RASMAP: Plataforma de Realidad Aumentada Sin Marcadores en Entornos Móviles para el Desarrollo de Asistentes Personales TIN2006-15418-C03

Plataforma Universal de Realidad Aumentada Móvil
TIN2006-15418-C03-01
José Luis Los Arcos*
Investigador Principal

Sistema de posicionamiento 3D sin marcadores basado en visión por computador
TIN2006-15418-C03-02
Diego Borro
Investigador Principal

Procesamiento-Distribución de Video y Reconocimiento de Imágenes en Entornos Móviles
TIN2006-15418-C03-03
Xabier Basogain
Investigador Principal

José Luis Los Arcos***
Responsable del Proyecto Coordinado

Abstract

The aim of this project is to advance in the knowledge of the technology that makes possible the development of a platform that by means of the application of the augmented reality technologies and using tracking technologies based in vision without markers, facilitate the development of Wearable Personal Assistant.

The development of this platform implies approaching several technological challenges:

- To overcome the limitations inherent in the mobile devices: speed, capacity of memory, capacity of storage, graphical features, …
- To obtain tracking systems that they do not need to alter or to adapt the environment.
- To optimize for the transmission and reproduction of multimedia contents through wireless networks on mobile devices

The quality and usefulness of the scientific-technological results obtained will be validated developing 2 demonstrators, one in the area of the Cultural Heritage as a guide for visitors and other one in the area of mechanical engineer as assistant for the e-learning.

Keywords: augmented reality, markless tracking, wearable personal assistant.

1 Project Objectives

Augmented reality is nowadays a technology that is acquiring great relevancy as a research area [1][2]. This technology complements the perception and interaction with the real world and allows placing the user in a real environment augmented with additional information generated by computer. The concept of Wearable Personal Assistant - WPA based on this technology opens novel possibilities for the accessibility of the society to the information through the technology. The aim of the research raised in this project is to advance in the knowledge of the technology for the development of these WPAs. With this aim it makes necessary to approach a series of technological challenges that are not yet solved.

Augmented Reality applications have experienced a high degree of development in fixed environments. However, the evolution to mobile environments presents some problems still

*** Email: josel@labein.es

unresolved. Some of these problems will be approached within this project: Hardware and software limitations of the mobile devices; There are a lot of experiences in the utilization of different technologies for positioning and tracking of the user/device inside the environment. However, most of these technologies need the adjustment of the environment for the specific intentions; Integration of video with applications of 3D technology for augmented reality applications in mobile environments.

The aim of this project is to advance in the knowledge of the technology that makes possible the development of a platform that by means of the application of the augmented reality technologies and using tracking technologies based in vision without markers, facilitate the development of Wearable Personal Assistant. The aim of the project can be split in the following objectives:

1. Establishment of the conceptual Framework of the research areas:
2. Research activities:
    - Graphical Libraries for Mobile Environments
    - Algorithms for Image recognition based on 3D representation
    - Algorithms for representing and positioning in 3D environments
    - Methodologies for Transmission and reproduction of video in mobile environments
3. Implementation of the Mobile Augmented Reality Platform
4. Validation and evaluation of the obtained result through the development and evaluation of two demonstrators
5. Management, diffusion and exploitation of the results

In order to obtain the mentioned objectives the following workplan was defined.

PHASE/TASK	DURATION	PARTICIPANTS (bold Responsable)	DESCRIPTION
PHASE I	M1-M9		ESTABLISHMENT OF THE CONCEPTUAL FRAMEWORK OF THE AREAS OF INVESTIGATION
Task 1	M1-M3	LABEIN ESI CEIT	Review of the State of the Art
Task 2	M4-M9	LABEIN ESI CEIT	Analysis and conceptual design of Augmented Reality Architectures in mobile devices
PHASE II	M10-M24		RESEARCH ACTIVITIES
Task 3	M10-M21	LABEIN	Graphical libraries for Mobile Environments
Task 4	M10-M21	ESI	Algorithms of Images Recognition based on 3D Representations
Task 5	M10-M21	CEIT	Algorithms of Representation and Positioning in 3D environments
Task 6	M10-M21	ESI	Methodologies for Transmission and Reproduction of video in mobile environments
Task 7	M19-M24	LABEIN ESI CEIT	Implementation of the Augmented Reality Platform.
PHASE III	M25-M36		VALIDATION AND EVALUATION OF THE OBTAINED RESULTS
Task 8	M25-M30	LABEIN	Development of the Demonstrator of Cultural Heritage
Task 9	M25-M30	ESI CEIT	Development of the Demonstrator of e-learning
Task 10	M28-M33	LABEIN ESI CEIT	Implementation of the Augmented Reality Platform. (Final version)
Task 11	M34-M36	LABEIN CEIT	Evaluation of the Augmented Reality Platform
COMPLEMENTARY ACTIVITIES	M1-M36		MANAGEMENT, DIFFUSION AND EXPLOITATION

