NAV – THE ADVANCED VISUALIZATION STATION: A MOBILE COMPUTING CENTER FOR ENGINEERING PROJECT SUPPORT

Gabriel A. Fernandes, Msc.[(a)], Gerson G. Cunha, DSc.[(b)], Tiago Mota, MSc.[(c)], Celia Lopes, DSc.[(d)]

[(a) (b) (c) (d)] Universidade Federal do Rio de Janeiro – LAMCE/COPPE

[(a)]gabriel.ufrj@gmail.com, [(b)]gerson@lamce.coppe.ufrj.br, [(c)]tiagosmota@lamce.coppe.ufrj.br, [(d)]celia@lamce.coppe.ufrj.br

ABSTRACT

This paper reviews the development progress of the Advanced Visualization Center (NAV). A mobile laboratory focused on outdoor Augmented Reality (AR) Research and collaborative project development. The NAV is composed of a series of integrated solutions which combined aim to improve project management performance, by improving, on the field, information access and remote project supervision. The approach uses several mobile work stations linked by a wireless network, which can provide positioned based information, such as, comment ready CAD sheets, 3D models, outdoor Augmented Reality visualization and constant GPS navigation/tracking. The NAV overall system also provides panoramic telepresence for remote project supervision, inspection and decision making. The work presents the NAV overall concept, and then describes the main solutions and their current development status and last finishes by discussing the tool integration and possible future continuous research.

Keywords: Augmented Reality, Collaborative Decision Making, Construction, Project Management

1. INTRODUCTION

This paper reviews the development progress of the Advanced Visualization Center (NAV). A mobile laboratory focused on outdoor Augmented Reality (AR) Research and collaborative project development. The NAV is composed of a series of integrated solutions which combined aim to improve project management performance, by improving, on the field, information access and remote project supervision. The approach uses several mobile work stations linked by a wireless network, which can provide positioned based information, such as, comment ready CAD sheets, 3D models, outdoor Augmented Reality visualization and constant GPS navigation/tracking. The NAV overall system also provides panoramic telepresence for remote project supervision, inspection and decision making. The work presents the NAV overall concept, and then describes the main solutions and their current development status and last finishes by discussing the tool integration and possible future continuous research.

The evolution of AR is a continuous search for the complete tangible interface which completely integrates visual perception and information in a seamingless manner. Several researches have been published discussing the use of AR in Civil Engineering, among those is the extensive work of (Wang and Dunston 2006) which lists the possible applications in projects and the ergonomic difficulties from mobile visualization gear, there is also the work of (Shin and Dunston 2008) which have categorized in detail the activities in the construction environment and identified possible areas which could benefit from AR use. Another important consideration is the potential of remote observation allied to collaborative decision making and possible ramifications when integrated with solutions such as the virtualization gate by (Petit, Lesage et al. 2009). Not only must we map the activities that could benefit from AR but also predict what new services and resources could be created to improve current project work routines in the entire production chain. Examples of collaborative work using AR can be found in (Kim and Maher 2008), (Kim and Jun 2008), (Chen, Chen et al. 2008).

Although very present in marketing campaigns, toys and games the practical use of AR solutions in engineering projects has been discussed and elaborated over the past few years. The difficulty lies in the development of solutions which could be widely adopted by the market. Main issues still lie in heavy/large precision tracking devices, head mounted displays are still clumsy/fragile and are not prepared for outdoor heavy duty activities. We could also add that they do not adhere to safety regulation in dangerous environments, such as a construction site. The NAV main objective is to fill the gap between experimental and practical application in mobile visualization for engineering. Over the past years, several solutions at NAV have been put in constant field testing. These experiments have led to several improvements in interface design, hardware specifications and wireless network configuration. This mobile laboratory was originally developed for long term research in remote areas with small or no technological infrastructure, as such, it has solar panels, rechargeable high capacity batteries, accommodations, office work environment, kitchen, bathroom, local network system, air conditioner, surveillance, high performance computers, RTK GPS kits and a full computer controlled infrastructure. Its spaces are composed of draws which can be retracted and provide it with a common container shape.

