IMPROVE: Designing Effective Interaction for Virtual and Mixed Reality Environments

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Abstract. In this paper we present evaluation results of an innovative application designed to make collaborative design review in the architectural and automotive domain more effective. Within IMPROVE, a European research project in the area of advanced displays, we are combining high resolution multi-tile displays, TabletPCs and head-mounted displays with innovative 2D and 3D Interaction Paradigms to better support collaborative mobile mixed reality design reviews. Our research and development is motivated by application scenarios in the automotive domain involving FIAT Elasis from Naples, Italy and in the architectural domain involving Page/Park architects from Glasgow, Scotland. User evaluation took place at Glasgow (UK), Naples (ITA) and Darmstadt (GER), where we tested the integrated IMPROVE prototype application. The tests were conducted based on several heuristics such as ergonomics and psychomotorial factors and they were conducted based on guidelines recommended by ISO 9241 to verify whether the developed interfaces were suitable for the applications scenarios. Evaluation results show that there is a strong demand for more interactive design review systems, allowing users greater flexibility and greater choice of input and visualization modalities as well as their combination.

1 Introduction

Design Review is one of the most prominent areas benefiting from Virtual Reality and Immersive Projection Technologies. Today Virtual Reality is used to present design

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alternatives, but fully interactive commercial VR or AR design review applications are still being developed or not available. Use cases generally comprise many observers in front of a back projection wall discussing a design decision on a virtual model. This is why in IMPROVE we include support for large single- or multi-tile displays as well as support for TabletPCs. In the above mentioned scenarios we can have users controlling what is visualized on the power-wall from their TabletPCs and vice versa. In addition we also aim at supporting mobile mixed reality using optical see-through HMDs which allow architects to go on site or meet around a table to look at the virtual model of a new building inserted into the real environment featuring the same lighting and reflections as the surroundings.

Components of the IMPROVE system tested by users and performance aims:

- 2D Interaction techniques as well as 3D Interaction techniques for 3D environments were assessed, as is the case when users use a TabletPC to alter the design of a model or proceed to attach annotations or choose material properties or when they use a stereo optical see-through HMD or stand in front of a Power-wall. In any case both performance and learnability were assessed.
- For the combination of display technology and rendering techniques the image quality was assessed, e.g. a comparison between standard OpenGL Lighting and GPU-based pre-computed radiance transfer.
- For the HMD ergonomic issues have been addressed such as brightness, weight, display resolution and power consumption.
- Marker-less tracking for mobile mixed reality environments has been paid special attention during the tests with respect to tracking accuracy, tracking speed, tracking area and final cost of the system.
- The mobile video transmission component has been tested to analyse whether image quality and latency times are enough for the target scenarios. Stereo video stream transmission is used to transmit high quality rendered images to a mobile user receiving the compressed 3D stereo video stream and decompressing it onto the optical stereo-see-through HMD.

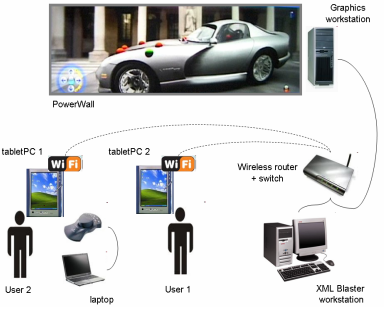

Fig. 1. A possible IMPROVE Setup

For the first user evaluation in IMPROVE (Figure 1) we set up the following scenarios at the following locations:

Glasgow (UK): We tested collaborative Design Review between TabletPCs for the architectural domain.

- Darmstadt (GER): We tested the mobile video transmission component and 3D interaction in a 3D virtual environment.
- Naples (ITA): We tested the collaborative Power-wall scenario for the automotive domain, where multiple users have a TabletPC of their own and can control and interact with the design of a vehicle.

The usability tests main goal was to assess the functionalities and performances of the interfaces as well as the level of usability of the interaction paradigms developed.