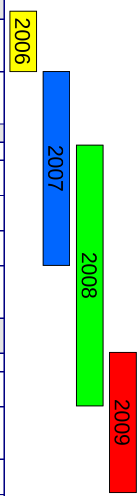

Figure 1 RASMAP Project Workplan

2 Summary of Project results

Following the timetable presented in the previous section (see Figure 1) RASMAP project is currently in its final phase (Phase III). Following are the most relevant scientific and technological results achieved in each of the tasks into which the project has been divided:

2.1 Review of the state of the art

The objective of this task is to review the state of the art of the latest results regarding the development of augmented reality in mobile environments. As a result of this review it has been generated a detailed report on the state of the art of technologies and applications related to the most important objectives of the RASMAP project.

2.2 Analysis of conceptual design of augmented reality architectures in mobile devices

The objective of this task is to analyze the possible architectures on which can be developed the augmented reality platform for mobile environments, as well as select the most appropriate one. With this objective the following activities has been made:

As a first step, a detailed definition of use scenarios has been made; the scenarios represent 5 environments of potential application for mobile personal assistants based on the platform to develop. From these scenarios have been identified associated services. For different scenarios have been detected common services and other specific of each scenario. Subsequently have been identified and grouped the services identified. 7 services are obtained as a grouping of services defined in the scenarios. These have been subsequently revised and refined through an analysis from the viewpoint of the scenarios described initially. The following table shows the classification of the services identified.

Service	***Description***
Interaction	Different kinds of human computer interaction
Tracking	Real-time and accurate user position and orientation
3D Rendering	Visualization of 3D information
Multimedia reproduction	Reproduction of multimedia contents (audio, video, image, etc.)
Information Management	Insertion, edition, deleting and organization of information required for the application.
Transfer of information	Manages the communications between the mobile devices and the remote services.
Contextual information	Information required for the definition of user context.

Table 1 Classification of identified services

Once identified the main services and defined the main characteristics of them, it is presented as the best suited solution a modular designed architecture. An architecture in which services with high-order response time (eg interaction) or ratio of frames (eg rendering and reproduction) are processed directly on the mobile device, while other services related to external information (eg contextual information) or communications (eg transfer) are processed entirely remotely. Tracking services and information management are implemented partially locally and remotely. Based on a previous analysis of different alternatives for the architectural design of the platform service oriented architecture (SOA) is chosen with a final application based on services offered by different processes. The figure below (Figure 2) shows the architecture and the distribution of services.

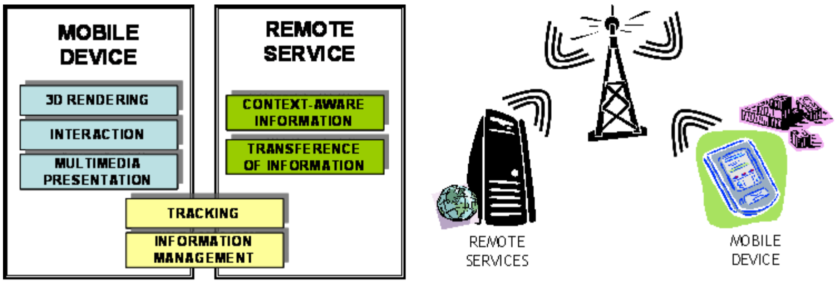

Figure 2 Distribution of services in RASMAP architecture

2.3 Graphical libraries for mobile environments

This work focuses on the development of rendering technologies for augmented reality applications on mobile devices. To achieve this goal, we worked in the design and development of an engine for displaying virtual and augmented reality applications on PDA-like mobile devices.

The main activities carried out within this task are:

- Analysis of the major limitations of the technology to display three-dimensional content on mobile devices.
- Review of alternatives for the development of a rendering engine for mobile devices.
- Design rendering engine for displaying mobile augmented reality applications
- Develop engine for displaying applications of mobile augmented reality

It has been developed a rendering engine for virtual reality applications (visualization of 3D models generated from basic editing tools or high-level ones like 3D Studio Max) and an engine for displaying mobile applications of augmented reality, including image capture, 3D visualization and positioning. The figure below (see Figure 3) shows the design of the described engine.