Currently the NAV mobile computing support center combines a series of visualization tools to integrate functions and activities in engineering projects, its main role is to develop and implement practical Augmented Reality applications and collaborative work solutions. Currently the prototype is localized at the Technological Park at the Federal University of Rio de Janeiro Campus and is under the supervision of the Applied Virtual Reality Group (GRVa) which is a part of LAMCE. Figure 1 shows NAV and LAMCE expansion. It has been positioned near the LAMCE expansion construction site which has been for the past years the main test ground for new developments in AR tools. The LAMCE expansion presents many construction challenges due to its unusual interior and exterior design, and so pushes the development of solutions to new boundaries. The current challenges include the transition between the current AR sensor tracking system (based on Intersense IS-1200) to the parallel tracking proposed by Klein (Klein and Murray 2007; Klein and Murray 2009).

Figure 1: NAV mobile lab and LAMCE Construction.

2. AR AND THE NAV SOLUTION

Practical AR depends on a combination of hardware, software and content. The following text will present a brief overview of general AR implementation demands: Physical Device, Interaction, Tracking and Application. Through a "device" point of view the equipment must weight mobility, high processing power, network performance and screen visibility under diverse weather and light conditions. Interaction can be achieved through gesture recognition, multi-touch controls, voice recognition, normal input buttons/controls and sensor input (device orientation and movement). As for tracking, there are two main approaches: Sensor and Camera tracking. These can be used separately or combined in a fused priority/opportunity based solution. Sensor tracking is a straightforward method and can be implemented by the use of gps, gyroscopes and accelerometers, as for camera tracking, a solution can range from fiducial (Hornecker and Psik 2005) placement to feature recognition (Zhuo and Xinyu 2010) and/or parallel tracking (Castle, Klein et al. 2011). When a camera based tracking system is being used, there will also be the need for computer vision calculation to determine the users point-of-view, otherwise sensor tracking is reasonably straightforward and requires only alignment between real/virtual content. The Application is where the user can access and input general visual information and compare expected and obtained results. Interface requirements can vary from one solution to another, such as touchscreen input, 3d model navigation options and CAD style layer control. The following items present three of the undergoing NAV AR solutions.

2.1. Panoramic AR Remote Supervision

The remote supervision tool allows a decision maker to inspect a project from any location. Usually this can be easily achieved through a simple camera surveillance system. The Panoramic AR remote supervision steps further into this idea by adding new layers of 2D/3D information over the video stream. This tool allows a user to view undergoing activities and overlay this with the final expected work, or synchronize this with other project management tools and compare real status with a conclusion schedule. The current prototype is based on two modules: remote system and user terminal, Figure 2 shows a schematic view of the system. The remote module is composed of four main elements: high resolution GPS, mobile/handheld computer, surveillance camera with one or two rotation axis and long duration battery, Figure 3 shows some of the proposals for the module. The module is small and is supported an adapted medium load tripod. Determining the camera point of view is crucial for the system to function, in this case, position is obtained through the GPS and "look-at" direction is specified by an orientation sensor coupled to the camera. The remote module can be placed in strategic fixed locations or be entirely mobile and constantly repositioned. Since it is not composed of any majorly expensive components it can be manipulated by inexperienced personnel. In a situation the GPS is not reaching good resolution the user can always manually adjust virtual camera position to compensate small tolerance errors. The terminal is composed by a 3D model viewer with a video stream background, and can be controlled by a Bluetooth remote (camera movement and layer adjustment) which makes easy to use in with large screens and projections. Figure 4 shows a photo of an access terminal during field tests.

