Viaconferencing 3D: Usability Study of a Collaborative Virtual Environment Prototype for CAD Project Reviewing

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Abstract

Collaborative tools are more and more required in design processes that involves several industrial teams. Existing tools have technical, ergonomic and economical limitations mainly due to: size of data files, use of various design software, network bit rate or data confidentiality.

In order to overcome these issues, France Telecom R&D and INRIA/LIFL have performed a Collaborative Virtual Environment (CVE) platform called Spin 3D. Thanks to a programming interface mechanism, it allows to develop new synchronous CSCW applications as an alternative to application sharing techniques.

One application is dedicated to CAD project reviewing. In this paper we describe the technical architecture and present the first results of an experiment carried out by European Aeronautic Defence and Space (EADS) on aeronautic use-cases. Two key points were particularly discussed: The first one concerns a technical comparison between CVE and remote control technique. The second one is related to the interest of aeronautics industry for CVE.

1. Introduction

The most complex industrial processes have in the past years adopted a concurrent engineering organization. Concurrent engineering, as stressed by Prasad [1], is based on:

- simultaneous/parallel design activities with strong interdependencies between each parallel team,
- integration of all lifecycle constraints in the early phases of the project
- teams made of multidisciplinary backgrounds.

In the recent years, another factor has been strongly affecting the design organization: the growth of distributed design teams and distributed work in general. This trend is general to most design industries, as reported by Simienuch and Sinclair [2] in their study of automotive industry. In aeronautics, the average number of nationalities involved in a program has risen to 40 different nationalities for a single program. Design has shifted from a co-located sequential process to a globally distributed, parallel process. Therefore, communication and coordination within and among teams became crucial to the design process, especially since all teams rely on design progresses of other teams.

Despite theses striking needs, a large industrial deployment of collaborative tools has not yet occurred, even though tools based on remote control techniques (e.g. Webex^{TM}) are easy to carry out and exists since several years. That situation is partly explained by technical, ergonomic and economical limitations of the available tools, mainly due to: network band-width available, size of data files, use of multiple design software, data confidentiality, etc.

In order to overcome these limitations, France Telecom R&D and INRIA Futurs/LIFL have designed a collaborative platform based on distributed technique. This paper begins with a summary presentation of this distributed platform, called Spin 3D. Then we present our CAD project reviewing application developed on it and called Viaconferencing 3D. We give here the first experimental results based on both technical and usability's aspects and achieved from EADS (European Aeronautic Defence and Space) use cases. Finally we compare Viaconferencing 3D with conventional tools based on remote control techniques, and discuss about its potentialities and future prospects.

2. Viaconferencing 3D: a collaborative platform for CAD project reviewing

2.1 Spin 3D: concept of distributed platform

Since several years, France Telecom R&D and INRIA-Futurs/LIFL have carried out joint studies on design and realisation of a new 3D CVE called Spin 3D. The aim of this work is to perform a synchronous collaborative application that allows to small group of users, strong collaboration around virtual objects. The work is mainly focused on the interface design and the technical platform development. The first objective is to create a user friendly 3D interface that privileges the ease of use, the collaborative task interactions, and the quality of the communication between the participants. The second objective is to perform a technical platform supporting the management of collaborative applications running on standard PCs connected to the Internet. In order to validate the interface's concepts and to test the technical effectiveness of the whole platform, several applications have been developed all along the course of the project.

The visual interface of the Spin 3D platform is built on a "meeting room" metaphor (see Figure 1), within which all documents and avatars are displayed [3]: a rotative band around a table is a place holder for all the documents needed for a given task, and the central table is a manipulation area on which the users put the documents they want to interact with at a given time.