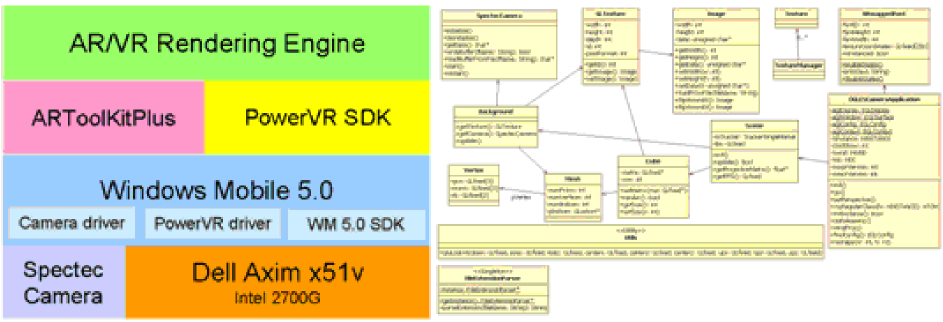

Figure 3 AR/VR rendering engine

Within this task two alternatives for the development of the engine have been analyzed, a low-level one (OpenGL ES[7]) and a high-level one (OGRE3D[8]). Finally, the engine has been designed and developed based on the low level graphics library for mobile devices (OpenGL ES) running on both hardware and software implementations.

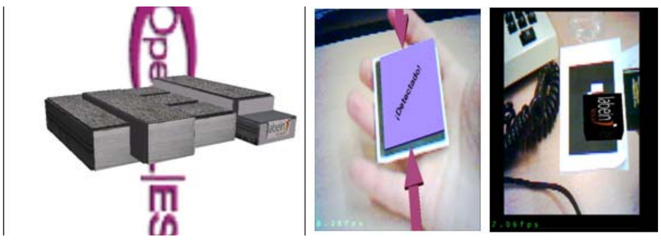

Figure 4 Screenshots using the rendering engine

2.4 Algorithms for Image recognition based on 3D representation

This line of the project aims to make a study of the interesting points of an image using image processing, object recognition, segmentation, etc. in order to allow the positioning of the camera within a three-dimensional environment.

The main activities carried out within this task are:

- Analysis and comparison of different methods of detection of interesting points.
- Development of algorithms corresponding to different methods.
- Implementation of a GUI in Matlab (images, methods and parameters).

The general idea is to compare two images of the same scene generated independently, extract the characteristic points from the real image and identify these points in its 3D representation. Figure 5 shows both images and the different stages of the image positioning system.

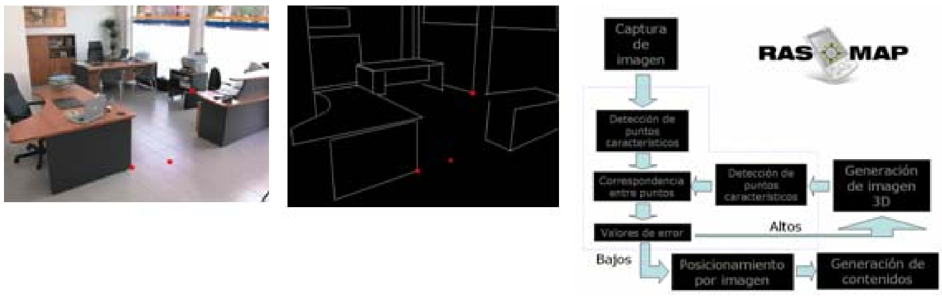

Figure 5 Correspondence between the characteristic points of the real and virtual images, and block diagram of the image positioning system.

The development of the GUI evaluator allows the comparison of the three methods Moravec[4], Harris[5] and Trajkovic[6] (see Figure 6) of detection of characteristic points. The methods have been compared on the edge detection, topological methods and methods of auto-correlation, with selection criteria and detection of actual vertices (detection) and location, repetitiveness (invariant to scaling, rotation and deformation 3D), robustness to changes in lighting, noise, textures, and efficiency versus computational workload.

