AugNav. A Location-Based Augmented Reality System for Outdoors Navigation with Smartphones

Agustín Rizzo[1], Damián Flores Choque[1], Silvia Castro[1], Cristina Manresa-Yee[2], Sandra Baldassarri[3]

[1] VyGLab, Dpto. de Cs. e Ing. De la Computación, Universidad Nacional del Sur, 8000 Bahía Blanca, Argentina
[2] Unidad de Gráficos, Visión por computador e Inteligencia Artificial, University of Balearic Islands, Palma, Baleares, España
[3] Dpto. de Informática e Ingeniería de Sistemas, Universidad de Zaragoza, Zaragoza, España

agustinrizzo@gmail.com.{df,smc}@cs.uns.edu.ar,cristina.manresa@uib.es,sandra@unizar.es

Abstract. *Augmented Reality (AR)* is one of the most revolutionary technologies of recent times. It makes possible to enhance the real world by contextualizing computer generated data overlaid on top of it. The AR paradigm opens the way for the development of innovative applications where the user perceives virtual and real objects as coexisting in the same space.
With the advent of smartphones with ever increasing advanced features, AR has the opportunity to emerge as an interesting option to have wide ranging applications on these devices. In this paper, we present the design, implementation and testing of an AR client application targeting the Android-based smartphones that will allow 2D and 3D efficient navigation in the real world enriched with virtual information through visual annotations contextually associated with the real places.
Keywords: Augmented & Mixed Realities, Navigation Systems, Mobile Systems.

1 1 Introduction

The Augmented Reality (AR) introduces a bridge between the real and the virtual worlds allowing content that exists virtually to be contextually associated with real objects and places. Until recent, the developments in the field of mobile AR used platforms built from specialized hardware and often require highly specialized tools and equipment. Traditionally, the overlaid virtual objects are viewed through wearable Head Mounted Display (HMD), processed by portable computing units and interfaced with via mice, tracker-balls, digital gloves, stylus, pens, or specially designed visual code markers ([4],[6]).

With the rapid development of mobile devices capabilities and their feature sets, many researchers began exploring its use as a platform for AR applications. These projects have made clear the potential for PDAs and smartphones undisputed as a means for the spread of AR and laid the foundations of this new paradigm. The advances in available devices integrating, among others, processing power, the freedom to share and re-use Web content, geo-localization and connectivity capabilities, integration of a variety of sensors in commercial devices and advanced graphic capacities to render registered 3D augmentation, are a very attractive alternative to traditional solutions to have countless AR applications without custom hardware. AR applications can become achievable on a larger scale. In this context we develop a 2D and 3D navigational real time AR application.

In this paper, we present an Augmented Reality 2D and 3D efficient client application system targeting the Android-based smartphones to navigate in the real world and enriched with virtual information such as visual annotations contextually associated with the real places. The system is implemented on the Android platform that due to its open nature can be used in almost any type of mobile device developed by hardware manufacturers, and from the developers' point of view, the SDK facilitates the implementation and testing of innovative applications to suit their needs ([1], [5], [15]). The application is a client designed to display 2D and 3D views of the user surrounding area on top of the captured camera frames; the observer position is obtained from the GPS, the orientation from the sensors and the geo-referenced data are downloaded in real time from *OpenStreetMap* project servers [19]. In section 2 we introduce the outdoors AR mobile systems and also present the related work. In section 3, we describe the application detailing its architecture and how the users are able to interact with it. In section 4 we identify some possible difficulties and we propose several tests to the system. In section 5 we draw our overall conclusions and a discussion of ongoing and future work.

2 Outdoors Augmented Reality in Mobile Device

Augmented Reality is the registration of projected computer-generated images over a user's view of the physical world [4]. With this extra information presented to the user, the physical world can be enhanced or augmented beyond the user's normal experience. In AR environments, the user's perception of the real world is enhanced by computer-generated entities such as 3D objects and spatialized audio [3]. Meanwhile, the Mobile Augmented Reality Systems, o MARS, combine such capabilities allowing users to walk around and explore the physical world overlaid with computer-generated information without being restricted to a fixed location. This feature makes MARS extremely versatile and suitable for an almost unlimited suite while their development poses new technical challenges.

While indoor applications are useful, the ultimate goal of AR research is to produce systems that can be used in an environment without restrictions on the user ([2],[9]). The mobile outdoor AR applications constitute the technology to achieve the goal of unrestricted environments.

