Team work in Distributed Collaborative Virtual Environments

by

Gernot Peter Josef Goebbels

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Today's technology and advances in networking and telecommunications stimulate a change in the way everyday business is carried out, making it a globally distributed process, in which communication and collaboration of geographically dispersed groups is of vital importance. Virtual Environments are adapting accordingly, by providing not only a better man-machine interface, but also by facilitating human-to-human interaction and collaboration over distance.

Therefore, new challenges are introduced in terms of distribution and interaction in Virtual Environments. It is not only a question of solving the technical problems of gathering and transmitting multimedia data streams with sufficient quality and speed, but also a question of addressing the specific needs of human communication and collaboration.

The vision of Collaborative Virtual Environments (CVE) is to provide distributed, collaborative teams with a virtual space where they can meet as if face-to-face, co-exist and collaborate while sharing and manipulating in real-time the virtual data of interest.

The objective of this thesis is to provide the Virtual Environments research community with a thorough investigation of distributed, collaborative interaction between geographically dispersed teams using projection based Collaborative Virtual Environments.

Thesis Supervisor: Prof. Dr. Vali Lalioti
Department of Computer Science

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Introduction

The motivation for providing multi-sensorial interfaces for human-computer interaction is rooted in the nature of human perception and cognition, which uses several sensory channels at a time to construct what is generally referred to as reality.

Naturally, the more sensory channels are stimulated coherently in a man-machine interface, the richer the interaction models. The more of our innate and culturally acquired perceptual and cognitive skills are exploited in an interface, the more refined and efficient the interaction may be. This is especially valid for interfaces which mimic to a large extent certain aspects of our everyday environment to create what we call Virtual Environments (VE).

One of the underlying assumptions of these interfaces is that the more a Virtual Environment perceptually resembles the environment we are familiar with, the easier it will be for us to orient, navigate, and act in such an environment. But it has to be seriously doubted if technology will ever be able to create a synthetic sensory experience completely indistinguishable from the one we experience in our everyday world. Fortunately this is not a drawback of Virtual Reality technology but its most interesting aspect as it forces the designers and developers to create efficient interaction techniques and metaphors which refer to our cognitive skills but which do not necessarily attempt to mimic interaction as it happens in everyday life. This is how new interaction techniques evolve and become candidates for developing a new framework or language of expression. Virtual Environments are currently developing their own language of expression which is still very rudimentary.

Therefore, **chapter 1** provides a detailed survey on Virtual Environments. This survey includes various display systems and input devices for interaction. In addition, selected software toolkits are introduced. The particular reason for choosing these software toolkits is their uniqueness with respect to their special capabilities for implementing Virtual Environments.

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The need for such high-end Collaborative Virtual Environments is becoming more pressing due to the globalized nature of today's market. Distributed companies are more common and their business requires not only a distributed structure but also effective collaboration over distance in order to minimize time and travel costs. Another category of businesses where there is a need for Collaborative Virtual Environments that integrate tele-conferencing facilities is businesses where the raw data are gathered from remote areas while the experts and the high-end infrastructure for visualization are located on the company's sites.

Collaborative Virtual Environments that include face-to-face communication can also greatly benefit remote consultation and tele-education, providing means of accessing the experts or infrastructure that are not available at the consultation or education site.

The advances in networking and high performance computing can provide the basis for such advanced Collaborative Virtual Environments. However, this is not enough. Since Virtual Environments denote interactive computer simulated worlds, the implemented interaction techniques and visual representation components have the highest impact on the usability and thus on the acceptance of the designed CVE.

Therefore, **chapter 2** deals with a detailed comparison of interaction techniques. It is reviewed whether these interaction techniques can be used to complete the five basic interaction tasks, selection, position, text and numeric input as well as confirmation [39]. It is also reviewed whether these techniques are usable in Virtual Environments [1]. Additionally all related work relevant to this thesis is presented. This includes additional new three-dimensional interaction techniques and a survey on selected Collaborative Virtual Environments. The particular reason for choosing these Collaborative Virtual Environment systems is the fact that they specifically address the needs of users working cooperatively together in a Virtual Environment. Teleport and the NTII were chosen due to their use of tele-immersion approaches. The objectives of the applications are introduced and it is shown how interaction in these Collaborative Virtual Environments is designed.

In general interaction can be seen as cultural techniques of expression that tend to mix and merge, reference each other, and are transformed and rethought in the context of new media. They form the rich tissue of a culture's means of expression most consequently explored and developed in its art. It is not necessary to get into contemporary art theory in order to illustrate what this means. An analogy is evident in today's advertisement design which more and more refers to the desktop metaphor of current computer graphics user interfaces. The concept of a window, e menu-bar or pull-down menus suddenly can be used to present different aspects of a product. Such an advertisement never would have been understood before a significant fraction of members of a society became acquainted with modern human-computer interfaces.

However, for the Virtual Environment interaction designer it is a very complicated and challenging task to create a user interface that fits the user's requirements. Problems with the design of user interfaces are manifested in the lack of user interface standards for Virtual and Collaborative Virtual Environments. Furthermore there are no formalizing approaches which are capable of supporting the implementation of Collaborative Virtual Environments with design guidelines.