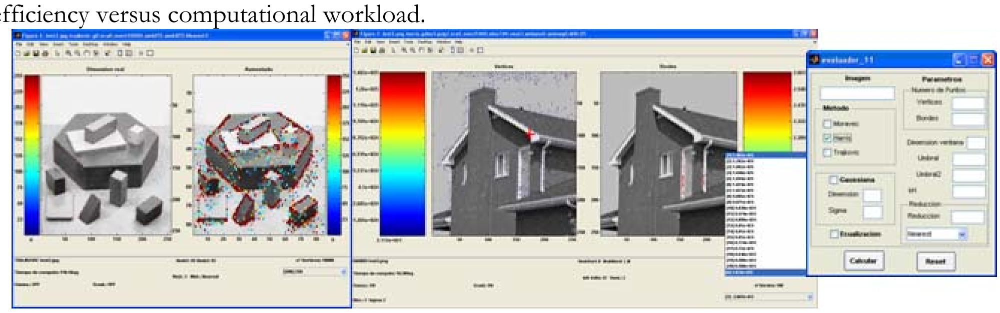

Figure 6 Screenshots of GUI evaluator and Trajkovic and Harris visualization results.

Evaluation of the methods for detecting characteristic points using a GUI makes easier to change the methods to analyze, the test images and the parameters of image processing. The results are presented in a graphical format with a color indicator to evaluate the cornerness of the points identified.

2.5 Algorithms for representing and positioning in 3D environments

The main goal of this task is the study of new methods for computing the camera pose (translation and orientation) based on markerless computer vision and using information generated in the previous section (“algorithms for image recognition based on 3D representation”) and a 3D model of the environment.

The first step was an improvement of marker based methods. More specifically, we have development a special module for conferring more robustness to the public library of augmented reality ARToolkitPlus[1] in order to overcome the problem of the partial marker occlusions (see Figure 7).

Figure 7 The 3D model is visible even when the marker is partially occluded

The second part of the work (and the main goal) is the markerless 3D tracking. For that, we are developing a tracking system based on edges and a 3D model of the object. Firstly, the algorithm uses the Canny detector for detecting edges in the image. After that, the system tries to match those edges with the lines of the 3D model every single frame.

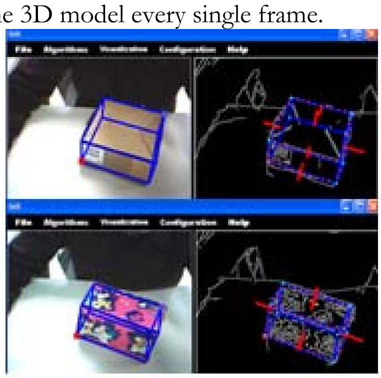

Figure 8 On the left, camera images augmented with the 3D model. On the right, Canny images showing the detected edges

2.6 Methodologies for Transmission and reproduction of video in mobile environments

This line of work aims to develop a transmissions system for mobile oriented applications of augmented reality, and also a communication system that allows from the mobile devices (PDA) to access multimedia content residing on a remote server or other mobile devices.

The main activities carried out within this task are:

- Analysis of the wireless communications and multimedia resources of the mobile devices.
- Design and implementation of a set of webservices that provide a communication platform.
- Development of a software tool, called MobiMedia as a suite of tools that allows to create, edit and store text, images, audio and video in mobile devices PDA based on Windows Mobile 5.0.

The communications platform allows users to share and collaborate on such multimedia content through web services transparent to the user. Figure 9 illustrates the infrastructure of the communication process and the main menu of the mobile multimedia application.

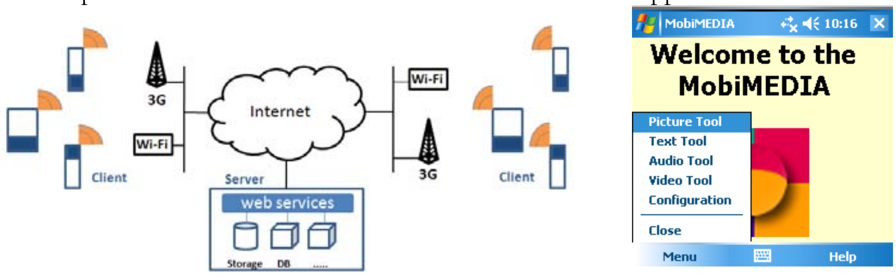

Figure 9 Infrastructure of communications for WPA and the MobiMedia software application.

