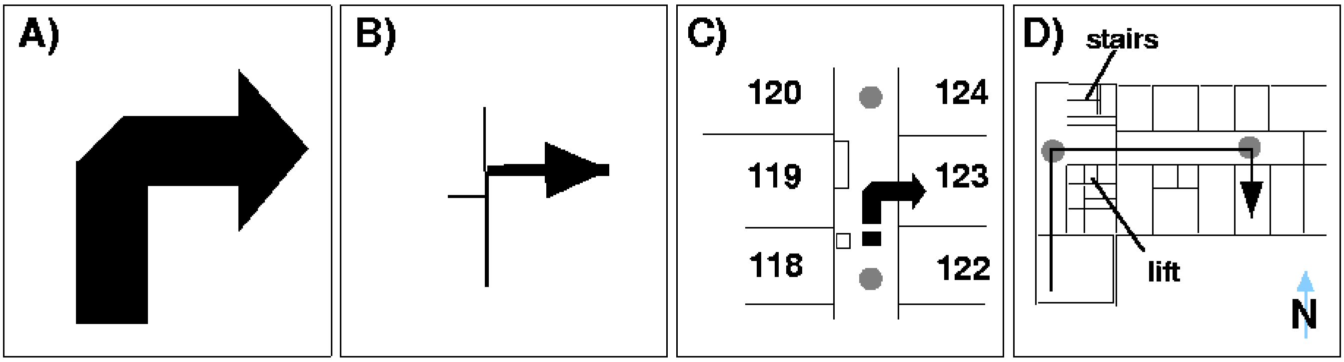

Figure 1: Four different resource adapted graphical way descriptions used by the indoor navigation component

A system is said to be active location-sensitive if it determines the actual position on it's own. An example is the use of the GPS to determine a location on a map. In contrast to that a system is called passive location sensitive, if it only receives information that is specifically designed for a certain location without knowing it's own location. A local radio station, for example, provides local information for a certain area. The receivers don't know their actual location but nevertheless can provide localized information, thus making them passive location sensitive.

The REAL indoor component IRREAL (Infrared REAL) uses strong infrared sender and PDAs that are passively receiving way descriptions generated on the presentation server. The outdoor component ARREAL (Augmented Reality REAL) uses GPS to determine the user's position and can therefore be considered as active location-sensitive. REAL is the first approach, which seamlessly combines both technologies. More difficult than the adaptation to technical limitations is the adaptation to the limited cognitive resources of the user. The system considers a variety of parameters that affect the cognitive resources, i.e. the walking speed, spatial familiarity and time pressure. The adaptation task is especially difficult, if subtasks have to be completed in parallel to the wayfinding process. For example if the user is using the mobile phone while walking or if heavy luggage has to be carried along. REAL already considers this in the wayfindig process. Instead of choosing the shortest route, REAL tries to avoid complex redirections along the way at costs of a slightly longer route, and thus minimizes the additional cognitive load on the user.

3.1 IRREAL: The indoor navigation component

For the navigation in buildings the IRREAL subcomponent was developed, where we looked for a smart but simple solution, which should transfer as much intelligence as possible to the environment relieving the load on the user's end device. IRREAL uses handheld computers running PalmOS. For the transmission of data to the handheld strong infrared transmitters with the ability to cover a range up to twenty meters were constructed. The aforementioned information booth serves as presentation server, which constantly provides the transmitters with data. In order to cover up the long distance between the transmitters and the receiving devices a special unidirectional transmitting protocol was build, which resembles the technology known from videotext-technology, where all the information is transmitted in cycles again and again. In contrast to the videotext- technology IRREAL transmits interactive texts and graphics, very much like hypertext documents. This enables the user to interact with the presentation, although there is no bi-directional connection. The generated presentations are arranged in a presentation tree consisting of nodes, which may contain texts or graphics. Since all the information has to be transmitted in cycles the protocol has to ensure that response time is not too long. Instead of transmitting every node of such a presentation as often as any other, we differentiate between important and less important ones. Through the use of transmission probabilities assigned to the different parts of a presentation tree it is possible to adapt the presentation to the user's walking speed. If the user stays in a transmission area for a short time the device will receive only the information with high priority, e.g., graphical walking directions. The more time the user spends in a transmitting area more complex the information about the environment will become available. Thus, the user can simply stay close to a transmitter if she wants to enhance the amount of detail of the presentation and the possibilities to interact. Figure 1 illustrates the IRREAL adaptation services. It further explains how varying information about the user's location and orientation influences the system's output behavior. In figure 1A the system knows enough about the actual position and orientation of the user to produce a simple navigation instruction (i.e., an arrow to the right). If the quality of the orientation information decreases and the system can not