We have prepared two questionnaires with specific goals, heuristic testing and isometric testing according to ISO 9241.

Among the heuristic goals were: Ergonomic factors; Hardware and Setup; Scenario and Tests; Human factors; Psychomotorial factors.

Further tests, followed the guidelines defined by the International Standard ISO 9241 recommendations, aimed at validating whether the interface developed could be considered suitable to the application scenario chosen. Here the assessment has been done on the basis of the following categories: Suitability for the task; Self descriptiveness; Controllability; Conformity with user expectations; Error tolerance; Suitability for individualization; Suitability for learning. Each of these categories was accompanied by a questionnaire. For each question the user was asked to answer through a scale from 1 to 5 (from strong disagreement to agreement). Additionally the tests were supported by recording of video and audio during the session for further analysis.

2 User Tests of the Architectural Scenario

This usability tests took place at Lighthouse, the Scottish Centre for Architecture, from the 24th to the 27th of April, with the participation of six users with different experience and tasks in architecture:

- Two users were undergraduate students, working at Page & Park, Architects, Glasgow. They were younger than average age and more willing to experiment new approaches;
- The remaining four users were graduate architects with experience in user review scenario, working at Page & Park. They also have experience with common 3D drawing tools such as ArchiCAD. Furthermore, only one user had minimal experience with GIDeS.

Each test had the duration of approximately 1 hour and 10 minutes.

*Initial Questionnaire:*The initial questionnaire is divided into 3 groups of questions: The first group explains the review collaborative scenarios definition used in the questionnaire and presents generic questions regarding Tablet PC usage and professional experience in both scenarios. The second and third groups present specific questions regarding each scenario. The second gathers information about annotation and its importance in a review scenario. The third gathers information about collaborative work and what type of collaborative work was executed by the user.

Our objective was to interpret user expectations regarding our software and review collaborative scenarios. The Usability test consisted in three modelling tasks of different complexity. At the beginning of the Usability tests the users were briefed about the required tasks. A task description document was provided so the users would not lose track of the tasks workflow. This document can be found in the appendix. Once the briefing was concluded and the users were given the task descriptions, the actual test execution began. The initial questionnaire was composed of 23 questions from which we present an excerpt and the conclusion:

Concerning the project design, I classify computers as helpful
I often use CAD systems in my work
The annotations taken during design review with clients are relevant to interpret their requests
The annotations taken during the design review session with clients are enough to track and solve their requests
I often use software to take annotations during design review sessions with clients
I am satisfied with the way annotations are taken during design review sessions with others designers
I am satisfied with the software already used in design review.
I perceive computer software as a good aid on taking annotations on collaborative work
I often use software to take annotations during collaborative work
I am satisfied with the way annotations are taken during collaborative work
I am satisfied with the software already used in collaborative work

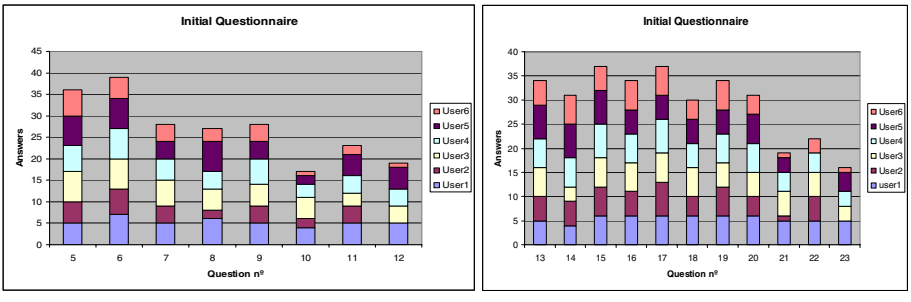

Fig. 2. Initial Questionnaire Results

Conclusion: Every user often uses CAD systems in their work and reviews collaborative sessions with other team members. All of them have the need to make annotations during design review sessions with clients and they consider these notes to be very important to interpret their requests.