Outdoor AR is commonly performed in one of two ways, using handheld or immersive hardware technologies ([2],[9]). Handheld AR is achieved by rendering a camera view and overlaid computer graphics on a handheld device such as a mobile phone or PDA. AR with a HMD allows images to be overlaid directly on the user's view of the world achieving higher levels of immersion. Recent trends have been moving toward the use of handheld over immersive hardware.

Creating an AR overlay that is accurately registered to a user's view requires three primary devices: computer, display, and tracker. The computer generates 3D graphics that are rendered to the display and the tracker is used to determine where the graphics are rendered to achieve correct registration.

When using handheld devices for outdoor AR, video see-through uses the device's camera to capture the real world view. The camera's video stream is combined with the virtual graphical objects generated by the graphics hardware and displayed on it.

The position and orientation of the device must be accurately tracked. A wide variety of tracking technologies are available for indoor use including magnetic, vision based, inertial, or ultrasonic devices. However, the choices available when working outdoors are significantly more limited. There are magnetic trackers or vision tracking algorithms that can be used outdoors but they have very limited range and require preparation to make the area suitable for tracking (such as installing sensors or modeling the environment). GPS is currently the most suitable position tracking technology for use outdoors that supports an unlimited tracking area in open spaces and does not require previous preparation of the environment.

2.1 Related Work

A pioneering piece of work in mobile AR was the Touring Machine [7]; this is the first example of a mobile outdoor system. This provided users with labels that float over buildings, indicating the location of various buildings and features at the Columbia University campus, USA. Interaction with the system was achieved through the use of a GPS and head compass to control the view of the world. By gazing at objects of interest longer than a set dwell time the system presents additional information. Since 1997 were developed a large number of backpack-based wearable computer using combinations of various tracking technologies including GPS, electronic compass, inertial sensors, etc., in order to explore new ways to interact with the outside world [11]. One of these prototypes was the Map-In-The-Hat [22], a mobile navigation system that could guide users towards waypoints in unfamiliar terrain. This system could also be referred as the Tinmith-I. Although the computer used was designed for mounting on a belt, there were too many components to carry and so a back pack was used instead. After this experience a new system was designed from the ground up for the purpose of performing the mobile navigation task much more effectively. Instead of just providing simple navigation cues, this software was designed to support both 2D maps and 3D immersive wire frames with optical overlay [23]. This version was implemented using a flexible software architecture [20] designed to be extended for other tasks in the future. Later AR based systems use this software architecture for the development of many applications.

By that time, another revolutionary AR Project was the Touring Machine extension, developed by Höllerer et al. [12] for the placement of what they termed situated documentaries. This mobile AR system shows 3D building models overlaying the physical world, giving users the ability to see buildings that no longer exist on the Columbia University campus. This system used a backpack for the computer and its external battery. This is the first mobile system combining RTK GPS technology with a inertial-magnetic orientation tracker and also new forms of interaction among AR system's users.

Julier et al. [13], at the Naval Research Laboratory developed the outdoor Battlefield Augmented Reality System (BARS), a descendent of the Touring Machine planned for use by soldiers in combat environments. The system consists of a wearable computer, a wireless network system and a see-through HMD; the system targets the augmentation of a battlefield scene with additional information about environmental infrastructure. For the user interface, a gyroscopic mouse is used to manipulate a 2D cursor and interact with standard 2D desktop widgets.

More recently AR research has been moved to include a strong focus on handheld devices. At the early 2000s, the first projects of this type, AR-PDA Project at Siemens [8] and BatPortal [17], use a PDA-based, wireless AR system. Both use the PDA as a client to capture and transmit video to a dedicated AR server on which all processing such as image analysis, 3D rendering and compositing is made. While the first prototypes were based on a distributed strategy delegating in a server the graphics overlay processing, the rapid advance of mobile phones made possible the emergence of applications that worked based on the recognition of markers in the environment. Subsequently, the integration of new sensors enabled devices from commercial sources to create a variety of applications for outdoor AR.

Since the increasing computing and graphic capabilities of personal mobile devices, it was really possible to move AR systems from the PC AR systems to Tablet PCs [18], PDAs [24] and then mobile phones [16].

Reitmayr et al. [21] presents a model-based hybrid tracking system for outdoor AR in known urban environments enabling accurate, real-time overlays on a handheld device and Nokia [11] presents Mara, a multi-sensor mobile phone AR guidance application for mobile phones. The prototype application overlays the continuous viewfinder image stream captured by the camera with 2D overlaid information and text in real time, annotating the user's surroundings. In 2007, Klein and Murray [14] present a system capable of robust real-time tracking and mapping in parallel with a monocular camera in small workspaces.

