Pervasive Information Acquisition for Mobile AR-Navigation Systems

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Abstract

Today car-navigation systems are increasingly penetrating the automotive market. However, the need for location-based information systems is no longer limited to cars. Mobile outdoor navigation systems for pedestrians and electronic tourist guides are already available on PDAs. In addition, new indoor positioning technologies extend the area of application for location-based systems.

Unfortunately, current navigation systems are burdened by the fact that they are bound to a specific tracking technology (e.g., a car navigation system works exclusively with GPS) and therefore cannot be employed in areas with alternative tracking equipment. Furthermore, the information is provided through an abstract metaphor that the user has to understand and translate into action.

This paper presents a new augmented-reality-based paradigm and a framework for mobile navigation systems[1] *that pervasively extracts position and orientation information from any sensory source and enhances the association to the real world by combining video techniques and 3D-graphics in an augmented reality view.*

Keywords

localization, mobile navigation systems, exchangeable output devices, augmented reality.

1. Introduction

Modern tracking systems offer many ways to locate objects in the real world. They range from the well-known satellite-based GPS tracking system for determining, e.g., the position of cars to GSM, GPRS (and UMTS) systems, which enable identification and location of mobile phones within an area of influence [9]. Radio frequency identification systems (RFID) enable non-contact reading of transponders equipped with a world-wide unique identification number [5]; they are consequently effective in manufacturing and in hostile environments as well as for identifying and locating people (e.g., at marathon running competitions). Even modern wireless network systems enable the tracking of mobile devices that are connected to the network through a wireless network card [4]. There are also other methods for wirelessly locating and identifying objects (e.g., Bluetooth, IrDA, acoustic localization systems, etc. [1][13]), which complicates the development of a generic localization system combining all these methods.

The counterpart to the different ways of receiving localization information is the divergent representation of this information for the user on different devices: A car navigation system, e.g., either displays the position information on a 2D map or shows a flat arrow on the navigation screen and guides the driver with a built-in voice.

A wireless network system can remotely request its access points to collect position information for the currently served mobile devices. In connection with a geographical map containing the positions of the access points, it is possible to provide information about the location of a mobile device [4].

In all cases, however, the provided information is bound to a special output device; i.e., the navigation console cannot be taken out of the car and used for guidance through a wireless network area, and a palmtop cannot be connected to the car navigation computer in order to separately have the navigation information on a handheld device.

In addition to the incompatibility of the output devices, there is an abstraction gap between the provided information and the mapping of these data to the real world. Even though a car navigation system displays an arrow to the right and a voice enhances this information

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[1] The framework has been implemented within the cooperative work of Siemens Corporate Technology in Munich, the University of Linz and the Ars Electronica Center Futurelab in Linz.

by instructing the driver to turn right in 200 meters, there is still an interpretation problem for the driver to determine the distance of 200 meters. It is the same with a 2D geographical map on a palmtop that guides the user through a wireless network area. The user still has to interpret the provided data and project them to the real world.

Thus there are three major aspects that strongly influence the design of future navigation systems: (1) the variety of sources and technologies for localization and orientation, (2) different (exchangeable and mobile) output devices, and (3) the abstraction gap between the virtual and the real worlds.

This paper describes a novel approach for a mobile navigation system INSTAR (Information and Navigation Systems Through Augmented Reality) based on a framework that engages all three aspects and indicates how augmented reality helps to diminish the human interpretation problem.

2. System Overview

From a black-box perspective, the INSTAR system provides an input interface for receiving the current position and orientation and another interface for obtaining the routing information from a conventional navigation system (see Figure 1).

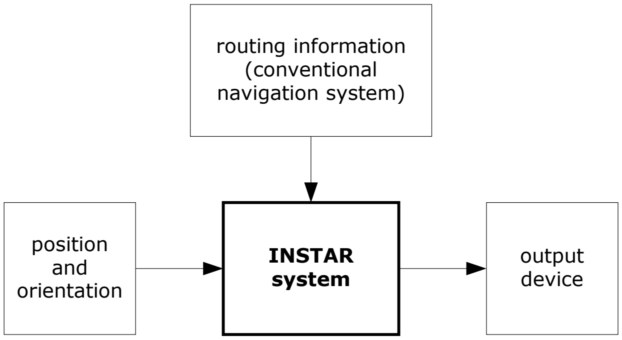

Figure 1. The system as a black box

The system has one output component (on the right side of Figure 1), i.e., any kind of screen capable of displaying AR views of the system's output.