However, only two out of six users use software to take annotations during design review sessions with clients. We have verified that only two users are clearly satisfied with the way annotations are taken during design review sessions with other designers and with the software they already use.

In the collaborative section, we have verified that only two users often use software to take annotations in collaborative work sessions and the majority is not satisfied with the software already used by them in collaborative work.

So, based on the most representative questions we could conclude that the participants recognized the importance of the annotations as a method to record information from clients and other team members during review sessions but most users don't often use software to take annotations in collaborative or non-collaborative work and are not clearly satisfied with the software already used in these contexts.

Usability: The Usability test was divided into three modelling tasks of different complexity. Each task increased the last task difficulty. The first task had an easy difficulty. We asked the user to create simple shapes and create an annotation on the back face of the shape. The main aim of this task was to assess the annotation creation

in a non-collaborative environment. We'd also tried to assess if the annotation system integrated well with the rest of GIDeS. Finally, we asked the user to execute this task three times, so that we could evaluate the tools learning curve regarding simple operations such as annotations.

The second task also focused on annotations. It involved the user being presented to an already loaded scene in order to find and execute three annotations. The annotations were inserted into the scene. The users needed only to track and execute their instructions. This allowed us to evaluate the impact of annotations, open and closed, and whenever the users could easily identify existing annotations.

The final task required two users to execute a collaborative task. In order to simulate a real collaborative environment, the session users had different tasks assigned to them. The user using the 12'' Tablet PC was given the User-A assignments while the 15'' Tablet PC user was given the User-B assignments. The collaborative task involved both users connecting to the OSGA Server and create simple shapes and annotations. It also involved the execution of instructions included in annotations created by the other user. Even though users had different assignments, the experience was the same for each user. The difference relied on the assignment order. User-A would first create shapes and annotation and then respond to the annotations created by User-B. User-B would first respond to User-A's annotations and then create his own shapes and annotations. The task allowed us to recognize problems presented in collaborative work, to evaluate the users notion of collaboration and to test annotations and its uses on a collaborative environment. Users were given specific instructions on how to transmit information regarding instructions; we are looking forward to evaluate the feedback created by users when completing an instruction.

Based on users' tasks observations, user comments and video analysis, it was possible to notice that users enjoyed the annotations over objects 3D and the collaboration features of the system, such as shown for the next user sentences:

Table 1. Positive user statements on architecture collaborative scenario

The software is quite easy to operate and add annotations;
Open and close (annotations) is very easy. Editing needs improving;
As a tool for reviews this could be very helpful. Especially remote working - dynamic update of information is content to success.

The users have clearly manifested some pertinent comments about the system. The most common was on how to write on annotations using pen / tablet PC. It has produced by user statements like the following:

Table 2. User suggestions on architecture collaborative scenario

Hard to annotate with handwrites on screen;
Takes a few tries to get used to write on the screen;
I found it quite difficult to write (probably my lack of experience with tablet PC). Difficult to zoom while writing;
It's easy to create but not write to in it;
I found it difficult to write in general;
It is difficult to find space to write and not always obvious how to erase the writing.

These comments were due to different aspects, such as: the limited rendering speed which made writing of annotations not very interactive, the limited amount of screen space available for notes and difficulties to zoom in the annotation areas.

Another important comment manifested by users were about the difficulty in finding annotations on 3D scene space. The anchors of annotations are attached to the objects surfaces and if the view point of the user is not synchronized with anchor view, he is not able to see it. This matter produced statements like the following:

Table 3. User comments about the to find annotations on 3D scene space

It is sometimes difficult to find the annotations again;
It was often hard to find them (annotations);
Not always easy to find the annotation.

One user has made a suggestion to this issue:

Table 4. User suggestion about to find annotations on 3D scene space

I find it a little hard to imagine how this would work a simple list would be the generally this takes too long perhaps.

Some miscellaneous comments about annotations were produced, like the following:

Table 5. Some miscellaneous comments about annotations

More amounts of info - and quicker creation;
It is difficult to delete things from annotations box;
Audio notes may be quicker.