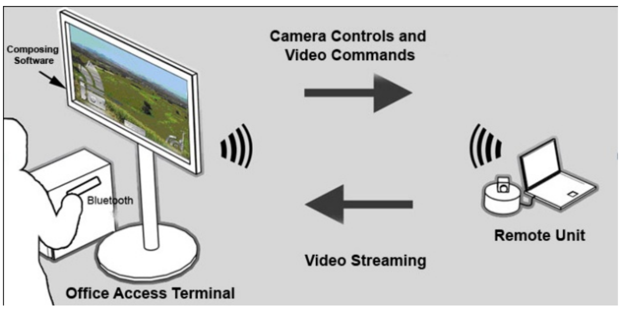

Figure 2: Schematic view of the Remote AR System.

Figure 3: Mobile module prototypes.

Figure 4: Interface terminal for mobile camera system.

2.2. Outdoor AR Multipurpose

Outdoor AR has had much progress and is viable support tool ((Behzadan and Kamat 2005), (Boun Vinh, Kakuta et al. 2010), (Joonsuk and Jun 2010), (Karlekar, Zhou et al. 2010)). Precision, stability and reliability are currently dependent on wide variety of sensor technologies which comes in all shapes, sizes and prices. The NAV outdoor AR development has had the opportunity to experiment with a wide range of hardware combinations, outdoor image capture devices, interface designs, lcd screens and other performance related elements. The objective has always been to provide practical and reliable on site information system for engineers. The system specifications included low weight mobile hardware, touch screen interface, good visibility under strong sunlight, long battery life and the ability to use unconverted project 3D models.

The initial trials covered a wide variety of outdoor tracking systems using a selected group of image detection systems, such as, game controllers with sensors, electrical controls, fiducial marking, infrared lights and others which led to an illumination dependent and low resolution tracking system. Although, at this point, the outdoor mobile solution seemed hard to achieve using visual tracking, these activities led to the development of the Remote Panoramic AR system, based on digital servo controls already presented. The continuous experiments led to a different kind of sensor technology commercially available, the vision-inertial self-tracking system (IS-1200)4. This sensor proved to be extremely reliable outdoors, but limited to areas which have visual fiducials. The new software developed on this technology had higher performance benchmarks on mobile computers, mostly because the sensor did most of the tracking within itself and passed the result to the software.

Tracking is an important factor, but there was also much discussion on how to give the CAD like look to models being seen on low performance computers. One approach was the render streaming library being developed by the GRVa software team, which still hadn’t overcome bandwidth and resolution demands. Visualization experiments where done comparing formats and rendering engines, which led consider the shortest path between the CAD system and the mobile AR, in this case it was perceived that OGRE3D provided a good similarity with original models and needed few to no adjustments for export. This engine also had achieved good performance scores when used on mobile computers. The coordinate systems between sensor and 3D space integrated smoothly with the need for conversions.

Video Capture was also an issue as the outdoor area around the LAMCE expansion is usually under a strong sunlight. This extreme light element showed that most of the web cameras used for indoor AR could not compensate or reduce exposure to provide a good image. Tests with several cameras and filters brought other issues, related to the size and aesthetic and ergonomic issues related to cameras attached to mobile computers. The current solution uses a high quality web cam, with an altered casing, allowing easy attachment and removal from the computer. The current camera model in use is a Microsoft HD-5000.

The specification of the mobile computer fitted the description of a typical TabletPC, but the main problem any computer outdoors is screen visibility which needs a brightness of at least 400 nits (cd/m2). Although some vendors can change the display hardware to match specific needs, the screen usually needs to be at maximum brightness to meet visibility demands. The sensor and camera already use up a lot of energy (and produce a lot of heat), so keeping the screen brightness at maximum only adds up to a short battery life, even for a 9 cell battery. The energy issue is still a matter to be resolved. The current Tablet PC on field use is the DELL Latitude XT. Figure 5 shows the combined hardware being used in a field experiment; the final solution was heavier than originally anticipated.

The last aspect of the solution is the application itself, which combines camera capture a 3D rendering engine and interface design. The many resources being used where integrated using a multimedia software toolkit known as Adobe Director, and extensions where developed in C++ to include sensor support, camera video capture and Ogre3d engine. This integration was chosen so it would give freedom for the design team to work and experiment with interface possibilities, animations and visual ergonomic factors. The current interface is fairly simple and has only layer visibility control. Figure 6 shows a screenshot of the application with a visible 3d model in outdoor environment. This outdoor tool has served as base for the NAV AR project management system toolset which is explained in the following topics.

