FIELD EXPERIMENTS FOR ENGINEERING AUGMENTED REALITY TOOLS

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ABSTRACT

This paper presents the field experiment results for a civil engineering augmented reality tool. The tool allows you to mark any number of interest points in large areas and link relevant information to them, such as: assembly, maintenance and inspection data. The information is seen on the screen through Augmented Reality technology. The system also has a specific content manager to help organize and manage information. The field experiment points out activity execution performance improvements when using Augmented Reality tools when compared to more traditional task management and execution methods.

Keywords: Augmented Reality, Mixed Reality, Virtual Reality, Civil Engineering.

1. INTRODUCTION

Augmented Reality (AR) is a major step in visualization technology, as it allows a user to interact with the combined strength of eye visible perception and digital information. Digital, in this case, can range from a simple text to a complex interactive multimedia presentation. This combination can be seamingless in a way that the digital content seems totally integrated in the real world, or not directly related in a visual manner, such as reading a QR Code and navigating to webpage.

When contextualized in any engineering field, this technology can be fitted to improve creative thinking and project design ((Shen, Ong et al. 2010), (Fuge, Yumer et al. 2011), (Huang, Yang et al. 2012), (Ran, Wang et al. 2011)). It can help in real assembly tasks or simple training ((Anastassova and Burkhardt 2009), (Ong and Wang 2011)). Also it can be fitted to support maintenance, supervision and inspection operations ((Shin and Dunston 2010), (Lee and Akin 2011)). As last, but not limited to, it can provide useful visual feedback and interaction between a diverse professional scope (Designer, Engineer, Technician, Manager, Client, User and others), allowing fast idea and knowledge transfer.

As presented in previous works ((Fernandes, Cunha et al. 2011), (Fernandes, Coutinho et al. 2010), (Fernandes and Cunha 2009), (Fernandes and Cunha 2010)) AR has been discussed, studied and experimented in various ways. The Applied Virtual Reality Group has focused a great effort in bringing together theory and practice in the AR field. The main AR system, currently under development, connects a project management system and a visualization tool which can be deployed through a wide range of platforms. The system is entirely based on a project database which delivers controlled XML files depending on tasks and user location. The system is scalable and can be easily adapted to interact with new tracking technologies and visualization techniques.

The objective has been to propose practical visualization tools for activity management and support. AR is mostly known for its marketing approach, usually to give products, ideas and services a technological front to the general public. Usually it faces a barrier when crossing to industrial scenario. The tool presented in this work has a polished user interface and a interaction concept based on at least five years feedback from direct projects with the Brazilian oil industry. This has the purpose of founding the current system with controlled field testing and general user feedback.

2. THE EXPERIMENT

This paper presents an experiment developed to test and analyze the previously created AR support system for engineering. The experiment is executed in a controlled environment where a sample group of ten will be asked to execute a series of activities using de the AR system. These activities focus on series of inspection, assembly and maintenance tasks where the user observer and interact with interest points and fill a report checklist during the process.

The experiment measures, through user feedback multiple tool aspects. It compares general visibility/readability under different lighting conditions and screen resolution limitations on mobile hardware; it measures interface design and ergonomic aspects; as for functionality the experiment measures task execution time and correct completion. The users also input information through a score questionnaire which covers on several unique aspects of task and tool. The experiment collects subjective user input through multiple choice questions on personal perception and thoughts.

The environment is based on the second floor of the LABCOG building at the Technological Park at the Federal University of Rio de Janeiro. It proposes the ideal testing spot due to its unfinished status. Figure 1 presents a top view of the floor with four suggested enviroments. Each enviroment contains three to four interest points and each point has designated symbol which designates its location.

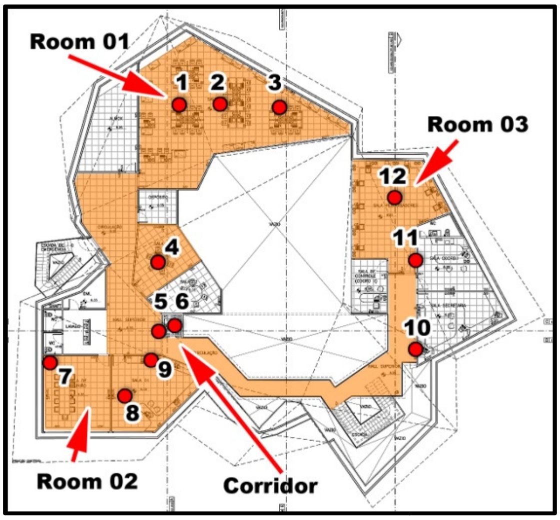

Figure 1. LABCOG Second Floor, Red Dots -> Interest Points.