Other pertinent issue was the navigation process (camera operations). Some users found it difficult and produced some comments, like the following:

Table 6. User comments about navigation process

Finding a "plain" view is not very obvious;
Rotation of the camera is difficult to control;
It should has more control over movement needs;
Difficult to navigate to the right position (zooming);
Sometimes zoomed in close rotating object makes harder to understand its position.

Some users have made the following suggestions about navigation:

About the difficult to rotation the camera: “Maybe would be easier if you could control the viewpoint graphically (pointed represented in plan?)”;

About more control over movement needs: “such as ArtLantis/Sketchup - move control over individual axes”.

Another issue was related to the use of the contextual popup menu. Some users have considered difficult to select a menu option after they taped with pen. Some comments were produced about this issue, like the following:

Table 7. User comments about difficulties to select menu options

Difficulties in working out the pen. How to touch and switch? A move in the menu?
Takes a few tries to work out tools;
The tablet PC can be difficult to use.

About the collaborative issues the users had some problems about the sharing of the annotations and the objects between the two GIDeS++ system instances. So, when a user create one of this resources, it is sent to the other user GIDeS++ system. But if the receiving user's scene viewpoint is not appropriate, he doesn't see it. Some comments were produced about this issue, like the following:

Table 8. User comments about collaborative issues

Sometimes I can't see in my view perhaps. A small notification could tell me that userB has made an annotation - and show me this;
It was not always obvious who had done it;
It is not always obvious which users are online.

So, it is important to notify the users when resources are created on this scene, as well as when the resources created by them are sent to the other users. In this collaborative issue it's important to know which are the users online in that project review.

Final Questionnaire: At the end of the experience, we gave the users another questionnaire to obtain more feedback from the users experience. The final questionnaire was organized according the ISO-9241 – part 10, thus we grouped the questions according the following groups: Suitability for the Task; Self Descriptiveness; Controllability; Conformity with User Expectations; Error Tolerance; Suitability for Individualization; Suitability for Learning.

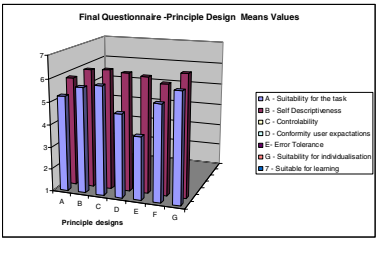

Fig. 3. Means values of the ISONORM principles

We allowed the users to comment and measure the level of importance of each question for their work. Our questions focused mainly on annotation and collaborative tasks, as the other features were previously tested. Finally, during verbal debriefing, we asked for general suggestions and criticism from the users, getting additional user input that users felt wasn't covered by the questionnaire. Overall our system got the lower rates on Error Tolerance and Conformity with user expectations (see the next Figure). The prototype wasn't very error tolerant mainly because annotations could not be undone or deleted. Arguably on could imply that the low question number - Just two - brought the group average down, nevertheless the problems encountered are relevant to future work. Users were expecting a lot more from Annotations. Our idea was to make annotations work just like real post-it notes, with free-sketch. But the resulting implementation

was not what users were expecting. They wanted to be able to use sound and typing to define their annotations. This doesn't not mean that annotations are not useful as they are, the suitability for the task was high, it just says that there is room for improvement.

2.1 Future Changes for 2nd Prototype Version

Accordingly to the tests executed and users interviewed the following changes are suggested:

Annotations

- Improve annotations with handwriting on screen, maybe complemented with typing (faster and more legible);
- The speed to handwrite an annotation should be improved;
- Tighten the switch between graphic edition mode and annotation edition mode
- Eliminate the use of keyboard (type 'A') to create annotations;
- The list of annotations should be provided to users and allow them to select and open one of them, because the user only sees the annotations on his view;
- Allow users to delete annotation and erase information from it;
- Provide ways to add audio and text file attachments to annotations;
- All annotations should stay attached to object, independently of the user view (Implementation error.);
- The colours of anchors should be evaluated;
- The annotations should support attributes like ID author, timestamp creation, timestamp, solved, etc;
- The process to zoom in/out the annotations should be improved;
- The size of annotations should be improved;
- Implement a undo/redo system over annotation edition;
- Annotation should have a comment history.