Although more input components (such as the current speed) are essential for the INSTAR system, they are not taken into account here because their role is of minor importance to the focus of this paper.

Position and Orientation Acquisition

Naturally, the framework abstracts from the different kinds of localization input methods (GPS, WLAN, GSM, transponders, indoor positioning systems, etc.) and orientation input methods (gyros, magnetic trackers, etc.) and provides a common interface for all kinds of tracking data. Here two different approaches of location and orientation sensitivity have to be distinguished [2]:

1. *Active* sensitivity systems are able to determine their current position and/or orientation on their own. As an example, a GPS receiver card plugged into the CF slot of a PDA enables the PDA itself to detect its current position.
2. *Passive* sensitivity systems are not (directly) aware of their current position and/or orientation. A central reference station (a tracking server) holds the tracking data of all devices (tracking receivers) moving within its area of influence. Many indoor navigation systems can be regarded as passive sensitivity systems, as a central server first collects the data of the floating receivers within a network of static antennas and then provides the receiver's location information to any interested device via a certain interface (see Figure 2). Actually, the tracking receiver is usually mounted to the requesting device (e.g., a PDA), so that the device itself can again be tracked.

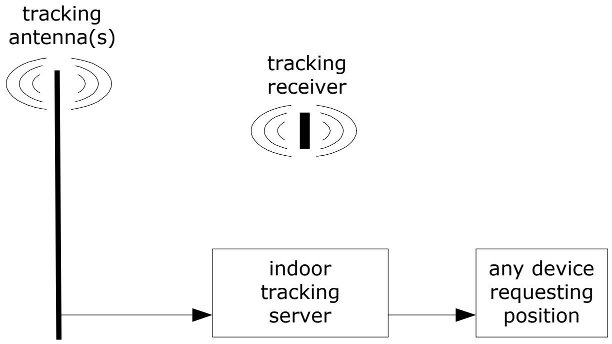

Figure 2. Indoor positioning system structure

The INSTAR system, however, inserts an additional process between the indoor positioning server and the actual device to be tracked in order to accomplish a generic design that combines all input technologies penetrating the current market (see Figure 3).

This additional process (betokened generic tracking supplier) requests location and/or orientation data from the indoor tracking server, converts potential relative indoor tracking coordinates into GPS coordinates, and wirelessly transmits them via a slim protocol (e.g., UDP packages) to the INSTAR system (e.g., running on a PDA). Due to diverse location systems, the generic tracking supplier must obviously have a customer-dependent front-end (expressed by the hatched left border in Figure 3), but at its back-end already defines a common protocol to the tracking interface component of the INSTAR kernel system.

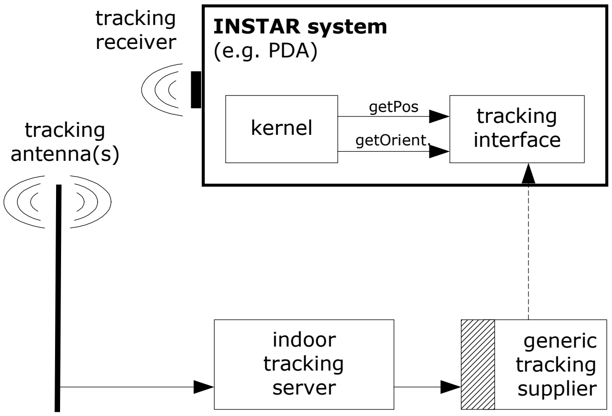

Figure 3. Indirect position acquisition

The generic tracking supplier may also be executed on the tracked device itself, receiving position and/or orientation data (via a different customer-specific interface, e.g. from a GPS module and/or an orientation tracker directly connected to the device; see Figure 4).