Table 1 presents a list of task distributed through their respective locations on the experiment floor. The task type is identified as: Insp (Inspection), Assem (Assembly) and Maint (Maintenance). The tasks are simple and are restricted to visual inspection and simple interaction. To assist the user, the AR system provides visual information to guide and propose standards for comparison. Visual information is made available by images, diagrams, texts annotations and 3D models.

Grp	N.	Task	Type
R1	1	Installed Air Duct	Insp.
	2	Missing Air Vent	Asse.
	3	Adjust Color Button	Main.
Cor r.	4	Whole Repair on Floor	Inps.
	5	Exposed Structure	Asse.
	6	Missing Emergency Intercom	Asse.
R2	7	Read Equipment Values	Insp.
	8	Pending Lighting Installation	Asse.
	9	Pending Energy Connector	Asse.
R3	10	Fire Extinguisher Installation	Insp.
	11	Missing Electric Panel	Asse.
	12	Ajust Button on Wall	Main.

Table 1. Task distribution for AR Experiment.

Each interest point is marked with a printed panel which is unique and can be identified by the number on the top left square. The panel allows the tool to identify the interest point and overlay the correct visual information. Each panel is composed of four symbols, also known as fiducials, which provide redundant information for obstructed or partial visibility. For the identification to work, at least one symbol on the panel must be entirely visible. Figure 2 presents two panels used in the experiment.

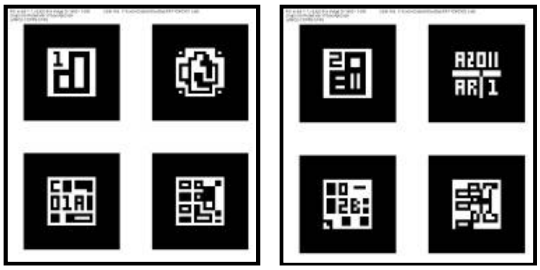

Figure 2. Symbols for interest points one and two.

Each task has an instruction set based on its category. The inspection guides the user to observe certain visual points and request feedback through the checklist. Figure 3 shows the user inspecting a fire hose compartment and observing key points marked by augmented reality content.

Figure 3. Fire hose box; top: application screenshot; bottom: user holding the tablet.

The assembly tasks are presented to the user as part numbers and part position. The user must choose the correct element based on photograph, 3d model or only identification number. Afterwards the user must place the part in the marked position seen through the

AR display. So the user is not overwhelmed by specific assembly steps the elements are represented by printed images which must only be placed correctly. Figure 4 shows the collection of parts used in assembly tasks during the experiment, there are a total of 15 elements which are divided in groups of three. Figure 5 shows an assembly scene where the user is observing the position indication on the tablet screen.

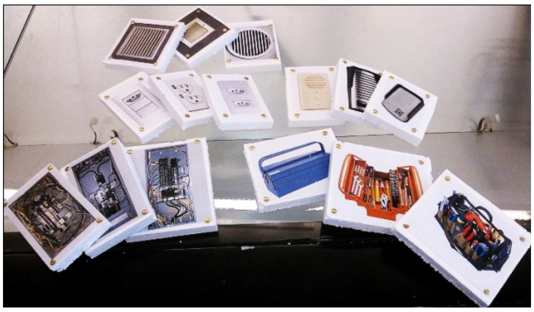

Figure 4. Parts used in assembly tasks.

Figure 5. Top: Assembly task screenshot; Bottom: user inspecting installed part in place.

The maintenance task is presented as a rotation button which needs to be correctly set to the value displayed through the AR screen. A button used in the experiment is shown on Figure 6, while the AR overlay display can be seen on Figure 7.

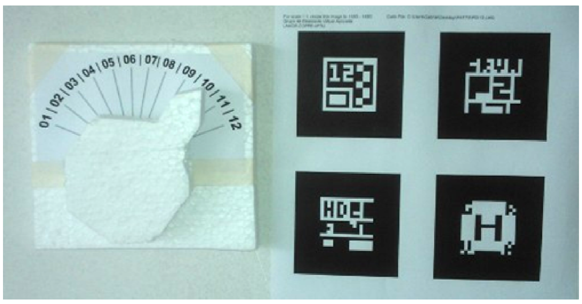

Figure 6. Maintenance part beside fiducial panel.

Figure 7. Maintenance task screenshot.

