A New Visualization Concept for Navigation Systems

Wolfgang Narzt[1], Gustav Pomberger[1], Alois Ferscha[1], Dieter Kolb[2], Reiner Müller[2], Jan Wieghardt[2], Horst Hörtner[3], and Christopher Lindinger[3]

[1] Johannes Kepler University Linz, Altenbergerstr. 69, A-4040 Linz, Austria
{wolfgang.narzt,gustav.pomberger,alois.ferscha}@jku.at
[2] Siemens AG, Otto-Hahn Ring 6, D-81730 Munich, Germany
{kolb.dieter,reiner.e.mueller,jan.wieghardt}@siemens.com
[3] Ars Electronica Future Lab, Hauptstr. 2, A-4040 Linz, Austria
{horst.hoertner,christopher.lindinger}@aec.at

Abstract. At present, various types of car navigation systems are progressively entering the market. Simultaneously, mobile outdoor navigation systems for pedestrians and electronic tourist guides are already available on handheld computers. Although, the depiction of the geographical information on these appliances has increasingly improved during the past years, users are still handicapped having to interpret an abstract metaphor on the navigation display and translate it to their real world.
This paper introduces an innovative visual paradigm for (mobile) navigation systems, embodied within an application framework that contributes to the ease of perception of navigation information by its users through mixed reality.

Introduction

Modern navigation systems follow up different approaches of presenting geographical information to their users. Whereas the constitution of information may either be verbal or spatial, the presentation can be visual or auditory [6], [19] (see Fig. 1).

	visual	*auditory*
verbal	text message: "turn left"	spoken message: "turn left"
spatial	←	tone to the left of the driver

Fig. 1. How to present navigation information.

The combination of those characteristics builds up the basis for the man-machine-interface of current navigation systems: So called turn-by-turn systems display a simple, flat arrow indicating a turn or pointing to the desired direction (spatial, visual) together with a dynamically changing designation for the distance to the next maneuver point (verbal, visual) (see upper part of Fig. 2). A built-in voice enhances this information by instructing the driver where to go next (verbal, auditory). A two-dimensional bird's eye view showing a geographical map and the driver's current position and orientation on it is just another state of the art method for illustrating navigation data to the users (Fig. 2, lower part).

However, all these attempts of an adequate visualization method face one common problem: 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 left and a voice additionally directs the driver to turn left in 100 meters,

C. Stary and C. Stephanidis (Eds.): UI4All 2004, LNCS 3196, pp. 440–451, 2004.

the driver still has to determine the distance of 100 meters. It is even harder for a two-dimensional geographical map: The driver has to handle a vast quantity of data within just one glimpse to the navigation display while driving. In addition, he is not capable of recognizing possible hazards on the street during this time.

Fig. 2. Current visualization techniques.

Consequently, we cannot consider these types of visualization methods as adequate for safety reasons and urge for a secure navigation guide that defeats the problems concerning the man-machine-interface.

A Novel Paradigm for Visualization

The navigation information shall easily be accessible to the drivers in an intuitive and natural way, thus maximizing the degree of perception. To support the drivers in perceiving navigation data, we propose a see-through-based theatre experience of visual perception, seamlessly merging the components of the real and the digital world. Every car's windshield can transact the allegory of the see-through-based theatre and be used to superimpose the navigation information in front of the real world outside the car. So, we extend the characteristics for the constitution of navigation information by annotated reality and mark the route in a translucent color (see left part of Fig. 3).

The advantages should be obvious by viewing the picture: By virtually painting the road in a semi-transparent color the new paradigm eliminates ambiguity which may arise at conventional navigation systems when the driver is requested to turn left with two junctions back to back. This visualization concept even enables a driver to recognize junctions, which are hidden to his eyes in the real world, because other vehicles or blind summits restrict the driver's view (right part of Fig. 3).

No more counting of exit ways out of traffic circles is necessary in order to get off at the designated exit (Fig. 4, left). Furthermore, the driver always surveys the road ahead, because he is no longer handicapped by a constrained view of the current traffic and driving situation (Fig. 4, right).