The advantages offered by this developed multimedia suite with respect to other business applications such as windows mobile notes (text and audio), proprietary software camera (video and images), and utilities sending content via email include, among others, the following: a) integration into a single application; b) standard file formats (txt, wav, mp3, avi, mp4, wmv); c) multimedia content records: local storage and remote storage; d) collaborative content (send & receive); e) rich media presentation. Figure 10 illustrates different instants of the process taking a picture or making manual annotations, and the server hosting the web services of the collaborative mode[9].

Figure 10 Picture tool of MobiMedia with annotation, PDAs and Webserver.

2.7 Implementation of the Mobile Augmented Reality Platform

RASMAP mobile augmented reality platform consists of a group of devices with complementary functionalities connected and integrated through a software platform. From the hardware point of view the three main elements of the system are: The processing device, the visualization device and the positioning device.

The hardware device selected for the developments described here is the PDA Dell Axim x51v, mainly because its processing power, graphics card and screen resolution. Developments have been tested also in other PDAs (Dell Axim x50v, HP 6915, HTC TyTN, HTC P3600) with poorer results in rendering tasks. For image capture, cameras Spectec SDC-001A and Spectec SDC-003A have been used. The only difference between both cameras is the resolution, 300KPixels and 1,3MPixeles respectively. The camera is attached to the Dell PDA through the SD slot. HTC and HP PDAs have the camera integrated. All PDAs have microphone and audio output in which conventional headphones can be plugged. The screen of the PDAs itself, the Dell one provides VGA resolution, is used as a visualization device. For the positioning, the system is based on marker-based optical tracking. As web server we are using a Dell optiplex GX745MT commercial PC.

From the software point of view, the followings are the services developed according the previously described architecture:

- **Interaction:** Basic touch pad and GUI interaction implementation.
- **Tracking:** Marker based optical tracking based on ARToolkitPlus library including developments for allowing partial occlusion of the markers.
- **3D Rendering:** Development of our own rendering engine for OpenGL ES hard and soft implementations.
- **Multimedia reproduction:** Reproduction of multimedia files consisting of a sequence of photos, text and audio (SMIL files) using an external tool.
- **Information Management:** Provides the user with a multimedia management service that lets her/him record video and audio, take pictures and draw or write over the photographs manually, and also write text notes.
- **Transfer of information:** Manages the remote communication between users integrating a video conference application.
- **Contextual information:** Image capture for the positioning of the user using the information provided by the camera attached to the PDA.

2.8 Development of the demonstrator of Cultural Heritage

For the development of a first prototype of the Wearable Personal Assistant (WPA), we choose the task of diagnosing state of preservation and accessibility of buildings and public spaces of a historic centre, as one of the key tasks for the management of cultural heritage.

For the diagnostic procedure, we defined three main diagnostic elements: a residential building attached to the wall, a building of historical interest and a public area. On the other hand, we defined two different types of user: an expert user, and a non-expert user. For each of the elements and for each type of user a diagnosis procedure is defined.

The main functionalities provided by the system for the first prototype are the following ones: Multimedia information reproduction; Multimedia library reproduction; Augmented reality visualization; 3D models library visualization and interaction; Remote expert assistance; Multimedia recording, downloading and annotation. The following figure (Figure 11) shows the use of augmented reality for the diagnosis of accessibility in heritage buildings.

Figure 11 Mobile augmented reality for the diagnosis of accessibility

2.9 Development of the demonstrator of e-learning

For the development of the second prototype, we choose the task of e-learning in the mechanical field. The goal is to guide workers when they are doing assembly/disassembly tasks over mechanical systems.

Using the research that has already done in previous tasks, it's possible to augment the camera images with additional information that can help to the users for accomplishing maintenance tasks. This help can be 2D text, multimedia information (pictures or videos), and even the 3D model itself. Thanks to the 3D model, the user could see, for instance, which element is the next to be disassembled and in which way is has to be done. The task of implementing this demonstrator is still on an early stage.


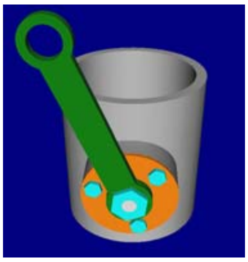

Figure 12 On the left, a real image of a valve (it is not the real mechanical system but a prototype) and on the right the virtual 3D model

2.10 Future Tasks

The main task until the end of the project is to provide the final version of the augmented reality platform. For the time of project development have emerged new mobile devices with features of mobility and at the same time with similar capabilities to desktop PCs. To compare the advantages and disadvantages of the use of PDA devices and new mobile devices (UMPC and Netbook) the second version of the platform will be developed for such devices.