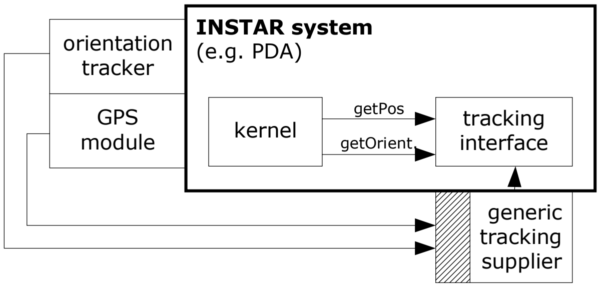

Figure 4. Direct position acquisition

Thus, no matter which type of location sensitivity is used for tracking a device — active sensitivity through a plugged on GPS receiver or passive sensitivity through an indoor tracking system with relative coordinates — the kernel of the INSTAR system requiring such data is not affected by these circumstances.

Mobile Displays

The INSTAR system is distinguished not only because of its pervasive tracking data acquisition; it also asserts a claim to the exchangeability and primarily the mobility aspect of navigation devices. Regarding the exchangeability aspect, the proprietary displays of car navigation systems (mounted within the cockpit console of cars) should be controlled in the same way as ordinary computer displays or PDA screens. Current navigation systems, however, strictly define one certain output display for one type of navigation system; e.g., an indoor navigation system (usually executed on a PDA) cannot be used in connection with a car navigation system and vice versa. As one of the major goals of INSTAR, the compatibility and mobility aspects have been optimized, enabling a pedestrian navigation system on a PDA to be plugged onto a car navigation system in order to display output on the latter. Consequently, it is possible to take the navigation system out of the car and use it as a mobile indoor navigator. The subsequent sections in this paper provide insight into the architecture of this system and examples of this scenario.

A Novel Paradigm for Information Visualization in User Interfaces

Besides the demand for mobility of the navigation system, there is also the need for a better user interface: Conventional car navigation systems, e.g., instruct the drivers about the calculated route by displaying an arrow pointing in the intended direction or drawing a bird's eye view of the current location (see Figure 5). In both cases, though, the driver has to interpret the graphical metaphor and translate it into the real world. Furthermore, while viewing the navigation display, the driver is handicapped by a constrained view of the current traffic and driving situation.

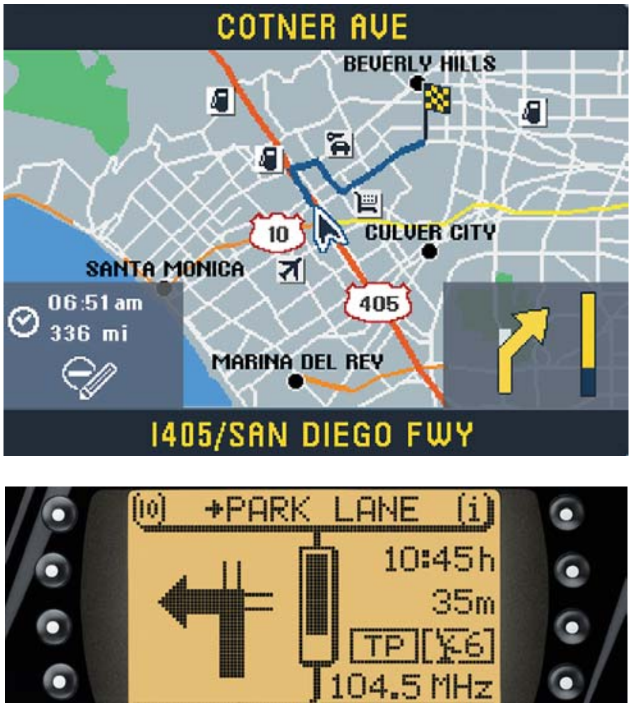

Figure 5. Conventional navigation displays

This type of output has been changed radically for INSTAR navigation systems: Augmented reality is the key to reducing the level of abstraction for the user by showing a live stream video of the current street ahead on the navigation display with the intended route marked in color (see Figure 6).

Figure 6. Augmented reality display

The advantages should be obvious from the two pictures above: By virtually coloring the road, the new system eliminates ambiguity, which may arise at conventional navigation systems when they request the driver to turn left with two junctions back to back. No more counting of exit ways out of traffic circles is necessary in order to find the desired exit. Furthermore, the driver always surveys the road ahead — even when viewing the navigation display — because a live stream video simultaneously to the real world also indicates possible hazards.