As a consequence, we consider this paradigm to be a self-explanatory and easy to understand visualization method, which helps to avoid indistinctness concerning maneuver instructions, and conspicuously increases safety aspects. In the course of a three years project, we (i.e. the University of Linz, Austria, Siemens Corporate Technology in Munich, Germany, and the Ars Electronica Futurelab in Linz, Austria) have developed a software architecture that engages this new visualization concept. The main principles and the prototypical implementations of this idea are described in the following sections.

Fig. 3. Translucent path for navigation.

Fig. 4. Roundabout and Safety Aspects.

Approach

Present head-up displays [7] using the windshield are not yet maturely conceived to be used as a see-though window as originally intended. Instead, the annotation of the route is superimposed on a live-stream video showing the road ahead on the navigation display. Accordingly, augmented reality is our technical instrument for the realization of the new concept, which is also reflected in the name of our navigation system: INSTAR – Information and Navigation System Through Augmented Reality.

The first obvious approach for calculating the virtually colored route – the use of picture recognition algorithms [20], [27] – would be insufficient, as those algorithms are poorly conceived. They are too complex, too expensive and, by the way, could not cope with the entanglement of the streets in large cities. The INSTAR system follows a different strategy: It simply uses the data coming from a conventional navigation system (the current GPS position and orientation, the maps, the topography information and the route) and calculates a three-dimensional depiction of the street as it may look from the driver's perspective (see Fig. 5).

This technical approach is also advantageous in terms of daylight conditions, for, it only visualizes pure, measured data and does not utilize picture recognition algorithms, which would be dependent on weather and lighting situations.

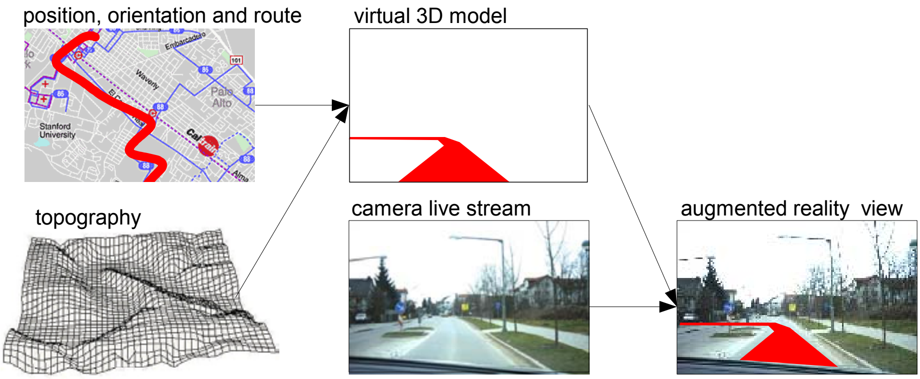

Fig. 5. Thought model of AR view.

System Architecture

In order to receive the required data from the navigation system the INSTAR software has to provide a variety of input interfaces (see Fig. 6): Most car navigation systems are equipped with a GPS receiver and in some cases additionally keep track of the car using wheel sensors when GPS is not constantly available, e.g., within city areas. However, the system is also prepared for alternative tracking technologies, like indoor tracking systems (ITS) and other wireless positioning approaches. Usually, the orientation of a car comes from the GPS signal, but the generic system architecture of the INSTAR kernel facilitates different orientation trackers (compasses, gyros, etc.) as input sensors, as well. Static model data (i.e., 2D and 3D maps typically stored on a compact disc), dynamic model data (i.e., ongoing road works and accidents) and the route planning algorithm finally enable the INSTAR kernel system to compute the virtual 3D road image. The video interface for transferring the live-stream from the camera completes this list of interface components.