To include in the final version, apart from the already developed services, we are developing new services for Tracking (markless tracking and GPS) and also for management and transfer of information to be used in the wearable personal assistant for e-learning. The conclusions drawn from the results of the demonstrators will allow us to validate the project's development

3 Performance indicators

3.1 PhD and educational activities

A total of 3 PhD Tesis are actually in progress in the context of the RASMAP Project:

- LABEIN: Jose Luis Izkara "Plataforma de realidad aumentada móvil orientada a entornos abiertos y dinámicos: Aplicación en actividades del sector de la construcción"
- CEIT: Hugo Álvarez Ponga "Sistema de Tracking 3D sin marcadores para su aplicación en tareas de mantenimiento de sistemas mecánicos".
- ESI: Aritz Etxebarri has done two pre-doctoral research works entitled:
  - "Evaluación de métodos de detección de puntos característicos en imágenes digitales"
  - "Analisis de correspondencia entre imágenes reales y virtuales"

Apart form that the following educational activities have been carried out:

- Grant Aula Iberdrola – Colaboración Labein- ESI. Project "Realidad Aumentada para Operaciones de Mantenimiento Eléctrico". 2007
- Grant Aula Robotiker – Colaboración Robotiker – ESI. Project "Algoritmos de localización indoor a través de tecnologías WiFi y/o RF-ID". 2008
- Grant Aula Robotiker – Colaboración Robotiker – ESI. Project "Sistemas de localización en interiores. Continuidad de localización outdoor-indoor". 2009

Senior Projects

- Sistema de localización indoor en entornos conocidos mediante tecnología WiFi. Ana Campo Pérez. Dic-2008
- Plataforma Multiusuario de Generación y Distribución de Contenidos Multimedia para Dispositivos Móviles. Leiba Cantera. Marzo-2008

CEIT has supervised 5 master thesis (final year degree project) related to augmented reality:

- "3D modelling and simulation of augmented reality applications".
- "Study of augmented reality techniques based on image processing".
- "Development of a cooperative augmented reality system for mobile devices".
- "Development of algorithms for auto-calibration of cameras".
- "Particle filter for 3D tracking using GPGPU".

3.2 Publications

A total of 9+1(abstract accepted) publications have been accepted until now in the context of the RASMAP project.

Mobile Locator: Helping The Context Awareness. *Abstract accepted to the IEEE International Symposium on Broadband Multimedia Systems and Broadcasting 2009,* X. Basogain , S. Rentería, M.A. Olabe, A. Campo and A. Torrens

Wearable Personal Assistants for the Management of Historical Centres. 14th International Conference on Virtual Systems and Multimedia VSMM 2008 , dedicated on Digital Heritage. Proceedings of the 14th International Conference on Virtual Systems and Multimedia, pp. 325-332. October 2008, Limassol, Cyprus. J.L. Izkara, X. Basogain, D. Borro. ISBN: 978-963-8046-99-4.

Collaborative Multimedia Mobile Tool for Teaching Laboratories. 8th International Conference Developing Innovative Video Resources for Students Everywhere, Diverse' 2008. July 2008, Haarlem, INHOLLAND University, The Netherlands. X. Basogain, M. Olabe, K. Espinosa, C. Rouèche y J.C. Olabe

Towards the Augmented Reality in Wearable Personal Assistants.IX Congreso Internacional de Interacción Persona – Computador. II Jornadas sobre Realidad Virtual y Entornos Virtuales, JOREVIR'2008. Junio 2008 Albacete, Spain. X. Basogain, M. Olabe, A. Etxebarri, J. L. Izkara, R. Garrido, and H. Alvarez

Edge-Based Markerless 3D Tracking of Rigid Objects. Poster Contribution of the 17th International Conference on Artificial Relaity and Telexitence (ICAT 2007), November 28-30. 2007 Esbjerg, Denmark. Barandiarán, J.; Borro, D.

Mobile Augmented Reality, an Advanced Tool for the Construction Sector. Bringing ICT knowledge to work: Proceedings of CIB 24th W78 Conference in Maribor 2007, pp. 453-460, Maribor, Eslovenia, June 2007. ISBN: 978-961-248-033-2. Izkara, J.L.; Pérez, J.; Basogain, X.; Borro, D.