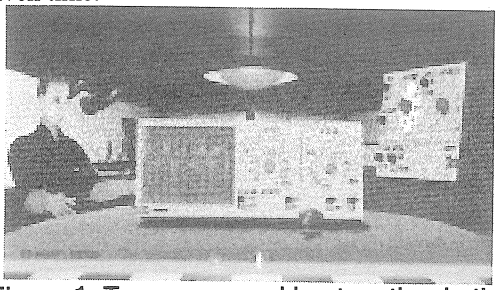

Figure 1. Two users working together in the Spin 3D environment

Spin 3D implements a two-phase bi-manual direct interaction mechanism. The dominant hand is first used for designation/selection of objects, with a 3D position tracker that controls a 3D virtual pointer. The other hand is then used for the object's manipulation, with a 6 degrees of freedom device (enabling 3D rotation and 3D translation).

There are many ways to represent the users in a CVE. Video technologies allow participants to be seen as they really are, but it is difficult to get a good representation of "where a participant is looking at" or "who is manipulating data". The camera direction also impacts on how users' gestures and attitudes are interpreted. Spin 3D uses 3D synthetic avatars, which are a realistic representation of users in terms of texture, morphology and animation [4].

2.2 Communication mechanisms

Most CVEs are built over a centralized architecture, but such an architecture introduces latency in user interaction. Indeed, to manipulate shared data, the user requests the remote server and waits for the updated state. To enhance interactivity, Spin 3D runs over a distributed architecture [5]. Each shared data is duplicated on each instance of Spin 3D present in the collaborative session. Thus this set of copies forms a logical group as proposed in [6]. Each user interacts with the local copy, and then the platform ensures the coherency of its logical group.

To support the co-operative activity, it is mandatory to guarantee that all the distributed copies belonging to the same logical group are in the same state. The Spin 3D platform provides a strong-coherency channel for group communication using a reliable transport protocol, at some cost. This channel is typically used to transmit one-time events: a user enters the session, an object has been selected, etc.

However, in some cases, the coherency can be relaxed: for example, some intermediary positions a moving object goes through, or some frames of a broadcasted movie. Therefore Spin 3D provides a second weak-coherency channel using an unreliable transport protocol. This channel should be used to transport streams of data which can be lost without harmful consequences.

2.3 Application development

All tasks needed to support a virtual synchronous collaborative activity (user embodiment through avatars, voice transmission and spatial localization, 3D interaction, shared data management, objects layout) are hidden to application developers and automatically performed by the Spin 3D platform. Therefore, developing an application is limited to the creation of contents using the VRML97 syntax [7]: the 3D object geometry, the definition of the user interaction, the description for shared objects [8] and the related object behaviors. The developers can write specialized display plug-ins that are loaded by Spin 3D, dynamically extending the capabilities of the platform.

2.4 Viaconferencing 3D: a new collaborative tool for CAD project reviewing

In order to evaluate and refine the Spin 3D concepts we have chosen to experiment the platform in the CAD sector, as we though that it could address problems encountered by big industries such as aeronautic and automotive.

We have first integrated a CAD viewer using the Spin 3D plugin mechanism. This integration implies to adapt the source code of the CAD viewer to the Application Programming Interface (API) of Spin 3D. We have also integrated Spin 3D in a complete existing data-conferencing product, called Viaconferencing, previously developed by France Telecom R&D. It allows us to take advantages of the conference management, the 2D functionalities and the hosting of data. This new collaborative tool is call Viaconferencing 3D (see Figure 3).

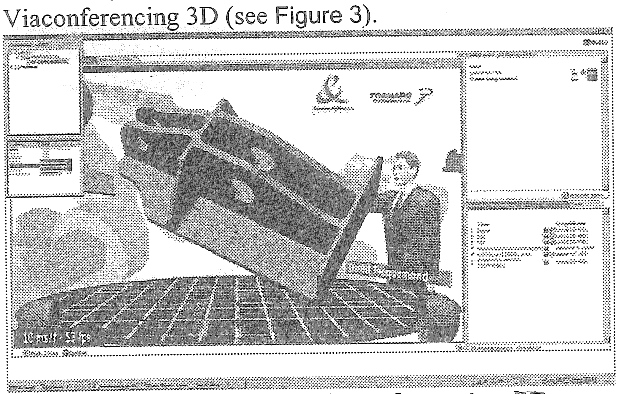

Figure 3. Snapshot of Viaconferencing 3D

Hereunder some of Viaconferencing 3D's major functionalities:

- Create a virtual conference and invite attendees
- Remote control of one host application
- Data sharing with distributed approach

3. Technical comparison between distributed and remote control techniques

In order to understand the impact of both distributed and remote control techniques regarding to the usability, let us compare the two approaches considering the network aspects: required bandwidth and network Quality of Service (QoS). Thanks to the both distributed and remote control techniques are integrated in the same platform (ViaConferencing), we have led the technical comparison using the same data and network condition. We will first study bandwidth requirements by using calculated values, because bit rate measurements are strongly impacted by other QoS features. Secondly, an empirical approach is used to evaluate QoS impact on systems stability and usability.

3.1 Bandwidth requirements

A theoretical study (i.e. not taking into account parameters such as bandwidth limitation, processor overcharge or QoS) allows us to underline main features of this comparison.

We won't take care of the sound bit rate, because this data flow is common to the both distributed and remote control techniques, and not upper (i.e. lower than 32 Kbit/s) than other data flows.

3.1.1 Distributed technique. The data flow used by the distributed technique is mainly made up of device updates or interaction and animations events. As demonstrated in some recent studies [9] a normal cooperative experience has not to be affected by parameters such as system latency which could be modified by the available bandwidth. So we consider that bandwidth requirements have to correspond to instantaneous bit rate needed during a user interaction situation rather than a medium bit rate. Measurements have been made on the Spin 3D environment, with typical sensibility devices, flowing animation and for the biggest interaction bit rate. We achieve a maximum value of 32Kbit/s.

Table 1 gives a theoretical traffic between the server and a client terminal. "x" is the number of simultaneous conferences supported by the server, and "n" is the number of users by conference. In order to compare with remote control technique traffic, we consider that only two users are manipulating at the same time.

Table 1. Bit rate for distributed technique

(Values in Kbit/s)	Client terminal	Bridge server
Upload	32	x.(n-1).64
Download	32	x.64

3.1.2 Remote control technique. The remote control technique is based on the "master/slaves" principle where the application to share is localized on one user machine ("master"). The "master" insures the periodic screen updates of the other user computers ("slaves") creating therefore permanent data flows. One particularity of CAD file manipulation is the high rate of information changing between two frames displayed during a flowing user interaction.

For instance, a 1024x768 pixels display, sampled for 256 colours and a conservative technique of compression, a bit rate of 1500 Kbit/s could be consider as typical for a standard user interaction.

From this value, Table 2 gives us theoretical traffic between a client terminal and the bridge server.

Table 2. Bit rate for remote control technique

(Values in Kbit/s)	Client terminal	Bridge server
Upload	1500	x.(n-1).1500
Download	insignificant	x.1500

It important to note that unlike remote control technique, distributed technique:

- allows two users to manipulate at the same time
- requires preparation time before sharing a file

3.1.3 Discussion about bandwidth requirements. Using the previous values, we have extrapolated the theoretical upload bit rate for a server managing several conferences at the same time, involving four participants per conference.

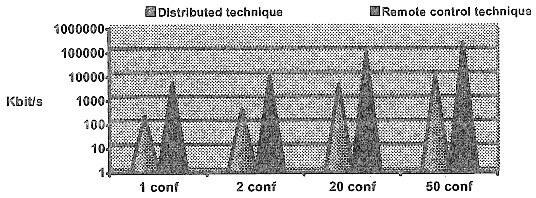

Figure 4. upload bit rate for a server

Figure 4 shows us that 50 distributed conferences of 4 users is equivalent to 2 remote control conferences of the same number of users.