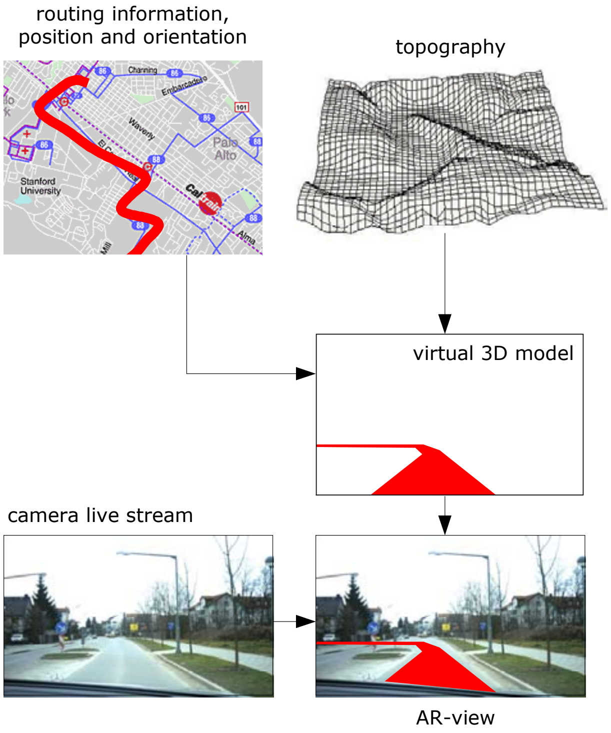

Figure 7. Calculation of AR view

Technically speaking, the INSTAR navigation system has to be extended by a video camera capturing the scene in front of the user. In combination with the current position, the orientation, topographical data and the calculated route (all these data are already available via the two input interfaces shown in Figure 1), a 3D model of the route can be computed and superimposed on the live stream video without consuming valuable time and computing power for picture recognition (see Figure 7).

The routing information from the navigation component is provided through a list of shape points (i.e., 3D geographical points) whose catenation (e.g., through cubic splines) results in the desired path (see Figure 8). This path is generically kept in a suitable data structure within the INSTAR system (scenegraph), which is detached from any graphical library or operating system needed to illustrate this routing information. As the scenegraph approach for storing 3D graphics is used by many popular 3D renderers [10], it has also been considered within the design of the INSTAR framework. A traversal of the objects and transformations stored in the scenegraph finally activates the AR drawing process, with several implementation variants for different operating systems and graphic libraries already contained in the framework (hashed square below AR renderer). This architecture, as shown in Figure 8, enables the user to arbitrarily exchange navigation devices.

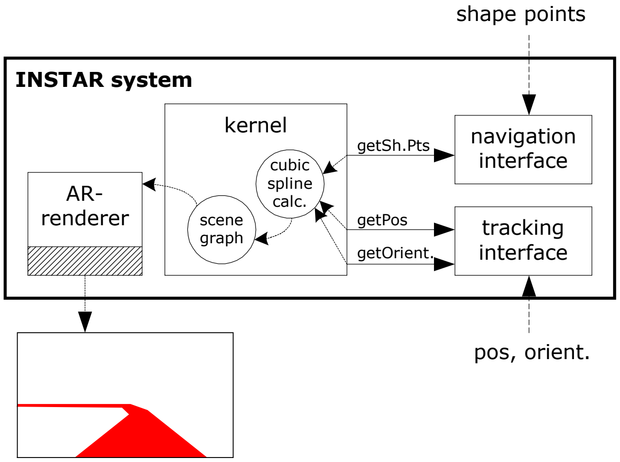

Figure 8. Generic AR data calculation and storage

3. Implementation

The first testbed for the INSTAR-framework was a simulation environment implemented in C++ for Windows 2000. All the navigation data coming from a commercially available car navigation system (Dayton 5000 by Siemens VDO) were recorded synchronously together with a video stream from a digital camera mounted inside a test car. These data repetitively served as the simulation input for the initial INSTAR system running on a commercially available personal computer. At the back-end, OpenGL was used to combine the computed 3D route and the AVI stream to an AR navigation display. Figure 9 shows an OpenGL window of the simulation environment with a semitransparent yellow path guiding the way.