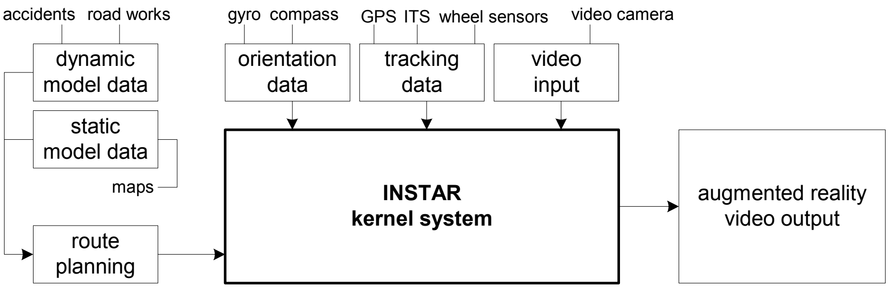

Fig. 6. The system as a black box.

Fig. 5 outlines the interaction of all input components in a simplified way. Naturally, the algorithms behind this thought model must handle a challenging and complex problem. Just to give an idea of what is meant by this assertion, consider the following scenario: Depending on the current position and pitch of a car and the topography of the street ahead, the augmentation to the next maneuver-point differs in its length even if the distance from the car to the maneuver-point is the same (compare the two driving situations illustrated in Fig. 7). Actually, the virtual arrow may grow in its length even if the car is continuously approaching the maneuver-point.

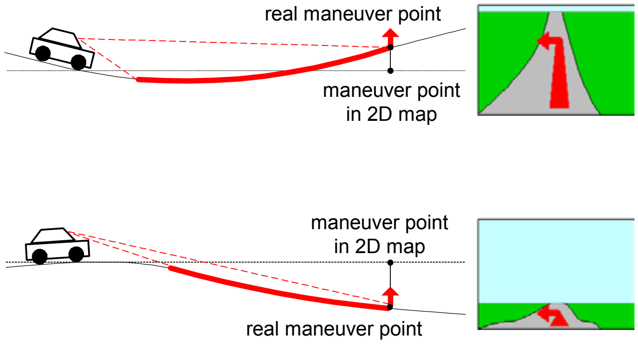

Fig. 7. Characteristics of AR view.

To go into detail, the route from the navigation component is provided through a dynamically changing sequence of geographical points in the three-dimensional space (see left part of Fig. 8). A distinction is drawn between shape points tagging the route in front of the car and maneuver points indicating upcoming navigation maneuvers.

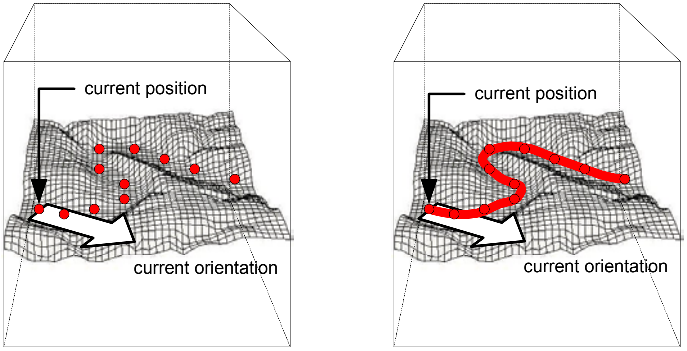

Fig. 8. 3D shape points tag the route.

The catenation of those points (e.g., through a cubic spline or by nurbs [23]) results in the desired virtual path (see right part of Fig. 8). Accordingly, the static topography information (as denoted in Fig. 5) is not directly retrieved from the three-dimensional maps of the navigation computer but considered indirectly by the spline.

So, the INSTAR system calculates a virtual three-dimensional model of the spline relative to a fictive origin within a virtual space. Corresponding matrix transformations rotate, shift, and zoom this model regarding the current position and orientation of the car (and also several other parameters like the current speed, wheel sensor data, etc.) so that the spline finally looks as if it was a colored part of the street viewed from the driver's perspective (see Fig. 9).