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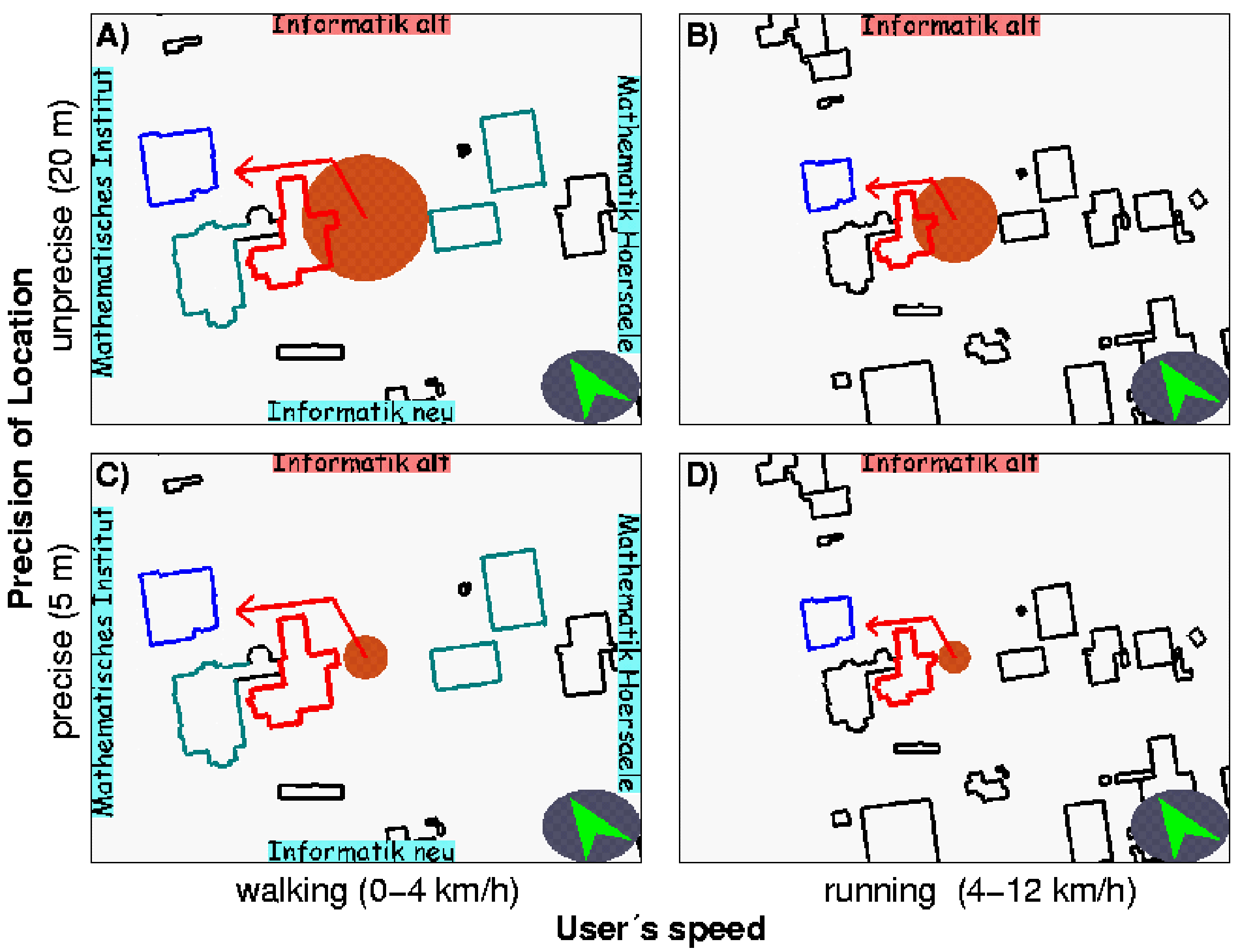

Figure 2: Four different graphical presentations adapted to the positional information and the moving speed of the user

exactly tell which way the user is looking, a simple arrow could mislead the user. Therefore additional information about the choices at the decision point has to be provided. Figure 1B shows such a graphical way description for an orientation resolution of +/-90 degrees. The topological diagram includes only the different choices at the current decision point, but doesn't show any additional landmarks. Please note that the map can still be roughly aligned to the user's walking direction to simplify her reorientation. In cases, where the quality of orientation and the position information further declines landmarks have to be included, as we mentioned before. Figure 1C shows a description, where the positional resolution covers three potential decision points (two are indicated as grey dots). In such situations a purely topological map could cause problems and therefore an appropriately clipped area of the surrounding (here: the adjacent rooms with numbers and parts of the hallway, pillars and a locker) are displayed. By clicking on the grey dots the user can inform the system about her actual position and resolve the ambiguity of location, thus allowing the system to switch back to the topological presentation of figure 1B.

In the worst case there is only very rough or no information about the actual position and orientation and the system cannot align the map to the user's actual walking direction anymore. Now a greater portion of the map has to be chosen that may include several (especially already passed) turns of the user (see figure 1D). Instead of including small landmarks that are only relevant at a single decision point, global landmarks, such as stairs or elevators have to be represented in the presentation. Since it is important to explain to the user that she can not rely on the orientation of the map, the presentation contains a North Symbol to underline the external frame of reference. Again the user can communicate her position to the system by clicking on the grey dots, resulting in a close-up of that area of the building. But in order to align the map to the walking direction, the system has to ensure the user's correct orientation. This task can be accomplished by advising the user to reorient herself towards a landmark e.g. by prompting a text, such as: “Turn around until the stairs are to your left and the lift is to your right.”