3.2 QoS

We consider as QoS the group of the following parameters: bandwidth, traffic delay, congestion, priority queuing, transmission errors and dynamic routing. QoS problems are mainly due to numerous network equipments (e.g. proxies, routers, firewalls, etc.) that generate traffic delay and an un-predictive bandwidth consumption between concurrent applications. Therefore, it's very difficult to determine all the impacts of QoS parameters as regards the platform reliability and usability.

3.2.1 Test-bed. We have set up an experimental test-bed using a network administrator in order to emulate realistic network traffic. We have used the NIST-Net emulator, an Open Source Software providing by the National Institute of Standards and Technology. Combined with a monitoring software, it allows to analyse traffic, application reliability, application usability and also determine individually all the feature effects.

As the Viaconferencing platform, includes distributed and remote control techniques, we are able to compare the both regarding to the network context and the data manipulation. The experiments are carried out by tacking into account the EADS-CCR use-cases.

We have empirically observed the impact of the variation of the main QoS parameters on system stability and usability for the both techniques:

- Bandwidth variations
- Transmission errors
- Temporary and permanent transmission cut
- Traffic delay
- Impacts of both techniques on QoS variations

3.2.2 Discussion about QoS. We have observed that each QoS parameter affects other parameters. For instance, a bit rate greater than the available bandwidth causes traffic delay.

To sum up, mainly due to the difference between the bit rate requirement (two orders of magnitude i.e. 10^2), we have demonstrated that:

- Distributed technique, such as CVE, provides to the users a better interactivity, but is today more sensitive to QoS variations,

- Remote control technique affects more the QoS than the distributed one, particularly in case of insufficient bandwidth.

4. Experiments and first results

This previous technical results show us that the choice between distributed and remote control techniques dependant of the use collaborative cases feature needed.

4.1 Aeronautical industry use cases description

In order to discuss the interest of using of collaborative virtual environments in aeronautical industrial design processes, a presentation of potential use cases in EADS processes is necessary.

During the three main phases of an aircraft design programme (feasibility, conception, definition) two major organisation follow each other: in a first time, the plateau phase, characterised by co-located design teams in an open space [10]; then, the plateau gives progressively way to a distributed design phase, where each team in charge of a sub-component returns to its offices. However, in the recent programs, the increase in aircraft complexity and involved nationalities has further enhanced the distribution of the design process. The plateau phase has been split into two distinct sub-phases. The first, similar to the one introduced by Garel [10], involves all design teams on a co-located area for the early design choices. But a second phase has been recently introduced: the distributed plateau, where plateau teams are split into major components and distributed in different locations.

Therefore, the need to collaborate at a distance is even greater in this new configuration. During those distributed design phases, the CAD models and 3D-mock-up are essentially used in three collaborative contexts: formal project reviews, informal and formal design reviews. The next sections develop the various use cases where designers collaborate and require 3D-sharing solutions.

4.1.1 Formal project reviews are mainly collocated as they regroup a review panel of high responsibility actors in order to validate or not some design solutions. For this sort of review, a dedicated person uses the 3D mock-up in order to navigate into it with a viewer tool; participants also refer to the 3D model by inserting screenshots of the CAD into classical presentations. This kind of meeting is not likely to evolve for the moment as they are very formal and there is a tremendous need for oral negotiation and physical co presence.

4.1.2 **Formal design team reviews** are planned and collocated reviews at this time, but may evolve according to the work practices. In order to facilitate understanding among the participants, discussions during the design reviews are often supported by paper drawings and sometimes by the 3D mock-up views. But using the 3D is still difficult due to the need of a dedicated person to manipulate a special workstation and because of the hardware required to display large CAD models. On those aspects a CVE could enable to perform those meetings in remote locations.

Moreover, for a distributed team, the number of reviews scheduled is partly limited by the physical distance. So an improvement of the collaborative tools should allow designers to exchange more frequently.