Figure 5: Outdoor AR system for viewing large scale projects.

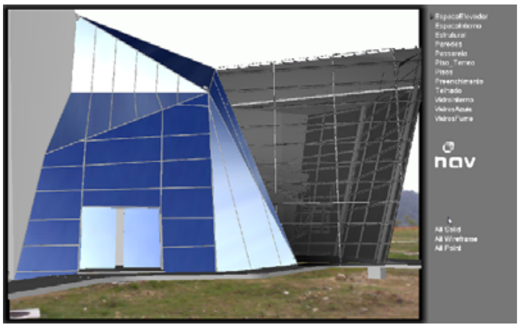

Figure 6: Outdoor AR screenshot, Expected versus Achieved Results.

2.3. AR Content Management (ARCOM)

Content management has always been a major setback to practical AR implementations. Content can also be considered a kind of visual annotation as observed by (Wither, DiVerdi et al. 2009). Currently there are many stable tracking options, as describe before, such as parallel, feature, fiducial and sensor tracking. Final build of AR applications have intuitive/ergonomic designs but, in most cases, have complex input, arrangement and removal of content, which forces users into manually editing parameter files which, in the best possible scenario, is in XML format. AR solutions, mostly exist as extensions for general multimedia development tools which are not developed to provide complete content management support.

The ARCOM system has been designed to fulfill a construction project demands for content management. The system is built considering a fiducial tracking system. The fiducial system was chosen for its application simplicity, implementation maturity and low cost. The ARCOM divides information in a hierarchic scenegraph which represents all project aspects which are relevant for on the field visualization. ARCOM databases can be viewed on the field with the ARDI tool. Figure 7 and 8 shows the ARCOM system with multiple annotations being added.

The project is the root of the hierarchy and divides into work environment, afterwards each environment divides in interest areas. Each area is represented by a unique fiducial symbol which can have any number of information layers. The layers are then divided inf the following content groups: images, 3d models, audio, textual description, field comments (which can be photos, text or drawings). Figure shows the full tree of an example project opened in ARCOM. Every element can be accompanied by versioning information and be arranged in to match real objects. Every element can be viewed and arranged independently.

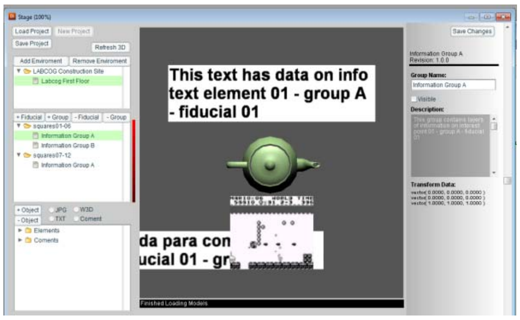

Figure 7: AR Content Manager Screenshot.

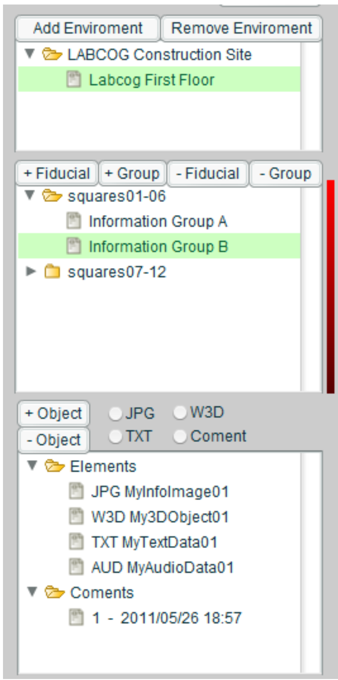

Figure 8: Hierarchical organization of project structure.