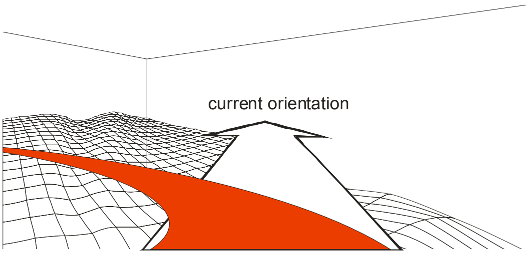

Fig. 9. The route from the driver's perspective.

The calculated 3D-path is stored in an appropriate data structure, a scenegraph, which is detached from any graphical library or operating system needed to illustrate the routing information. As the scenegraph approach for storing three-dimensional graphics is used by many popular 3D renderers [13], it has also been used within the software design of the INSTAR framework. A traversal of the graphical objects and transformation nodes stored in the scenegraph finally initiates the augmented reality-drawing process, with several customer-dependent implementation variants for different operating systems and graphic libraries already contained in the framework (expressed by the hashed square below the AR renderer in Fig. 10).

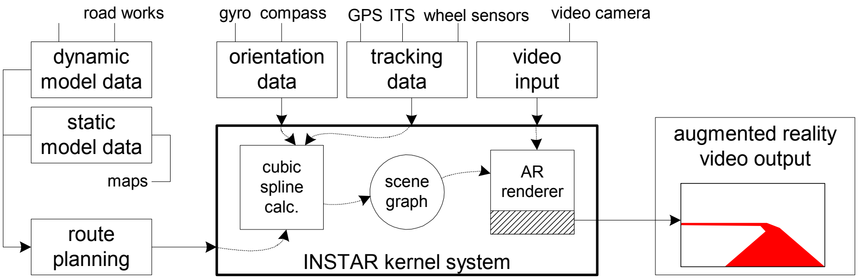

Fig. 10. Generic AR data calculation and storage.

This architecture enables users to arbitrarily exchange navigation devices. The generic scenegraph data structure can be processed by several different graphic renderers, which allow the output to be displayed on notebooks, handheld computers, and, of course, on conventional navigation displays, as well. The INSTAR navigation system is beyond this capable of dealing with various tracking systems, which enables users to take the navigation system out of the car and use it as a mobile pedestrian navigator [22].

Results

The INSTAR-framework has been developed by using a self-made simulation environment. All the navigation data coming from a commercially available car navigation system 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 personal computer. The software was written in C++ and developed for the operating systems Windows 2000/XP and Windows CE. At the back-end, OpenGL and PocketGL were used to combine the computed 3D route and the video stream to an augmented reality navigation view. Fig. 11 shows an OpenGL window in front of the simulation environment with a semitransparent yellow path guiding the way. The borders of the path are kept in diverse colors in order to denote different purposes: Red indicates a left turn and green indicates a right turn. You can also clearly recognize the shape points and the already covered distance in the backward simulation control window.

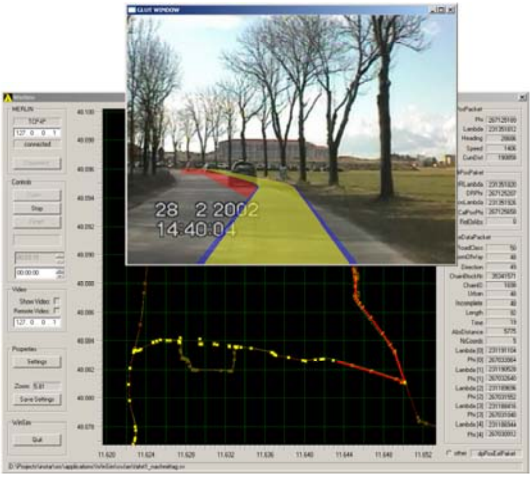

Fig. 11. INSTAR simulation.

When the implementations for the simulation environment had been finished, the INSTAR system started migrating into a test car. Initially, the system was still executed on a laptop computer, but already connected to the built-in Siemens VDO navigation system via a serial port. A digital firewire camera mounted behind the rear-view mirror provided the live stream of the scene in front of the car. For the premier time, the new visualization concept could be experienced in a real testing environment. The left part of Fig. 12 shows a picture of our first real world experiment in March 2002.