4.1.3 Informal design reviews are very important to the design process. When co-located, designers frequently meet informally around a workstation to discuss design issues. Informal meeting have a very high impact on the design progress, but in a distributed environment, they become almost impossible in the same form. Informal meetings are a strong potential application field for CVE methods and tools. Allowing designers to virtually meet and manipulate the 3D from the desktop would be a real improvement in the designer's daily collaboration.

4.1.4 Use cases Adequacy with Viaconferencing3D. Currently, 3D-sharing tools exist, but they are dedicated to 3D specialists given their very high bandwidth consumption. The use of more efficient CVE tools could greatly facilitate both formal and informal design reviews.

The major benefit of distributed CVE tools would be to facilitate design reviews set-up and increase design reviews frequency. Preparation time is not an issue for design reviews while interactivity is. Moreover, this increase in the meetings frequency would enable more accurate and efficient expert's involvements to the meetings. Indeed, meetings could be shorter and more targeted. If preparation time remains reasonable, distributed CVE tools could greatly enhance informal meetings. Current telephone or email solutions could be replaced by "around the mock-up" discussions.

4.2 Usability comparison between CVE and remote control techniques

From an industrial perspective both techniques can be compared based on their two main characteristics: required bandwidth and preparation time.

4.2.1 Interactivity. The use of distributed technique enables a better reactivity and interactivity compared to remote control. Therefore, there is no de-synchronisation during conversation, particularly for use cases allying audio and 3D elements. This point is very relevant, especially if different languages are used. In that case, a good audio quality and a synchronized interactivity are compulsory. Since users lose most of their usual "indicators" of co-located meeting (gaze and gesture mostly), it is very important that the system associates in real time synchronised vocal comments and visual aids to compensate for the loss of context.

A better reactivity makes possible as well more interactive meetings: users are not reluctant to manipulate the 3D models any more since the delays are limited. We observed that for simple document-sharing users did not want to remotely interact with the documents because they feared that their actions might be misinterpreted due to the delay between their action and the remote visualization.

4.2.2 Preparation time can be also a handicap for a meeting. In some cases, transformation of the CAD model can take up to several hours before being able to share it with a remote user. This delay does not allow for informal, on the spot meetings, when the immediate availability of the CAD models is critical.

On the other hand, current processes, based on physical visits to the remote teams, are much more time consuming than the CAD transformation time. Moreover, the transformation time forces users to adopt a certain formalism for their meetings, which may remove part of the spontaneity but may result in more efficient and well prepared working sessions.

Despite the interaction limits of CVE (e.g. only tool like pointers, highlighter or simple cutting plan or the long preparation time), solutions such as ViaConferencing3D could be applied to design scenarios and greatly enhance real-time collaboration for distributed teams.

4.3 Discussion

For the time being, as stressed by McGregor [11] in his study of distributed design, sophisticated tools are available but people tend not to use them. This is due in part to three factors:

- The inadequacy or inexistence of simple and efficient sharing tools.

- The lack of habit of end users. Most design meetings are still heavily relying on paper-based sketches.

- The lack of integration of tailored processes for distant and distributed collaboration.

However, even though current work practices may not extensively use 3D virtual meeting tools, the evolution of design practices towards globally distributed processes will force the adoption of new tools and specific processes to enable collaboration at a distance.

We are not yet ready to overcome typical and very common informal meeting scenarios: a discussion between two designers on a desktop corner, but tools make now more and more possible to envision alternative work practices. Informal design discussions will still exist, but new design processes and new collaborative tools could impact how those scenarios will be conducted in a distributed fashion. By enabling more frequent semi-formal discussions, by enhancing the communication supports and 3D model sharing, by facilitating the implication of remote actors to informal meetings those tools would enable designers to increase exchanges between remote teams and facilitate the involvement of experts during working sessions. This could as well reduce clashes occurrences between sub-components since designers could share more frequently their updated models and thus minimize design iterations.