Realidad Aumentada en la Educación: una Tecnología Emergente. Libro de Actas ONLINE EDUCA MADRID 2007 - 7ª Conferencia Internacional de la Educación y Formación basada en las Tecnologías, pp. 24-29, Madrid, 7-9 Mayo 2007. ISBN: 3-9810562-5-6. Basogain, X.; Olabe, M.; Espinosa, K.; Rouèche, C.; Olabe, J.C.

Mobile Augmented Reality for Providing Guide in Maintenance Tasks. Poster Contribution of the Laval Virtual, 9th International Conference on Virtual Reality 2007 (VRIC 2007), Laval, Francia, 18-20 Abril 2007.Barandiarán, J., Borro, D., Basogain, X., and Izkara, J.L.

Educational Mobile Environment with Augmented Reality Technology. Proceedings of the International Technology, Education and Development Conference (INTED 2007), pp. 369, Valencia, 7-9 Marzo 2007. ISBN: 84-611-4517-8. Basogain, X., Izkara, J.L., and Borro, D.

Engineering Multimedia Contents with Authoring Tools of Augmented Reality. Proceedings of the International Technology, Education and Development Conference (INTED 2007), pp. 440, Valencia, 7-9 Marzo 2007. ISBN: 84-611-4517-8. Olabe, M.; Basogain, X.; Espinosa, K.; Rouèche, C.; Olabe, J.C.

3.3 Visibility of the project

Since the beginning of the Project we maintain the project web site:
http://www.labein.es/rasmap
The website is updated and includes the following sections: Description, Work Plan, Participants, Subprojects (Labein, Ceit, ESI) and Documents

3.4 Technology transfer

Since the beginning of the project several companies have presented their interest in monitoring the project results. During these years there have been regular meetings with representatives of these companies which have submitted the main progresses in the RASMAP project.
These companies are:

- Virtualware (former Repair Systems)

- Ibermatica
- Asiris
- ITP
- Innovaevision

3.5 Collaboration with other research groups

Labein is currently collaborating with the following academic institutions and research groups within the project PATRAC (Patrimonio Accesible: I+D+I para una cultura sin barreras): INST. Biomechanics of Valencia, ITMA, ACCEPLAN-UAB, UNIV. POLYTECHNIC MADRID, UNIV. POLITECNICA CATALUNYA. This is a unique and strategic project funded by the Ministry of Education and Science. Labein is involved, among others, in the sub-project SP3: environments and intelligent control systems in assets, whose task is the use of mobile augmented reality technology to improve accessibility to heritage.

Labein has signed a collaboration agreement with the VTT technological centre in Finland for the development of R&D activities in the area of mobile augmented reality. During the last year José Luis Izkara from Labein has visited VTT and Petri Honkamaa from VTT has visited Labein.

ESI has participated elaborating a proposal under the 2007 eContentPlus programme, track Targeted projects for educational content. Later, the proposal was delayed for the call 2008, track Best Practice Networks (BPN), and also was extended to 14 European countries but finally, during the last meeting in Haarlem (NL), all partners agreed to participate in a next Lifelong Learning call.

Several project proposals have been submitted by partners in the RASMAP project, in the framework of different R&D regional, national and European programs.

3.6 Collaboration with companies

Labein is currently collaborating with the following academic institutions and research groups within the project PATRAC (Patrimonio Accesible: I+D+I para una cultura sin barreras): GEOCISA, CLAR REHABILITACIÓN, ACCIONA, ORONA /ORONA EIC, IBERMÁTICA, IN SISTEMAS, B_J Adaptaciones, ProA Solutions, EIDE, DDM Arquitectos S.L, Ciudades para Todos, S.L., SOCYTEC and Refoart. This is a unique and strategic project funded by the Ministry of Education and Science. Labein is involved, among others, in the sub-project SP3: environments and intelligent control systems in assets, whose task is the use of mobile augmented reality technology to improve accessibility to heritage.

Technological developments in the RASMAP project opened the door to Labein to the approaching to high-tech clients such as Telefónica I+D.

CEIT is using this technology of markerless augmented reality in projects with other companies like EADS/CASA.

3.7 International projects

Labein is participating in the project H-KNOW, an European project within the 7FP, which include the use of augmented reality technologies for the development of mobile tools for professionals in the field of cultural heritage.

CEIT and Labein are involved in the Skills Project funded by the European Commission. One of the workpackages deals with augmented reality and 3D tracking systems.

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