Designing a Mobile Collaborative System for Navigating and Reviewing Oil Industry CAD Models

Hildegardo Noronha
University of Madeira
Campus Univ. da Penteada
9000-390 Funchal, Portugal
hildnoronha@gmail.com

Pedro Campos
University of Madeira &
INESC-ID
Campus Univ. da Penteada
9000-390 Funchal, Portugal
pcampos@uma.pt

Joaquim Jorge
INESC-ID
R. Alves Redol, 9
1000-029 Lisboa, Portugal
jaj@inesc-id.pt

Bruno de Araújo
INESC-ID
R. Alves Redol, 9
1000-029 Lisboa, Portugal
jaj@inesc-id.pt

Luciano Soares
Tecgraf / PUC-Rio
R. M. S. Vicente, 225
22451900 Rio de Janeiro, Brasil
lpsoares@tecgraf.puc-rio.br

Alberto Raposo
Tecgraf / PUC-Rio
R. M. S. Vicente, 225
22451900 Rio de Janeiro, Brasil
abraposo@tecgraf.puc-rio.br

ABSTRACT

In this paper, we describe an industrial experience with the creation of a new product for collaboratively navigating and reviewing 3D engineering models, applied to the oil industry. Together with professional oil industry engineers from a large oil company, a team of HCI researchers performed task analysis and storyboards, designed, implemented and qualitatively evaluated a prototype that combines the power of mobility brought by tablets with new navigation modes that employ every sensor present in the tablet to deliver a better experience. The system was the target of a qualitative assessment made by architects and oil industry engineering experts. Lessons learned are valuable, both in terms of performance and experience design, issues that necessarily arise when creating new collaborative virtual reality systems.

Author Keywords

Collaboration, Interface design, Navigation, Virtual Reality.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors; Design.

INTRODUCTION

Multimodal user interfaces have revolutionized the way we work by combining different input modalities [1]. On the other hand, multitouch technology has become mainstream and tablet-based multitouch has emerged as a mobile interaction style standard, especially due to the success of products such as the iPad.

Despite these significant advances, most of the interactive technologies deployed in real world design and engineering contexts are still regarded as being difficult to use, especially when engineering teams need to collaboratively visualize and review large scale 3D CAD (Computer-Aided Design) models. This is what happens with the oil platform industry, which necessarily involves large teams that review, manipulate and discuss around large CAD models, which are sometimes difficult to visualize and navigate through.

In this paper, describe an experience with the creation of a new product for collaboratively navigating and reviewing 3D engineering models, applied to the oil industry. Together with professional oil industry engineers from a large oil company, a team of HCI researchers performed task analysis and storyboards, designed and evaluated a prototype that combines the power of mobility brought by tablets with a new navigation mode that employs every sensor present in the tablet to deliver a better experience.

SUPPORTING OIL INDUSTRY ENGINEERING

Several tools and research prototypes have been developed with the goal of improving the visualization, manipulation, design and review of 3D CAD models. Giga-Walk [3] and REVIEW [4] are academic solutions for real time visualization of very large models. They use advanced techniques such as occlusion culling to achieve good performance levels. Nevertheless, they lack integration with VR (Virtual Reality) resources, such as different displays and interaction devices, while also exhibiting some difficulties when rendering complex models.

Recent studies focused on the impact that CAD tools may have on creative problem solving for engineering. Researchers have examined how the computational environment may influence the engineers' ability to design creatively [5]. Surveys have shown good support for enhanced visualization and communication, circumscribed thinking – when the designer's ideas are circumscribed by the CAD tool's abilities – and for premature design fixation (premature commitment to a given design solution) [5]. Other studies went one step further and investigated how to reduce the visual cluttering through the use of auditory cues [6], an interesting approach that is currently outside of our scope, but that could be considered in the future.