The advances in processing power and inclusion of built-in cameras on mobile phones have made it possible to render registered 3D augmentation on mobile phones. In 2008 comes Wikitude [26], an application that combines GPS and compass data with Wikipedia entries; the Wikitude World Browser scans the surroundings for (e.g.) geo-referenced content using the camera and the device's sensors. The objects' information is displayed in the can where the real object is located overlaid on the real-time camera view of an Android smartphone. In 2009, White introduces *SiteLens* [25], a hand-held mobile AR system for urban design and urban planning site visits. SiteLens creates *3D situated visualizations*, (representations of geocoded carbon monoxide concentration data) that are related to and displayed in their environment.

3 *AugNav*. An AR Mobile Navigation System

AugNav (*Augmented Navigation* acronym) is an application that, through an AR interface, provides the user with points of interest in his/her field of view as it navigates a city. The system is able to track the user location and to display 2D and 3D augmentation of the markers indicating the important buildings in their field of view and a 3D augmentation of the surrounding terrain over a video image on the display in real time. The location of buildings and terrain information are obtained from the Web. The entire application was developed for a smartphone equipped with built-in camera, wireless connectivity, GPS receiver, accelerometer and orientation and magnetic sensors.

The application can display the user a 2D or a 3D view of their surrounding environment. The 2D display provides a map of an area centered in the user position and their surroundings; this view is augmented with a circular sector which represents the projections of their vision frustrum and a point indicating the location of each of the nearby buildings; additional information on the building names can be obtained on-demand. The 3D display presents a 3D view of the surrounding terrain and markers in perspective indicating the important buildings in their field of view on top of the captured camera frames; additional information about the buildings is also available on-demand.

In order to achieve this objective, the system is able to:

- *Determine the position and orientation of the user in the world*. To obtain these data, the GPS receiver and the sensors integrated into the mobile device are used by the application.
- *Obtain and store the geographic information concerning to the terrain and to the points of interest in their proximity*. The geographic information which may correspond to individual points or paths, is obtained from a server using the wireless capabilities of the device.
- *Depict the information in a graphical interface superimposing the generated graphics on the real-world images*. real world. The virtual images whose characteristics and positions are stored in the database are superimposed to the video stream, incorporated through the smartphone's built-in camera.

3.1 System Architecture

The proposed navigation system is conceptually divided in 3 blocks: the data structure to store the geographic information, the acquisition and update module, and the information visualization module (Fig. 1).

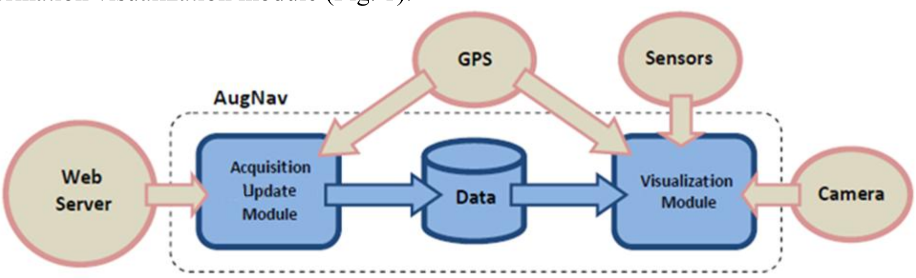

Fig. 1. Diagram of the Application's Dataflow

3.1.1 Geographic Information Storage

The geographic information is obtained by querying *OpenStreetMap* [19], a project aimed at the creation and production of free geographic data. Initially, the map for a small user-centered predefined region (Region Of Interest or ROI) and its surroundings are downloaded from the database (DB) and stored in the phone. The entire area is divided in 9 geographic map blocks being the central one the ROI. This area is delimited by two pairs of latitude and longitude values. The points of interest of the whole area are also downloaded and stored in the phone.

3.1.2 Acquisition and Update of the Geographic Data

At this stage, geographical data are acquired and updated, considering the ROI initially centered at the user position. Each block may be loaded by querying the DB; the smartphone progressively loads content from *OpenStreetMap* based on the GPS user coordinates. This information can be requested by specifying a particular block based on its distance from the user.

The depicted information corresponds to the ROI; this ROI corresponds to a circle centered at the user position (Fig. 2) and radius ½ of a block. This information should be presented in real-time as the user moves; therefore, the stored area should cover a larger area than the required *circle of vision* (Fig. 2); then it requires not only store the ROI but also its surroundings. Thus, the user perceives no delay during the acquisition and processing of new information obtained from the web server (Fig. 2).