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3.2 ARREAL: The outdoor navigation component

In the ARREAL project a navigation system for pedestrians in an outdoor scenario was developed. The scenario imposes special demands on the hardware used. The whole system should be composed of light, small and unobtrusive components. ARREAL consists of four components: A subnotebook, used for the relevant computations. For graphical or textual output a special clip-on for glasses is used. The users' position and orientation in the environment is determined through the use of a small GPS and a magnetic tracker. Both devices are connected to the subnotebook by a serial port. The magnetic tracker was modified and equipped with two additional buttons, so that it can be used to interact with the system analogously to a standard two button computer mouse. The modified tracker is used as a 3D-pointing device, e.g., the user can retrieve additional information by pointing on a building. On the small clip-on display (640x320 Pixel) sketch-like graphics are shown from birds-eye- or egocentric-perspective. While overview maps are used to visualize the user's current position in the environment, graphics from the ego-perspective view are used to present more detailed information about the environment, e.g., information about buildings in the current line of sight. In addition the system supports different levels of detail in the visualization. On one hand the system is able to visualize different portions of a map while changing from an overview to a detailed view of the environment. On the other hand textual or graphical annotations can be inserted, such as the names of streets or buildings (see also figure 2). Navigational instructions are given by means of arrows that indicate turns to the user. ARREAL reacts to the changing quality of positional and orientation information in different ways. First of all the system chooses between two modes: a birds-eye and ego-perspective. The ego-perspective mode only makes sense, if the system has adequate positional and orientation information. In cases were positional and orientation information is of inferior quality, ARREAL prefers the birds-eye perspective over the ego-perspective. If birds eye-perspective is chosen the precision of the positional information is encoded by the size of the dot, that represents the user's current position on the map. Decreasing quality of information about the location results in a bigger circle. The system also takes into account the user's current walking speed. If she moves fast, the system presents a greater portion of the map in order to help the user to orientate herself and at the same time to reduce the amount of information about buildings at the edges of the display. Since textual annotations at the edges of the display serve as menu-items, the system reduces also the possibility to interact with the system. Figure 2 showcases the combined reaction of the system to the precision of orientation information and the user's moving speed. Figure 2A) presents the system's output for slow moving user and unprecise positional information, whereas figure 2 D) shows the results for exact positional information and a slow moving user.

4 Related Work

One of the first systems that used location aware information to help tourists was the CYBERGUIDE-system [7]. An indoor and an outdoor navigation component were designed to assist tourists with active location sensitivity. The indoor component relied on infrared beacons broadcasting a unique ID, that was used to display an arrow on a map whenever the user entered a new room. Additionally the user's orientation was estimated from her actual walking direction and the topology of the building. The outdoor system instead used GPS to determine the user's position and to display it on a map. Both systems operated independently from each other and could not be combined. The MARS-system [5] is an augmented reality system that provides information for the buildings on the Columbia University Campus. More recently an additional indoor component has been developed that assists the user also in indoor navigational tasks [6]. The GUIDE-system is a location aware multimedia tourist guide for the City of Lancaster [2]. Based on a radio cell infrastructure adapted information is provided that is tailored to the personal preferences of the user, but also to her actual contextual situation. The DEEP MAP project [8] (carried out at the European Media Lab) focuses on a mobile tourist information guide that brings together results from natural language and intelligent graphics generation. This allows a multimodal user interface to offer the user a variety of information on the city of Heidelberg. Since GPS is used to determine the position DEEP MAP is at the moment restricted to outdoor scenarios. The MOBIS system [3] is a situational guide based on a PDA that provides a visitor with information on the exhibits of a museum. The PDA receives its position from IR beacons distributed in the environment and uses this position as a pointer to a specific content that is stored in a database on the PDA. A similar approach is taken by the HIPS system [9]. In contrast to MOBIS a radio back channel is used for downloading multimedia content. HIPS uses more powerful mobile devices (sub-notebooks) which are heavier but allow the playback of much better animations and sound files. HIPS does not only take into account the absolute position of the user but also the relative distances to objects in the exhibition. The NEXUS system [4] aims at providing a general framework for mobile and location aware computing. The concept of an augmented world is used to store information that may be relevant to a user at a certain location. This model is the basis for so called virtual information towers that connect information objects (i.e. from the WWW) to real places.

5 Conclusion

This article describes how a pedestrian navigation system can tailor it's presentations to different technical appliances obeying their limited technical resources. Furthermore, the system combines different types of location sensitivity and adapts the graphical presentations according to the quality of location information present. In the near future parts of the system will be transferred to an instrumented environment so that in addition to the user's position and speed the system will observe the user's interaction with virtual or real objects in such an environment and use this information to improve the adaptation capacities.

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