This paper is focused on design review of CAD models, i.e. the process of checking the correctness and consistency of an engineering model, and performing the necessary corrections to it [7]. The application domain we chose, for reasons explained ahead, is the oil industry. In this domain, visualization techniques and multimodal user interfaces can be particularly helpful in the engineering design and review process, for instance to assess the safeness of different emergency-escape pathways in the event of an emergency occurring in the oil platform [7]. Current tools have problems dealing with models featuring a high level of details, since they have to provide the user with a real time interactive visualization of the model(s). Our approach proposes the usage of mobile tablets with multitouch input combined with motion-based input to aid these tasks. Simultaneously it has the advantage of allowing engineers to visualize CAD models "in the wild", which is particularly advantageous for industrial oil platform engineering teams.

Other examples of multimodal user interfaces in professional work environments include real-time simulation of 3D complex phenomena, training and edutainment, telepresence and tele-robotics, and even simple business meetings [8]. However, our purpose here is to focus on the oil industry. This industry is well positioned to drive the directions of future research since it's one of the biggest users of high-end hardware and software [8, 9]. The cognitive processes involved in the three-dimensional engineering tasks at stake are also the perfect playgrounds for evaluating novel multimodal user interfaces like the ones we present in the following section.

CREATING THE PRODUCT

In this section, we describe the creation process for a collaborative system aimed at supporting the oil industry engineers' activities. These include mainly the design and review of large-scale CAD models of the oil platforms, manifolds, risers and other sophisticated structures, and was carried out collaboratively with oil industry engineers and researchers, throughout many meetings.

Requirements Elicitation

Several techniques were used for requirements elicitation. Task analysis such as task case maps proved ineffective, probably due to their high-level of abstraction. They facilitated communication with the oil industry experts, but were incapable of achieving a concrete shared vision about what the final product should be.

One of the main objectives of the engineering departments at large industries such as oil companies is the construction of integrated information systems to control their projects, offering resources for the 3D visualization of their models with enough realism to be used for virtual prototyping, design review, change management systems, and training, among other activities. The engineering, design and review of CAD models are complex, collaborative activities, in particular when large-scale models are involved, as in our case.

The use of advanced computer graphics and virtual environments *per se* has sparked a digital revolution in many activities, thanks to the novel visualization and manipulation possibilities they provide. Ironically, engineering teams still regard the usage of some of these systems as laborious and complex, and it hasn't been until recently that collaborative virtual environments have finally started to move out from research labs into the industry. The creation process was therefore highly focused on addressing these concerns.

Storyboards

We also employed storyboards to facilitate the ideation process as well as to better explore the possible design concepts. Figure 1 illustrates a particular one (textual descriptions omitted for brevity).

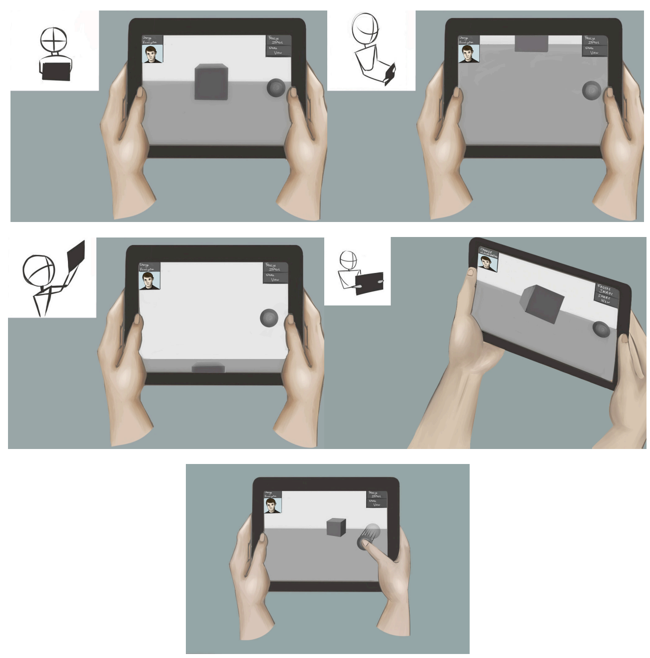

Figure 1. A particular part of the storyboards created, illustrating the navigation mode.