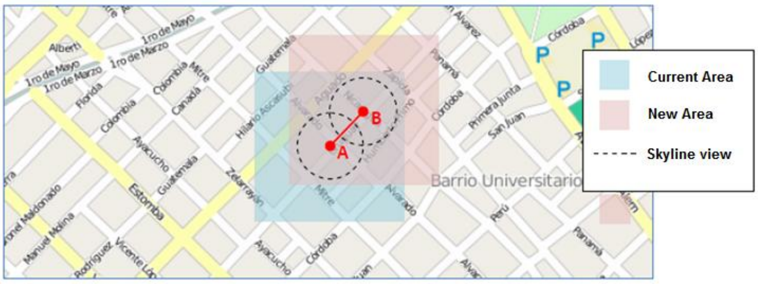

Fig. 2. Data Update.

The update strategy allows the reuse of a portion of the stored data, thus limiting the amount of data requested from the server, and therefore those processed by the application. This strategy consists in partitioning a geographic area on a square grid of 9 quadrants (3x3), each of these bounded by the corresponding latitudes and longitudes (Fig. 3).

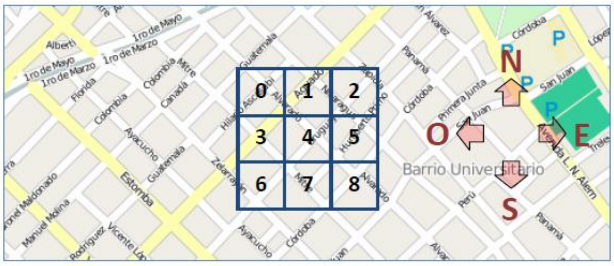

Fig. 3. Quadrants' Grid

Initially, the user is in quadrant 4 (Fig. 3). When any of the limits of this quadrant is crossed, the update process begins; it consists of both the elimination of the stored data relating to the quadrants that are no longer used, as in obtaining and storing information associated with the new quadrants which constitutes the current grid (Fig. 4).

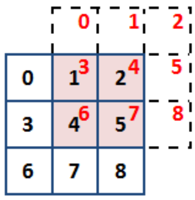

Fig. 4. Update Schema.

3.1.3 Visualization of Data

The application's 2D interface (Fig. 5a) shows the 2D map, a compass and two control buttons. The map image represents the ROI and makes easy to analyze the relationship among the geographical location of points of interest, the user's location and its orientation. The vision sector (in pink, in Fig. 5a) region is what the user sees and what can be shown in 3D. The buildings' labels are displayed on-demand.

The interface of the 3D scenario consists of the real world image obtained by the camera and the overlaid 3D surface generated graphically; this 3D scenario is presented on screen using perspective projection. To achieve a correct registration of the objects, the projection must be configured to fit the parameters of the camera integrated into the mobile device. In this case, the field of view specification is identical to the Google Nexus One phone (Fig. 5b). The black and gray squares represent the camera´s acquired image; in the emulator, the real-world images cannot be displayed. The user points of interest are represented with small rectangles also in perspective and the specific names can be obtained on-demand; bigger rectangles reveal nearer points of interest.

4 System Implementation and Testing

The *AugNav* testing was conducted entirely on the emulator included in the Android SDK. This emulator provides most of the Android based mobile device functions; it also supports the *Android Virtual Devices* (AVDs) configuration; this allows, among other things, specify the version of the platform that will be used and the hardware capabilities of the simulated device.

AugNav was designed to operate on mobile devices with Android 2.2 operating system and the following hardware requirements: built-in camera, touch-screen (resolution 320*480 and 160dpi), *wireless* connectivity, GPS receiver, accelerometer, and orientation and magnetic sensors.