The last step to each task is the checklist, which can be accessed through the AR menu of each interest point while it's visible. The checklist has mostly boolean answers to identify if the observations where made correctly. Figure 8 shows a simple checklist for task one accessed through the tool browser. All the checklists are based on a web php platform which saves responses to a local file on the tablet for data analysis.

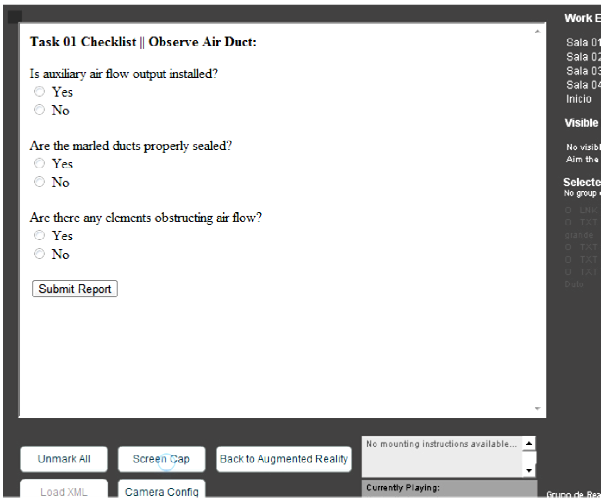

Figure 8. Task checklist screenshot.

1	App. presentation vs actual functionality
2	Camera Screen Visibility
3	Fiducial panel detection quality
4	Side menu visibility and touch screen interaction
5	Tablet comfort and ergonomical aspects
6	AR content quality
7	Inspection tools quality
8	Assembly tools quality
9	Maintenance tools quality
10	The whole experience of finishing the experiment
11	The prospect of future developments based on this tool

Table 2. Questionnaire: Tool usage aspects being observed by volunteers.

When the user completes the twelve interest point circuit he is presented with a short questionnaire to evaluate the tool and give feedback on key features. Table 2 presents the questionnaire. Each item can score from 0 to 7. At the end of the questionnaire the user is invited to give written feedback of aspects not covered by other evaluation methods. This personal feedback is presented further ahead.

3. FIELD OBSERVATIONS

The experiment was executed individually and each volunteer was presented to tool in turn. The overall perception and understanding of AR varied and the technological background was also very diverse. The volunteers can be distributed as follow:

- 2 – Graphic Designers
- 2 – Field Technicians
- 1 – Administrative Professional
- 2 – Product Designers
- 1 – CAD Professional
- 1 – Geographer

The experiment went well and each volunteer spent 5 minutes learning how to use the tool, around 11 minutes navigating the circuit, 5 answering the questionnaire and around 10 commenting the experience and providing verbal feedback. This sums a total of 30 to 40 minutes per volunteer. Most of the environment on the floor is crowded with interior finishing materials which delayed walking and proposed, in some cases, a challenge while holding the tablet. Most bad panel detection was due to low light conditions which were compensated by adjustable detection threshold values on demand. The volunteers used the tool well with almost no interruptions for questions. The tool itself worked flawlessly presenting no sudden crashes or slowdowns which could affect time or task execution.

4. COLLECTED DATA

As explained the data collected is distributed in three categories: execution time, circuit score and evaluation questionnaire. Figure 9 presents the completion time distribution. The time is distributed between 8 to 14 minutes. The variation can be associated with experience in the use of touch screen technologies, as some were able to quickly adapt to the interface while higher time scores had difficulty with screen finger pressure and finger aim. Although gender was not annotated during the experiment it should be noted that the female volunteers (3 out of 10) completed the track in the lowest times. Volunteer nine, being exposed for the first time to an AR tool, achieved the best time.

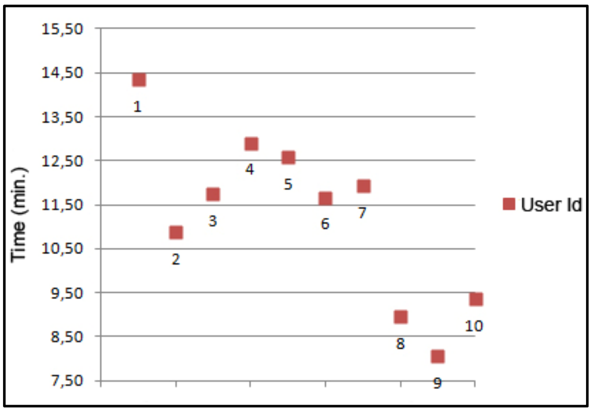

Figure 9. User time performance graph.