Due to the restriction that the INSTAR navigation system has been undisclosed until now, and that it is only available in one test car, no empirical research has been done, so far, to formally evaluate the acceptance of the new human-machine interaction method. However, the developer crew has acknowledged the intuitive way of perception of the navigation information in several test runs in the city of Munich.

As the INSTAR system was running properly within the test car, the exchangeability aspect of the navigation display could be validated. Therefore, the kernel of the framework moved onto a handheld using PocketGL as the graphic renderer. In the same way as in the laptop version, the handheld was directly connected to the car navigation computer (see right part of Fig. 12) and additionally plugged into a video jacket in order to receive the video signals from the camera. The successful port of the software to a handheld device can be considered as the first step towards facilitating the mobility aspect of navigation systems [22].

Fig. 12. Augmented reality car navigation system.

Future Work

The prototypical implementations have demonstrated the applicability of the INSTAR framework for navigation systems since the beginning of 2002. They ubiquitously retrieve tracking and navigation data and display an intuitive, augmented reality view of the route on exchangeable devices.

We believe the utility of our navigation system being even better exploited when it is presented in a more adequate manner than shown so far. So, we are also carrying out design studies on the augmentation of the digital information. 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 left part of Fig. 13), making the navigation aspect in cars natural as possible.

Fig. 13. Alternative augmentation methods.

A few manufacturers have recently started offering colored head-up displays [28] within their cars, using a small part of the wind shield to display important data, like the current speed, the fuel gage, but also conventional depictions of navigation information. With this technology emerging, we could also (e.g., by a command from the steering wheel) display the augmentation of the route directly in the front shield. The driver will not have to avert his eyes from the street, anymore (Fig. 13, right).

The INSTAR system may furthermore be extended by context-sensitive services: In coordination with external sensors or smart devices [4] it calls attention to points of interest located along the route. The left picture in Fig. 14 explains this idea where the system e.g., considers the refuelling indicator of a car and (when crucial) displays the location of the nearest gas station along the route (and maybe further information, e.g., about the price, when available within a pervasive computing environment [10], [12]).

Fig. 14. Additional location based AR information.

Hooks for further location-based services in the framework architecture extend the area of applicability of the framework, which until now only considers navigation aspects. Persons, things and places [18], expressed by positions, names (IDs), profiles, etc, could also be processed and displayed in an augmented reality manner to the users. Tourist information could then be added in the same way as security aspects or adventure games for the fun generation. The right picture in Fig. 14 illustrates just one example of these ideas, where a digital post-it displayed on a PDA provides location-bound information for private issues.

Related Work

The university of Nottingham focuses on human factors design issues in general, and also on human factors of in-car technology [8], [9]. The researchers present established and funded work as well as innovative and creative design issues concerning the perception of navigation information. However, they do not consider augmented reality as an alternative visual offer of information.

The research community for augmented reality proposes ideas for easily comprehensible, innovative augmented reality user interfaces for location-based services. As an example, the MARS project [14], [15], [16] (Mobile Augmented Reality System) presents an approach where augmented reality is used for path finding and orientation. Equipped with a huge backpack including a GPS receiver for position determination and a head mounted display, users are guided within a delimited area by textual location-based denotations and a graphical route displayed as a pipe system. This system, though, narrows the user's freedom of movement significantly, and a head mounted display is also far from being considered a natural interaction instrument, thus letting our prototypical implementation appear to be fairly applicable.

The university of Graz in Austria presents a hybrid positioning technique for an augmented reality outdoor tracking system using a wearable apparatus [24], [25]. However, the methods for locating and identifying points and objects in the real world by coordinating dissimilar positioning techniques represents the main focus of their research area. The augmented reality view seems to be just a means to an end for illustrating the results of their calculations.