The ARCOM is also accompanied by a fiducial panel builder and pattern creator which helps create proper identification for interest areas. The last tool is camera configuration utility which helps quickly identify AR compatible cameras and set thresholds for different lighting conditions. Figure 9, 10, 11 shows screenshots of the AR support tools.

Figure 9: Pattern Builder.

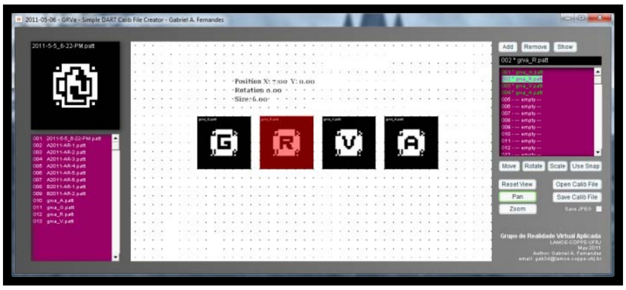
Figure 10: Panel Builder.

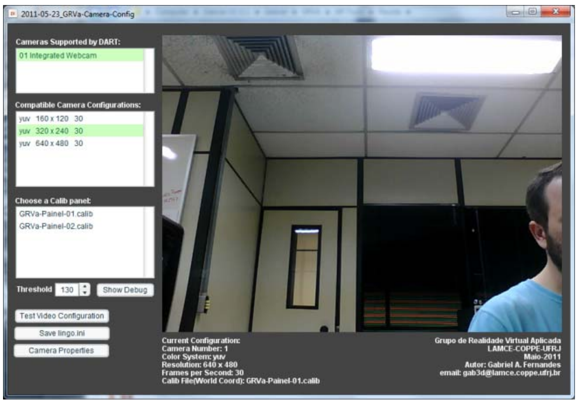
Figure 11: Camera Configuration utility.

2.4. AR Detailed Inspection (ARDI)

The AR detailed Inspection is a mobile access terminal for the content manager (ARCOM), its function is to present the visual database for supervision, management and inspection purposes. It is a project navigation solution where data is presented in tree like fashion and allowing users to dynamically add comments to previously defined interest points. These comments and observations are marked for content reviewers in real-time so, if necessary, proper action might be taken. The interface resembles the Outdoor AR application with upgraded layer/tree navigation options, as can be seen in Figure 12. The application is basically a viewer for XML files generated by the ARCOM.

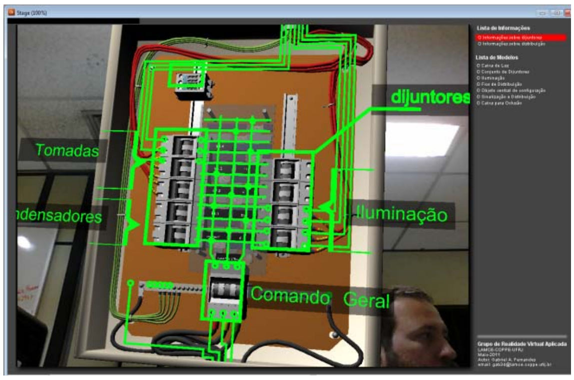

Figure 12: AR Detailed Inspection Screenshot: viewing a power distribution compartment.

2.5. Future AR management developments

The overall AR solution is still a work in progress, although much of its current form is based on years of field experiments and trials it still has a great deal of improvements pending. Some of the most immediate demands are development of the multiuser database, migration to a more sophisticated rendering system, support for a wider range of tracking solutions and the pen annotation system. The user database will be migrated to SQL server, where users will be able to access on-demand generated XML files. The rendering engine (in this case not Ogre3D) currently used is simple, although well integrated with 3d content creation tools, has many quality limitations, such as support for advanced shader language. As for the tracking, fiducials are very efficient and easy to use but there are many possibilities in the field of feature and parallel tracking that can be explored. The pen system is an upgrade to allow users to add annotations with pen or finger in the form of hand writing and drawings. Other directions for future developments could be the better use o low precision tracking devices such as cell phones and tablets to view spatially aligned annotations.