Collaborative review scenario issues

- The connection mechanism to OSGA should eliminate the IP input by user;
- The user should be notified when other user creates some annotation;
- The user should be notified when other user solves some annotation;
- When an annotation is being edited by one user the system should inform other users;
- The user should be notified when other user create an object on the scene;
- The system should show the users list that are online.

General issues

- The navigation process should be improved in order to allow camera rotation and find locate the annotation creation view;
- The brightness of tablet PC's screen must be calibrated suited to environment light conditions;
- The access to the popup menu should be improved to users;
- The system should provide some kind of parameter calibration system to the user, like pen sensitivity, screen brightness, etc;
- The system should have an help system.

Conclusions of the Architectural Scenario: The first prototype focuses on annotation operations and collaborative scenario. Using this first prototype we conclude that the second prototype requirements need to be reviewed.

The first prototype was implemented on a Tabletop workstation, however we feel that the second prototype must take into account other technical scenarios defined be IMPROVE – IMPROVE also defines a Powerwall and a see-through glasses scenarios. Regarding the tasks defined, the second prototype should also take into account navigation tasks and some object edition tasks. In conclusion, the second prototype requirements should take into account the following guidelines:

- The prototype should be implemented into two or more improve user scenarios;
- The prototype should apply new interaction techniques whenever possible;
- The prototype should implement not only Annotation tasks but also Navigation and Object edition tasks.

3 User Tests of the Automotive Scenario

The user test took place at Fiat, Elasis premises close to Naples on Friday 5th 2006. Graphitech, with the support of Technical University of Darmstadt, was responsible for the technical set-up and coordination of the activity (Fig.3).

Fig. 4. Pictures of the preparation of the test

The test results were similar to the ones in the architectural scenario. We will summarize the conclusions as follows.

From the test it has emerged that a number of changes have to be done on future implementations besides those already planned. These include:

- Possibility to delete and move notes.
- Improve the selection of already defined note by changing the picking mechanism.
- Improvement of the interface's level of feedback.
- Approval/disapproval of annotation should be better implemented.
- Annotation quality should be improved by increasing the efficiency of the rendering system and ultimately the refresh rate at which annotations are drawn.
- Some form of "help" (e.g. help, wizard etc.)function must be provided.
- Some form of shortcut available to the user for frequently used functionalities.
- Support of "abort" function to interrupt an action at any time.
- Support for some sort of calibration of the sensitivity of the pen's speed etc should be provided to the user.

- Error tolerance must be improved. More information should be also provided in case an error situation arise.
- Support for "undo" should be provided.

As far as the use of the TabletPC is concerned, given the current hardware performance, it is not possible to avoid strain and discomfort caused by overheating of the pc. Therefore the requirements related to degree of ergonomics after prolonged use of the system must be lowered, being aware that future more efficient CPUs/GPUs might lead to lower working temperature.

4 Results

The general feedback about the IMPROVE software was positive, although several unexpected comments have been made about the physical usability of the system like heavy weight of the TabletPCs, and their increasing heat levels. The use of pen and TabletPC has been considered fairly intuitive. A clear indication of the good performance is the perceived short latency time between users during the test sessions, which together with a generally good sense of collaboration and rendering quality, proved to be a good success of the collaborative feeling delivered by the system. Our system showed good results in particular regarding controllability and suitability for learning, however error tolerance and user conformity were lower that expected. This might reflect the fact that users are expecting modeling systems to be more robust and effective. The evaluation process based on ISO9241 norm shown several benefits since user recommendations were clearly identified as valid.

We consider the presented results as a good motivation to the future research to be handled in the next iteration of our collaborative system.

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