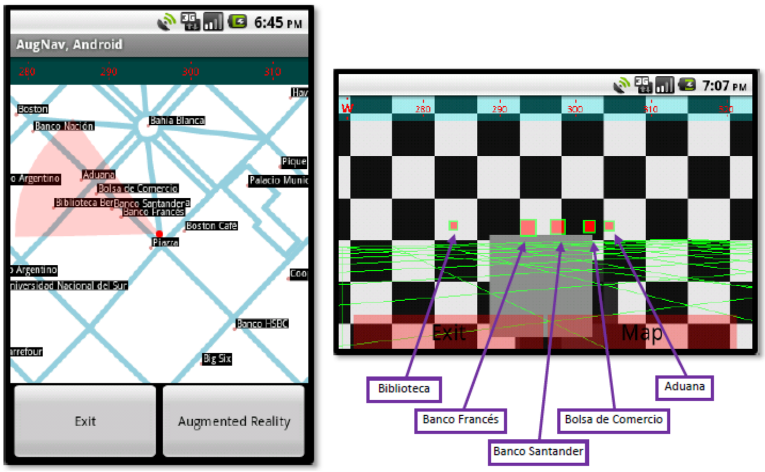

Fig. 5. a) 2d Map (b) 3D Scenario

The API v0.6 enables the connection with *OpenStreetMap*. This API allows for calls to create, read, update and delete the three types of basic elements that constitute the maps. Each call, as appropriate, returns or waits data in XML format.

During the application's test session, several static and dynamic tests were run. The most important are described below:

Declination Test. This test verifies that points of interest located in areas with different magnetic declination are correctly visualized. The test was run for several test areas, with different magnetic declinations.

Poinst of interest representation's test. This test verifies the relationship between orientation and distance from the observer to points of interest and their representation in the augmented reality interface. Several positions and orientations were chosen; for these parameters, points of interest at different distances within the field of view were selected.

Data update test. To evaluate the performance of the data updating strategy, we simulated a user carrying a mobile device with *AugNav* traveling along a geographic area. To simulate a continuous and predictable motion KML files containing a series of locations belonging to a tour were generated and sent to the virtual device. This information was matched against the data obtained from the *OpenStreetMap* oficial site along the tour points.

5 Conclusions and Future Work

Despite the technological advances of recent years have enabled the development of new and more versatile prototypes in the field of MARS, very few have succeeded as commercial solutions. Many of the technical challenges posed originally have been solved, but there are still difficulties which make unfeasible the widespread use of these technologies. Limitations in the accuracy of positioning and orientation of the devices over large areas, auto-calibration of sensors, battery life, display resolution and graphic processing capabilities, are still very restrictive to achieve the widespread dissemination of AR on mobile devices. Additionally, applications for outdoor AR involve particularly complex challenges. This type of mobile system must be capable of operating in very different environments and conditions and often disadvantageous, such as exposure to adverse weather conditions, vibration and use for extended periods of time. However, AR has great potential to revolutionize the way you perform the most varied human activities.

However, AR represents a new option over current alternatives in entertainment, and a truly useful and versatile tool in the organization and contextualization of information. The characteristics of today's commercial mobile devices allow different MARS be available to users in general. This arises from the developer's point of view, a major challenge in the design and development of AR applications for these devices.

We have presented the design and implementation of *AugNav* a mobile augmented reality application 2D and 3D in real time. From the design and implementation of *AugNav*, we analyzed the capabilities offered by Android as a platform for development and testing of applications for outdoor AR. With regard to development, Android makes easy not only the access to resources on the device (GPS, sensors, camera and connectivity) but also the generation of synthetic graphics overlaid on the video in real time. In regard to testing applications for outdoor AR, the absence of official tools to facilitate the simulation of sensors, and the limited control in the location information management, hinder the development of tests that otherwise would be performed on actual devices (with all the complications that this entails).

This work constitutes the starting point for the development of outdoors 3D mobile AR applications. We are working on the completion of outdoors interactive 3D real-time visualization with good graphic quality as an overlay of the real-world situation, on a mobile phone. This is a challenging research field where mobile devices are used for registering 3D graphics within unconstrained outdoor environments.

Acknowledgements. This research was partially supported by

- PGI 24/N028. *Representaciones Visuales e Interacciones para el Análisis Visual de Grandes Conjuntos de Datos*, granted by Secretaría General de Ciencia y Tecnología, UNS.
- FRIVIG. D/031964/10. *Formación de Recursos Humanos e Investigación en el Área de Visión por Computador e Informática Gráfica*, granted by MAE-AECID (Programa de Cooperación Interuniversitaria e Investigación Científica e/ España e Iberoamérica.