Several other research projects in this area deal with human interaction factors, augmented reality views and the growing range of divergent positioning techniques [1], [2], [3], [5], [11], [17], [21], [26], [29]. 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, thus making navigation intuitive and natural.

Conclusion

We consider the novel concept for visualizing navigation information by means of augmented reality to be an advancement in the man-machine-interface of navigation systems and have therefore applied the ideas for patents. The new paradigm appears natural to its users and helps to enhance traffic safety, for, the driver perceives navigation information quickly and intuitively and is always aware of the current traffic situation ahead. Even while looking at the navigation display he is able to keep his attention to the street ahead and to other road users.

The new navigation system also unifies diverse methods for acquiring tracking and orientation data, provides generic implementations for graphical output on different displays and different operating platforms, and consequently enables the users to arbitrarily exchange navigation systems, using an indoor navigation handheld as a car navigation system and vice versa. The applicability of the visualization concept has been demonstrated within this paper by presenting prototypical implementations.

A prospect of our visions reveals of one single mobile device as the navigation system, small enough to 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.

References

1. R.T. Azuma et al., "Tracking in Unprepared Environments for Augmented Reality Systems", Computers and Graphics, vol. 23, no. 6, Dec. 1999, pp. 787-793.
2. J. Baus, C. Kray, A. Kruger, W. Wahlster; "A Resource-Adaptive Mobile Navigation System", Proceedings of the International Workshop on IPNMD, Verona, Italy, 2001.
3. R. Behringer, C. Tam, J. McGee, S. Sundareswaran, M. Vassiliou, "A wearable augmented reality testbed for navigation and control, built solely with commercial-off-the-shelf (COTS) hardware", IEEE & ACM International Symp. on Augmented Reality ISAR, Munich, Germany, 2000.
4. M. Beigl, H.-W. Gellersen, "Smart-Its: An embedded platform for Smart Objects", Smart Objects Conference, Grenoble, France, 2003.
5. D. Benyon, B. Wilmes, "The Application of Urban Design Principles to Navigation of Information Spaces", Proceedings of the HCI Int. Conference, ISBN: 1-85233-766-4, Bath, GB 2003.
6. G. E. Burnett, "Usable Vehicle Navigation Systems: Are We There Yet?", Vehicle Electronic Systems 2000 - European conference and exhibition, ERA Technology, Ltd, 29-30 June 2000, pp. 3.1.1-3.1.11, ISBN 0 7008 0695 4.