Figure 9. INSTAR simulation

With the simulation testbed working, INSTAR moved into a car (a Mercedes E class). In an initial implementation, the system was still executed on a laptop computer (with Windows 2000 installed), but already connected to the built-in Siemens VDO navigation system via a serial port. An additional digital firewire camera mounted behind the rear-view mirror provided the live stream of the scene in front of the car (see Figure 10).

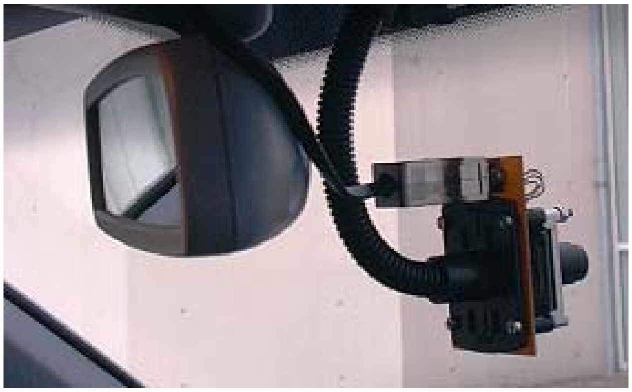

Figure 10. Firewire camera

Here the design of the framework was validated for the first time, as the relocation of the system from the PC into the car could be accomplished in very short time without any changes in the kernel system. The outcome of the new augmented reality navigation system is shown in Figure 11.

Figure 11. AR car navigation system

As this first prototype of the INSTAR system was running successfully, the exchangeability aspect of the navigation device had to be validated. Thus the kernel of the framework moved onto a PDA (a Compaq iPAQ 3850) with PocketPC 2002 as the operating platform and PocketGL as the graphics library. Only the platform-dependent parts of the system had to be exchanged for the corresponding implementations for the PocketPC (which are already included in the application framework part of the INSTAR architecture) and the INSTAR navigation system could be executed on a PDA connected to the car navigation computer and plugged into a video jacket in order to receive the video signals from the camera (see Figure 12).

Figure 12. Car navigation system on a PDA

The next step was to get the PDA out of the car and use it as a pedestrian navigation system with different tracking and navigation techniques than within the car:

- For determining the current position of the device, a GPS mouse receiver (Holux GM-210) was used; it was plugged onto the serial port of the PDA and supplied the tracking data through the NMEA protocol [11].
- A local navigation system for the Siemens campus in Munich wirelessly transmitted routing information to the PDA, requiring the use of a wireless LAN network card (Symbol Spectrum 24).
- The live stream video was provided by a PocketPC-sized camera (from LifeView), which could be attached to the video jacket of the PDA.

However, those three substitute techniques on their own would not enable the AR pedestrian navigation system to work satisfactorily. Whereas the camera in the car constantly captures the scene in front of the car, the PDA with its camera mounted can arbitrarily be moved in any direction, which forces the supplementary use of an orientation tracker; therefore the InertiaCube^2 by Intersense was employed. Unfortunately all hardware interfaces of the Compaq iPAQ have already been exploited, so the prototype implementation of the pedestrian navigation system was extended to a second iPAQ receiving the orientation data from the InertiaCube^2 and transmitting them to the first iPAQ via a wireless ad-hoc communication channel (see Figure 13).

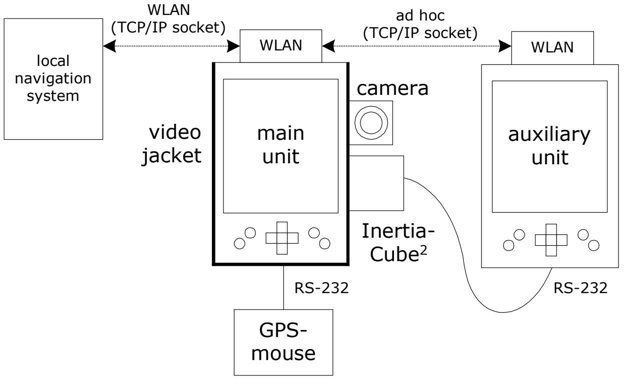

Figure 13. Pedestrian navigation components

Because of the lack of hardware interfaces for a PDA, the INSTAR system had to be adapted to these inconveniences, which required implementing details like software switches between ad-hoc and infrastructure mode for the wireless LAN network cards. Generally the two iPAQs communicate through the ad-hoc mode, which is independent of any available wireless network system. Just for the data transfer of the routing information, the mode is switched to infrastructure, which meanwhile excludes the main unit from receiving orientation information. Figure 14 shows the prototype INSTAR pedestrian navigation system.