6 References

[1] Android Developers, http://developer.android.com
[2] Avery, B., Smith, R.T., Piekarski, W., and Thomas, B., Designing Outdoor Mixed Reality Hardware Systems. In The Engineering of Mixed Reality Systems, Human-Computer Interaction Series, Springer-Verlag (2010)
[3] Azuma R., A Survey of Augmented Reality, Presence: Teleoperators and Virtual Environments 6, 355-385 (1997)

[4] Bimber O., Raskar R.: Spatial Augmented Reality: Merging Real and Virtual Worlds, A.K.Peters Ltd. (2005)
[5] Burnette E.: Hello, Android: Introducing Google's Mobile Development Platform, The Pragmatic Bookshelf (2009)
[6] Chehimi, F., Coulton, P., Edwards, R.: Augmented Reality 3D Interactive Advertisements on Smatphones. In: Proc. ICMB 2007, 21 pages (2007)
[7] Feiner, S., MacIntyre, B. and Hollerer, T. A touring machine: Prototyping 3D mobile augmented reality systems for exploring the urban environment. In 1st Int'l Symposium on Wearable Computers. 74–81. Cambridge, MA (1997)
[8] Fruend, J., Geiger, C., Grafe, M., Kleinjohann, B.: The Augmented Reality Personal Digital Assistan. In: Proceedings of the Second International Symposium on Mixed Reality (ISAR 2001), 2001.
[9] Gotow J. B., Zienkiewicz K., White J., Schmidt D. C.: Addressing Challenges with Augmented Reality Applications on Smartphones. In: Proceedings of MOBILWARE 2010. pp.129-143 (2010)
[10] Haller M., Billinghurst M., Thomas B.: Emerging Technologies of Augmented Reality: Interfaces and Design, Idea Group Publishing (2007)
[11] History of Mobile AR, https://www.icg.tugraz.at/~daniel/HistoryOfMobileAR/
[12] Höllerer, T., Feiner, S., Pavlik, J.: Situated documentaries: Embedding multimedia presentations in the real world. In Proc. ISWC '99 pp 79-86, San Francisco, CA, (1999).
[13] Julier, S., Baillot, Y., Lanzagorta, M., Brown, D., Rosenblum, L.: BARS: Battlefield Augmented Reality System. In: NATO Information Systems Technology Panel Symposium on New Information Processing Techniques for Military Systems (2000)
[14] Klein, G., Murray, D., Parallel Tracking and Mapping for Small AR Workspaces. In Proc. ISMAR 2007, pp. 225 – 234 (2007)
[15] Meier R., Professional Android 2 Application Development, Wiley Pub., Inc. (2010)
[16] Möhring, M., Lessig, C. and Bimber, C. Video See-Through AR on Consumer Cell Phones. Proc. ISMAR 2004, pp. 252–253, IEEE Press (2004)
[17] Newman, J., Ingram, D., Hopper, A.: Augmented Reality in a Wide Area Sentient Environment. In: Proc. ISMAR 2001, pp. 77-86 (2001)
[18] Newman J., Schall G., Barakonyi I., Sch¨urzinger A., and Schmalstieg D.*: Wide-Area Tracking Tools for Augmented Reality*. In: Proc. of the 4th International Conference on Pervasive Computing, 2006
[19] OpenStreetMap Wiki, http://wiki.openstreetmap.org
[20] Piekarski, W., Thomas, B., Hepworth, D., Gunther, B., and Demczuk, V. An Architecture for Outdoor Wearable Computers to Support Augmented Reality and Multimedia Applications. In: Proc. 3rd Int'l Conference on Knowledge-Based Intelligent Information Engineering Systems, pp 70-73, Adelaide, SA, Aug 1999.
[21] Reitmayr, G., Drummond, T.: Going out: Robust Model-based Tracking for Outdoor Augmented Reality. In: Proceedings of ISMAR 2006*,* pp. 119-122. IEEE Press, CA (2006)
[22] Thomas, B. H., Demczuk, V., Piekarski, W., Hepworth, D., and Gunther, B. A Wearable Computer System With Augmented Reality to Support Terrestrial Navigation. In: ISWC'98, pp 168-171, Pittsburg, (1998)
[23] Thomas, B., Piekarski, W., and Gunther, B. Using Augmented Reality to Visualise Architecture Designs in an Outdoor Environment. In Design Computing on the Net - *http://www.arch.usyd.edu.au/kcdc/conferences/dcnet99*, Sydney, NSW, Nov 1999.
[24] Wagner D. and Schmalstieg D.: First Steps Towards Handheld Augmented Reality. In Proc. ISWC'03, pp. 127-135. IEEE Press, Washington DC (2003).
[25] White, S., Feiner, S.: SiteLens: Situated Visualization Techniques for Urban Site Visits. In: Proc. ACM CHI 2009, pp. 1117-1120, Boston, MA, (2009).
[26] Wikitude, http://www.wikitude.com/en