7. G. E. Burnett, "A Road-Based Evaluation of a Head-Up Display for Presenting Navigation Information", Proceedings of HCI International Conference, Crete, 2003.
8. G. E. Burnett, S. M. Joyner, "An Investigation on the Man Machine Interfaces to Existing Route Guidance Systems", Proceedings of the IEEE-IEE Vehicle Navigation and Information Systems Conference, VNIS '93, Ottawa, Canada, 1993, pp 395-400, ISBN 0 7803 1235 X.
9. G. E. Burnett, S. M. Joyner, "Vehicle Navigation Systems - Getting It Right From the Driver's Perspective", Proceedings of the Mapping and the Display of Navigation Information Conference, Royal Institute of Navigation, "Nav 95", London, 7-9 November, 1995, pp201-209.
10. G. E. Burnett, J. M. Porter, "Ubiquitous computing within cars: Designing controls for non-visual use", International Journal of Human-Computer Studies, 55(4) 2001, 521-531
11. K. Cheverst, N. Davies, K. Mitchell, A. Friday, C. Efstratiou, "Developing a Context-Aware Electronic Tourist Guide: Some Issues and Experiences", Proceedings of CHI 2000, Netherlands, April 2000.
12. N. Davies, H.-W. Gellerseb: "Beyond Prototype: Challenges in Deploying Ubiquitous Systems", IEEE Pervasive Computing, Vol. 1, 26-35, 2002.
13. V. Ferrari, T. Tuytelaars, L. Van Gool, "Markerless Augmented Reality with A Real-Time Affine Region Tracker" Proceedings of the IEEE and ACM Int'l Symposium on Augmented Reality, vol. I, IEEE CS Press, Los Alamitos, CA., 2001, pp. 87-96.
14. T. Höllerer, S. Feiner, D. Hallaway, B. Bell, "User Interface Management Techniques for Collaborative Mobile Augmented Reality", Computers and Graphics 25(5), Elsevier Science Ltd, Oct. 2001, pp. 799-810.
15. T. Höllerer, S. Feiner, J. Pavlik, " Situated Documentaries: Embedding Multimedia Presentations in the Real World", IEEE Proceedings of ISWC '99 (International Symposium on Wearable Computers), San Francisco, CA, October 18–19, 1999, pp. 79–86.
16. T. Höllerer, S. Feiner, T. Terauchi, G. Rashid, D. Hallaway, "Exploring MARS: Developing Indoor and Outdoor User Interfaces to a Mobile Augmented Reality System", Computer and Graphics, 23, 6 (1999).
17. B. Jiang, U. Neumann, "Extendible Tracking by Line Auto-calibration", Proceedings of the IEEE and ACM Int'l Symposium on Augmented Reality, IEEE CS Press, Los Alamitos, CA., 2001, pp. 97-103.
18. T. Kindberg, et al., "People, Places, Things: Web Presence for the Real World", Technical Report HPL-2000-16, Internet and Mobile Systems Laboratory, HP Laboratories Palo Alto, 2000.
19. G. Labiale, "In-car road information: Comparisons of auditory and visual perception", Proceedings of the Human Factors and Ergonomics Society, 34th Annual Meeting, Santa Monica, CA, 1990.
20. C.P. Lu, G.D. Hager, E. Mjolsness, "Fast and Globally Convergent Pose Estimation from Video Images", IEEE Trans. Pattern Analysis and Machine Intelligence, 22 (2000) 6, pp. 610-622.
21. A. Müller, S. Conrad, E. Kruijff, "Multifaceted Interaction with a Virtual Engineering Environment Using a Scenegraph-Oriented Approach", Proceedings of the 11th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision'2003, Czech Republic, 2003
22. W. Narzt, G. Pomberger, A. Ferscha, D. Kolb, R. Müller, J. Wieghardt, H. Hörtner, C. Lindinger, "Pervasive Information Acquisition for Mobile AR-Navigation Systems", 5th IEEE Workshop on Mobile Computing Systems & Applications, Monterey, California, USA, October 2003.
23. L.Piegl, W.Tiller, "The Nurbs Book", Springer Verlag, ISBN:3-540-55069-0, London, UK, 1995.
24. A. Pinz, "Consistent Visual Information Processing Applied to Object Recognition", Landmark Definition, and Real-Time Tracking. VMV'01, Stuttgart, Germany, 2001.

25. M. Ribo, P. Lang, H. Ganster, M. Brandner, C. Stock, A. Pinz, "Hybrid Tracking for Outdoor Augmented Reality Applications", IEEE Computer Graphics and Applications, Nov./Dec. 2002.
26. K. Satoh et al., "A Hybrid Registration Method for Outdoor Augmented Reality", Proceedings of the Int'l Symposium on Augmented Reality, IEEE Computer Soc. Press, Los Alamitos, CA., 2001, pp. 67-76.
27. J. Steinwendner, W. Schneider, R. Bartl, "Subpixel Analysis of Remotely Sensed Images", Digital Image Analysis: Selected Techniques and Applications, chap. 12.2, W.G. Kropatsch and H. Bischof, eds., Springer-Verlag, New York, 2001, pp. 346-350.
28. Siemens VDO Automitive AG, "Head-up Display Module", Information Systems Passenger Cars, http://www.siemensvdo.com/.
29. L. Tijerina, E. Palmer, M. J. Goodman, "Driver workload assessment of route guidance system destination entry while driving", (Tech. Rep. No. UMTRI-96-30). Ann Arbor, MI: The University of Michigan Transportation Research Institute, 1998.