Almost all users achieved a perfect score and claimed that even with drawbacks they believed the instructions and visual aid to be clear and objective. Some volunteers also commented the task to be easy and could be more challenging. Following the circuit score is the questionnaire results which can be observed on Table 3 and Figure 10. Both present a good score, except for Menu and Comfort. The side menu was considered small and crowded, this affected finger interaction and aim. The letter size was considered small and in some cases the user needed to bring the display close to properly read the text. The comfort criteria was majorly affected by tablet weight and lack of grip around the edges, which made one hand hold unsafe. The users were explained that a score 7 in the fiducial criteria meant a perfect detection and tracking with imperceptible noise. In this case the fiducial was expected to receive a score around 6.

	User										
	1	2	3	4	5	6	7	8	9	10	Med.
Presentation	7	7	7	7	7	6	7	7	7	7	6,9
Screen	7	5	5	6	7	7	7	7	7	7	6,5
Fiducial	7	7	6	6	5	5	6	5	7	7	6,1
Menu	6	3	4	7	5	3	5	4	5	7	4,9
Comfort	5	6	6	7	7	5	7	3	5	7	5,8
AR Quality	7	7	6	7	7	7	7	5	7	7	6,7
Inspection	4	6	6	7	7	7	7	7	6	7	6,4
Assembly	7	7	5	7	7	7	7	6	7	7	6,7
Maintenance	5	7	7	7	7	7	7	7	5	7	6,6
Experience	6	6	5	7	7	5	7	5	7	7	6,2
Prospect	7	7	7	7	7	7	7	7	5	7	6,8

Table 3. User tool aspect evaluation and medium values.

The Inspection, Assembly and Maintenance criteria evaluates how the tool performed under the proposed tasks. The Inspection task was achieved the lowest score, as the pointing elements where considered confusing and hard to distinguish on the screen.

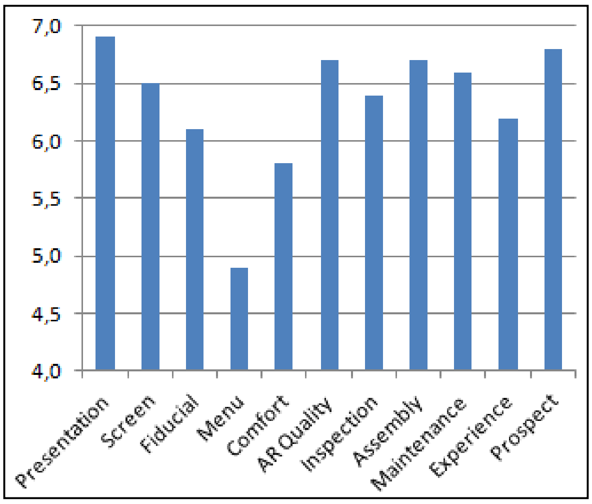

Figure 10. User tool aspect evaluation medium values.

5. USER FEEDBACK

Each user category made comments and suggestions relative to their expertise and personal experience. The following comments summarize post experiment talks: Both graphic designers commented constantly on the crowded interface, small text/buttons and tablet weight. The field technicians seemed fine with the whole tool and had no major complaints, as they observed the solution was light weighted compared to other materials normally carried. The administrative professional though the tool to be innovative and probably had much potential in field use. The product designers also made heavy comments on interface and weight; they also suggested improvements to reduce handleling discomfort. Bellow follows a list of the mains suggestion and comments:

- Fiducial ideal visibility distance indication, so the user doesn't stand too close or far from the panel.
- Tablet is uncomfortable for long period of work.
- Small interface controls make user interaction difficult.
- Interest point identification could be more evident, maybe marked on a map.
- Application tutorial within the tool guiding the between tasks.
- Computer verification of assembly activities alerting the user when the part is in the correct position or within tolerance levels.
- When the user is too close to the panel the content should auto-adjust to fit on the screen or suggest the user to take a step back.
- The inspection points could be more pronounced; currently they are small and not always entirely visible.

6. CONCLUSION

The experiment indicates that the AR tool can be useful and was well commented by the volunteers. Although well perceived, it needs adjustments in interface design and general comfort aspects. The presented tool was developed considering a wide range of applications and has many options not evaluated in current experiment, such as animation and audio feedback. The current tool would be more efficient if fragmented and task orientated. Further development and testing is in progress and could, in the future present, more impressive results. These results and further testing will help shape and direct the tool so it may reach an applicable build.

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