Figure 14. Pedestrian navigation system

Currently utilization of the prototype is still inconvenient for the user, who has two iPAQs and a lot of plug-ons to carry (as illustrated in Figure 13 and Figure 14). However, compared to presently known comparable archetypes, which require large-scale “background equipment” to get the system running, we consider this prototype as fairly slim. In the future, however, when GPS receivers, orientation trackers, cameras and wireless LAN are all integrated into one device, the complexity of the equipment will diminish, enabling users to conveniently handle the new generation of navigation devices and to individually use them indoors, outdoors, in cars or by foot, no matter how they are tracked.

4. Future Work

Long-term experiments (over more than one year) have proven the applicability of the INSTAR framework for car and pedestrian navigation systems, pervasively retrieving tracking and navigation data from diverse sources in order to display an AR view on exchangeable devices. However, there is still one aspect of the framework to validate when an indoor tracking system with relative coordinates is used to locate the device. Currently, the corresponding implementations are being finished; they take tracking and orientation data out of an acoustical indoor tracking system by Intersense.

We are also trying to vary the augmentation of the live-stream video. One promising modification could arise when we ask the most natural question on the subject of navigation systems: What is the easiest way to find a desired destination? Answer: Follow somebody who knows the way. This idea leads to an alternative augmentation variant showing a virtual car in front of one's own car, blinking, braking and accelerating (see Figure 15), thus making the navigation aspect in cars as natural as possible.

Figure 15. Alternative augmentation method

Of course, the flexible architecture offers hooks for further location-based services, extending the so far rather small area of applicability of the framework, which just considers navigation aspects. Persons, things and places [8], expressed by positions, names (IDs), profiles, etc, can be administered within the framework and displayed in an AR manner to the users. Different tracking technologies and output displays can be combined within the system, thus enlarging the application range to a maximum. Location-based security aspects can be added in the same way as AR tourist information. Figure 16, e.g., illustrates portholes on the runways of airports for maintenance staff.

Figure 16. The future

5. Related Work

The growing range of divergent positioning techniques have already been the field of research of many institutions and projects like the Interfaces and Infrastructure for Mobile Multimedia Applications [3] (an electronic tourist guide) and the Collaborative Research Center of the University of Saarbrücken/Germany [2]. The latter present a resource-adaptive mobile navigation system that abstracts from the type of the positioning technique and hides this technical detail from the user; no information about the architecture is provided in their paper.

In addition, the research community for augmented reality proposes ideas for easily comprehensible, innovative AR user interfaces for location-based services. The MARS project [7] (Mobile Augmented Reality System) suggests various approaches similar to ours. Ribo et al. present a technique for an AR outdoor tracking system that uses a wearable apparatus [12].

Nevertheless, none of the approaches developed so far enhances the navigation information by simply coloring the route to the destination and therefore decreases the level of abstraction at the user interface to a minimum.

6. Conclusion

The combination of three research areas (pervasive computing, augmented reality and software engineering) raises a novel, mobile navigation system INSTAR, the applicability of which has been demonstrated within this paper by showing the prototypical implementations.

The INSTAR navigation system unifies dissimilar methods for acquiring tracking and orientation data, provides generic implementations for graphical output on different displays and different operating systems, and presents an innovative way of communicating the calculated information to the user by means of augmented reality.

All these assumptions enable the user to arbitrarily exchange navigation systems, using an indoor navigation PDA as a car navigation system and vice versa, without needing to mind the type of tracking technique used.

Our vision of the future is a navigation system running on just one mobile device (e.g., a PDA), which can be easily kept in one's pocket and used wherever it is needed. The INSTAR framework can be considered as a first step in this direction of future navigation systems.

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