3. OTHER SUPPORT SOLUTIONS

The following items are ramifications of our project management solutions and make part in the overall NAV experience, but are not directly linked to the Augmented Reality support system. They provide content interaction options which are simpler to apply but still provide important project support.

3.1. Telepresence

Viewing large construction projects is quite a stressful task require time and manpower. Covering large areas for inspection is not a comfortable or easy assignment, to overcome costs for this activity the NAV solution has proposed a panoramic telepresence system. This system is composed of two modules a panoramic video receiver and a remote immersive access terminal. With these tools a decision maker can easily overlook large areas in a short time span without having to physically be there. The first module is placed on a work vehicle, small AR Drone, be carried by workers or even be placed on strategic observation points. Although similar to the remote AR solution, the panoramic system has high resolution cameras which can zoom-in at meter scale details. The remote module can be composed of stereo glasses for individual use or a large display wall in a meeting room.

3.2. Project Information Management

The collaborative information management system is a friendly interface to manage changes in project schematics. Usually composed of 2D Cad drawings, project information is analyzed and evaluated in printed form where observations can be easily proposed and registered. Afterwards, in a well organized work flow, these changes are taken to a chain of employees for review before it is ultimately approved and effectively implemented in the project files, becoming the original print version. Due to new tablet PC technologies some more demanding operations already use mobile computing to make on-the-field observations of CAD drawings in a pen and paper style through PDF readers (Figure 13). Figure 14 shows a user interacting with the system through a touchscreen mobile computer. The information management system takes this proposal a step further by including a sophisticated versioning platform where observations can be sent in real-time to a plant server and possible schematics changes are alerted to all interested parties. The result is a more efficient and dynamic error correction and project modification pipeline which could save resources such as materials, time and rework. The system also marks observations in combination with a GPS positioning device which makes it possible to search the database for geo-referenced information. Below is a description of the main solution aspects: User management, geo-reference information retrieval, collaborative versioning and user map.

User management is achieved by an encrypted login system which divides access into five groups: readers, reviewers, editors, project manager and administrators (Figure 15). Each user category has limited access to features and is directed to fulfill a predefined task. The reader can access approved information sheets mainly for task execution. A reviewer can make observations through a note system directly in the virtual printed CAD file, just as he would over paper, but he can only comment the latest version available. An editor can add files and create versioning trees which can be viewed by all parties. A manager can create new project database and manage overall content. An Administrator can make any sort of change on the database and has the privilege of permanently deleting files.

Data access is divided in three search engines: the common word search, the geo-referenced search and a data project tree search. The common word search allows the user to input terms and retrieve files with similar expressions. The geo-reference allows the user to input GPS coordinates and retrieves localized project files, the input can be the current location, manually inputted coordinates or select a point on a map. The tree allows the user to navigate through the project area files based on a pre-defined hierarchy generated by the project manager. The Collaborative versioning system alerts editors to errors observed on-the-field, then provides ways to update the files through a versioning platform much like a SVN. The user map is an extension screen within the solution which allows the current user to view other registered users positions on the field (Figure 16). Considering that all users have gps devices attached with their tablets. This way the workers trajectories and work paths can be recorded and/or monitored in real time.

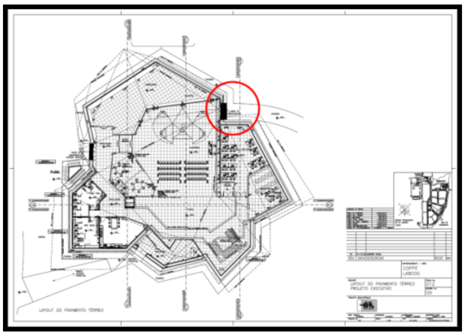

Figure 13: Screenshot of commented project file

Figure 14: User interacting with the plant manager.

Figure 15: Manager Web Portal.

Figure 16: GPS map system for geo-referencing observations and user mapping.

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