After long discussions, the team chose to employ the power of tablets to create different navigation modes in a collaborative prototype where CAD models are simultaneously shared and visualized through Wi-Fi, while the user can also videoconference with other remotely located engineers. One of the navigation modes is depicted in Figure 1. The storyboard illustrates the use of sensors to control the camera's orientation. Translations are performed through multi-touch gestures. The user is free to work whenever he wishes to, which is a significant step further regarding the current system being used by the company (based on traditional desktop-based PCs).

Final Prototype

The system is built upon the concepts of intuitive visualization and cooperation. To achieve our objectives while using those concepts we built several test navigation modes. Two of them ended up being selected for further improvement. Despite an apparent similarity on interaction styles, the two modes are quite different in both the technical and user interaction components: The first version uses built-in inertial sensors to position the virtual camera in a first person view manner, just as if the user was holding a real video camera and filming around. To allow the user to move around, it uses an in-screen touch-based joystick. The second version uses the tablet's camera to track its position and orientation, relative to a tracker. It works as if the user was filming the object on top of a table allowing all the natural movements he would do.

The second version can't use the built-in inertial sensors exclusively as none of them gives translation (the position can be doubly integrated from acceleration but the errors and drift are too significant to be useful). GPS, another possible alternative, can only work outdoors and doesn't have enough accuracy for this problem. The solution is to use the camera to track an object and from that deduce the tablet's position and orientation. The camera tracking is a suitable solution as it provides a surprisingly accurate translation, rotation and, indirectly, zooming without the need of another artificial input (like the virtual joystick on the first-person view navigation mode).

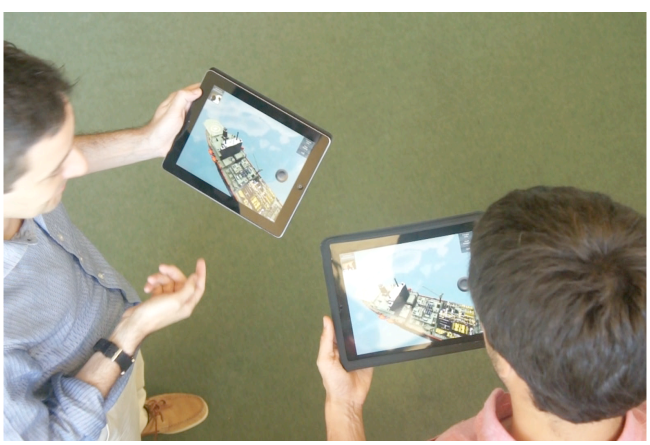

Figure 2. Two engineers engaged in a co-located collaborative session, one of the tablets shares the camera's view with the other, through Wi-Fi.

The first-person version can be shared between multiple tablets allowing one user to guide or show some feature on the model to the other users. Figure 2 illustrates this. The microphones and the front cameras are shared between multiple tablets, creating a videoconference that improves the cooperativeness of the system, as Figure 3 illustrates. A minor feature (freezing the camera) was also implemented. It allows users to freeze the current view and move around the tablet without fearing that the movements performed will change the camera's position and without stressing body positions. This feature can be used when showing certain features on the models or even when working on the models themselves on future work.

Figure 3. Navigating freely through the engineering model while videoconferencing. This illustrates the product's usage in a remote collaborative session.

QUALITATIVE ASSESSMENT

The qualitative user evaluation was composed of a quick presentation of the system and its goals while trying not to give away to the user any information that would change his interaction in any way. Following that, users were given some time (about 30 min. each) to play around with the prototypes while talking freely about the system. This experience was voice recorded and the most important remarks about the system were written down. The users experimented with the several prototypes so they could get a feeling of the different interactions types. At the end of the evaluation, the users were given some time to talk about the system and then were asked some key questions in order to assess:

- The perception of the *preferred* navigation mode;
- The perception of the *easiest* navigation mode;
- Differences in the navigation modes with respect to the level of complexity in certain tasks;
- General feedback about the collaborative system as a whole.