5. Conclusion

In this paper, we describe the viaconferencing 3D application prototype built upon the CVE platform Spin 3D. It enables a small group of users to cooperate in real time, around CAD mock-ups.

Thanks to a both technical and usability study lead in cooperation with EADS, we have underline three main results.

Firstly, in a general way, we have highlighted the importance of the group communication during dispersed collaborative work, through parameters like sound quality or nonverbal information between attendees. We concluded that the distributed approach is compatible with these requirements and on some points less disturbing than tools based on remote control technique (mainly due to the later's latency). Furthermore, we believe that virtual artefacts and animation techniques e.g. avatars, specifics to the distributed technique have a potential that could enhance the cooperative experience compared to classical tools.

Secondly, we have demonstrated that given the current shift of work practices towards a global distribution of design teams, and given the inadequacy of exiting collaborative solutions, the distributed approach of CVE could be today a way to improve formal design team reviews between distributed teams. This point was explored through EADS use cases.

Finally, even though nothing existing for informal meetings between distributed teams, we believe that CVE could be a real opportunity. Researches to facilitate the use of CVE for those informal meetings are conducted on two fields. The first one aims at reducing preparation time by adding a functionality to connect external applications (e.g. CATIA) directly to the distributed platform. This work is in progress with Spin 3D. The use of new 3D formats, like 3D XML, XVL or X3D CAD, could also improve preparation efficiency. The second field of study concentrates on the communication layer to reduce QoS variations and improve the scalability of the data flow.

6. References

[1] Prasad B. "Concurrent Engineering Fundamentals: Integrated Product and Process Organization. Prentice Hall", *ISBN: 0131474634*, December 1995.

[2] Simienuch, C.E. and Sinclair, M. "Real time collaboration in design engineering: an expensive fantasy or affordable reality", *Behaviour and information technology*, 18(5):361-371, 1999.

[3] Dumas C., Degrande S., Saugis G., Chaillou C., Viaud M.L., Plénacoste P. "Spin: A 3-D Interface for Cooperative Work", *Virtual Reality*. Springer-Verlag, 4, p. 15-25, 1999.

[4] Le Mer P., Perron L., Chaillou C., Degrande S., Saugis G. "Collaborating with Virtual Humans", *People and Computer XV – Interaction without frontiers*: Proceedings of HCI 2001, Springer, pp.83-103, September the 12th 2001, Lille.

[5] Louis Dit Picard S., Degrande S., Gransart C., Saugis G. and Chaillou C. "A CORBA-based platform as communication support for synchronous collaborative environments", In: *Multimedia Middleware Workshop (M3W)*, ACM Multimedia, Oct. 2001, pp. 56-59.

[6] Hagsand O., Herzog H., Birman K. and Cooper R., "Object-oriented reliable distributed programming", In: Proceedings of the *2nd International Workshop on Object-Orientation in Operating Systems*, Sept. 1992, pp. 180-188.

[7] Carey R., Bell G. and Marrin C. "Virtual Reality Modeling Language (VRML 97)", In: *ISO/IEC 14772-1:1997*, 1997.

[8] Louis Dit Picard S., Degrande S., Gransart C., Saugis G. and Chaillou C. "VRML data sharing in the Spin 3D CVE", In: Proc of *Web3D 2002 symposium*, Feb. 2002, pp. 165-172.

[9] Wolff R., Roberts D. J. and Otto O. "A Study of Event Traffic During the Shared Manipulation of Objects Within a Collaborative Virtual Environment", *Presence*, Special Issue: Collaborative Virtual Environments, Vol. 13, Issue 3, pp. 251-262.

[10] Garel G. "L'entreprise sur un plateau: un exemple de gestion de projet concourante dans l'industrie automobile", Article 3 Acte 19 du *GERPISA*, Université d'Evry, 1996.

[11] McGregor, S.P. "Towards a Prescriptive Design Process for Distributed Design Teams", *PhD thesis*, DMEM University of Strathclyde, Glasgow, UK, 2002.