Not surprisingly, the users felt that each navigation mode had pros and cons on different situations and tasks. For instance, for simple tasks the users were more inclined towards joystick and gesture based interaction styles while for more complex tasks they chose the virtual camera/first person navigation mode.

They all agreed that this kind of system would effectively help them on modelling and cooperatively reviewing constructions and construction sites.

Regarding the support for collaborative work, the feedback was particularly positive. There are very few solutions for navigating and reviewing 3D CAD models and those that exist are not mobile and/or are very difficult to use. Users even gave some examples as how they sometimes need to perform some cooperative work. In particular, the importance of several shared views, since current industrial solutions force all engineers to look at the same screen.

CONCLUSION

Supporting the needs of offshore engineering teams is an important industrial problem that should be addressed taking into account the rapid evolution in user interaction styles available. The potential for innovative solutions that is brought by tablet-based computing is enormous. In this paper, we described the industrial creation and evaluation experience of a new mobile system for collaboratively navigating and reviewing 3D engineering models, applied to the oil industry. We highlight that storyboards and scenarios were an effective way to elicit requirements together with oil industry experts, as opposed to high-level task analysis. We also note that, among different navigation modes, none is highly preferred over another: They are each adequate to given contexts and conditions.

Consequently, for future work, we will integrate different navigation modes and evaluate them to investigate if a better system can come out of that integration. Also, a suggested feature will be implemented and tested: the user touches a position on the model and is "teleported" there. This is especially useful if the above integration is complete. This way the user can be looking at the model from a bird's-eye perspective and touch the model in an area of interest to switch to a first-person perspective.

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REFERENCES

[1] Bolt, R. (1980). Put-that-there: Voice and gesture at the graphics interface. In *Proceedings of SIGGRAPH 1980*, pp. 262-270.

[2] McMahan, R., Alon, A., Lazem, S., Beaton, R., Machaj, D., Schaefer, M., Silva, M., Leal, A., Hagan, R. and Bowman, D. (2010). Evaluating natural interaction techniques in video games. In *Proceedings of the 2010 IEEE Symposium on 3D User Interfaces* (3DUI'10). IEEE Computer Society, Washington, DC, USA, pp. 11-14.

[3] Baxter, W. V., Sud, A., Govindaraju, N. K., and Manocha, D. (2002). GigaWalk: interactive walkthrough of complex environments. In *Proceedings of the 13th Eurographics Workshop on Rendering*, ACM International Conference Proceeding Series, vol. 28. Eurographics Association, pp. 203-214.

[4] Shou, L., Chionh, J., Huang, Z., Ruan, Y., and Tan, K.L. (2001). Walking through a very large virtual environment in real-time. In VLDB'01: *Proceedings of the 27th International Conference on Very Large Data Bases*, pp. 401–410.

[5] Robertson, B. F. and Radcliffe, D. F. (2009). Impact of CAD tools on creative problem solving in engineering design. *Computer Aided Design*. 41, 3 (Mar. 2009), pp. 136-146.

[6] Brown, M., Newsome, S. and Glinert, E. (1989). An experiment into the use of auditory cues to reduce visual workload. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (CHI'89), no. May, pp. 339-346, 1989.

[7] Santos, I., Soares, L., Carvalho, F. and Raposo, A. (2011). A collaborative VR visualization environment for offshore engineering projects. In *Proceedings of the 10th International Conference on Virtual Reality Continuum and Its Applications in Industry* (VRCAI'11). ACM, New York, NY, USA, pp. 179-186.

[8] Santos, I.H.F., Raposo, Gattass, M. (2006). A Service Oriented Architecture for a Collaborative Engineering Environment in Petroleum Engineering. *Research in Interactive Design*, Vol. 2, Springer-Verlag, 2006, pp. 106.

[9] Evans, F., Volz, W. et al. (2002). Future trends in Oil and Gas Visualization. In *Proceedings of the IEEE Visualization 2002*, pp. 567-569.