In order to overcome this problem the principle aim of **chapter 3** is the development of a theoretical interaction approach for Virtual and Collaborative

Virtual Environments.
The approach includes a taxonomy that creates, from a varied array of VE/CVE influence components, a hierarchy of groupings that have an orderly relationship to each other. This taxonomy is usable for the categorization of hardware and visual representation components supporting the user's awareness in the Virtual Environment. Further it categorizes operations, interaction metaphors and interaction techniques which mainly influence the user's interactions with the environment.
The developed taxonomy is not a hierarchy of classified VEs but a hierarchy of classified influence factors that show an impact on the design process of VEs and CVEs. With the help of this taxonomy of influence factors it is then possible to develop a VE/CVE design model which supports the VE/CVE designer to consider the large amount of these influence factors. Thereby the design model also shows the dependency of the influence factors and enables to simulate the appearance of the VE/CVE early in the design process.
The input for this simulation delivers the requirement engineering process that uses the task description and task analysis which determine the User+Need Space. An example for such a simulation is given at the end of chapter 3.
The reason for the development of a new VE/CVE design model instead of taking an existing one is that the existing models developed in the CSCW and HCI community do not pay enough attention at Human-to-Human communication and collaboration in large scale projection based Virtual Environments. Bowman et.al., for example, developed a taxonomy of different techniques concerning the three tasks navigation/locomotion, selection and manipulation. This taxonomy enables the VE designer to find the interaction technique best-suited for a given task. The orderly relationship between the classified techniques is obtained according to usability issues taking into account user input devices and tasks.
Bowman's taxonomy has been developed for and evaluated in HMD based systems (Head Mounted Displays) but not in projection based displays. Whether this developed taxonomy is valid also for projection based display systems needs to be evaluated in future.

In order to find the best interaction within this thesis the low-level makeup of interaction is analysed. Interaction tasks are narrowed down and interaction templates are defined which can be combined to form more complex interactions. The developed *Awareness-Action-Feedback* loops denote such interaction templates. These loops provide the possibility to understand and analyze very tiny steps in interactions. With their help it is possible to track down usability problems early in the design phase.
The taxonomy presented in this thesis attempts to group and categorize all the

influence factors. It is a practical tool that can be used as a framework for the design and evaluation of CVEs as shown in this thesis. Therefore, the utility of the taxonomy is considered rather than its absoluteness or completeness. The objective is to facilitate guided design of applications for supporting team work in CVEs.
In the last section of chapter 3 the simulation of an example CVE design is performed. With this example the reader will be able to understand the make-up and the process of CVE design making use of the VE/CVE design model developed from the taxonomy of influence factors at the beginning of this chapter.

Chapter 4 guides the reader through the whole design process of an Collaborative Virtual Environment. In this context it is illustrated how all the components of the theoretical interaction taxonomy can be put into practise. This also includes a detailed task description and analysis of the user requirements.

A technical description of the implementation of two Collaborative Virtual Environments follows in **chapter 5**. Firstly, the setup is described with respect to the used hardware configuration introducing the rendering and interaction equipment. The remainder of this chapter presents the software configuration describing the audio/video conferencing as well as rendering and distribution using the Avango software framework. Code fragments represent parts of the application programming and flow charts illustrate the combination of different techniques and equipment.

However, when implementing Virtual and Collaborative Virtual Environments designers and programmers usually tend to guess about the best realization and implementation of interaction techniques or even the whole application [53]. Many works have shown that user based assessment is an essential component of developing interactive applications and in this work it is shown that user based assessment is especially important for applications as complex and innovative as CVEs. Already the assessment of parts of the application by different users except the designers can substantiate or refute realizations of a specific Collaborative Virtual Environment. If those assessments are formalized they are called evaluations. But still there is a lack of formal approaches for efficiently carrying out evaluation of Collaborative Virtual Environments.

These evaluations are crucial for the implementation of Collaborative Virtual Environments because errors made in the early phases of the design are the mostly costly to repair later on. It is also a very delicate activity, as it requires heavy user involvements and evaluation approaches that are capable of assessing usability aspects. There exist four different approaches [79]. These are the:

- Interaction oriented approach
- User oriented approach
- Product oriented approach
- Formal approach

The *interaction oriented approach* is the most common one and is concerned with all kinds of usability testing with users. The *user oriented approach* tries to measure usability quality in terms of mental effort and attitude of the users. This is done by using questionnaires and interviews. The *product oriented approach* is concerned with measuring ergonomic attributes and thus quantitative measurements are necessary. Lastly the *formal approach* tries to simulate usability in terms of formal models. This approach can be seen in the context of theory based evaluation.

Therefore, **chapter 6** deals with the evaluation of the implemented applications according to usability and collaborative awareness. For performing intelligent evaluation, specific questionnaires and evaluation items are designed as the focus in this thesis is the user oriented approach.
For the statistical analysis of the numeric evaluation results the average values and the corresponding expectancy values are computed. However, for obtaining more subtle results which allow for the formulation of CVE implementation guidelines supporting team work a new analysis method is developed, namely the Variation Group Analysis.

In **chapter 7** a review of the results of this thesis is presented. Additionally to the developed interaction taxonomy for Collaborative Virtual Environments the defined Awareness-Action-Feedback loops are concluded. Furthermore the results of the evaluation assessing usability and collaborative awareness are listed in detail.
The chapter concludes with a discussion on possible enhancements and directions for future research. These are listed in detail trying to encourage further work in this area making use of the results of this thesis as a basic approach.

Appendix A is a glossary on special terms that are used in Virtual Environment technology. It might help to understand different expressions that are not used in the everyday language. In addition, it can be used by non-expert evaluators to assess the different aspects of usability since they are not familiar with the topic.

Appendix B is an example of a code implementation using the scripting interface of Avango. This scheme code creates the necessary scene graph for stereo video conferencing.

The **appendices C to G** present the designed questionnaires used for the usability evaluation. Appendix C is querying general information about the user in order to create a user profile. The remaining appendices are used for assessments of the evaluation items that are worked out in this thesis.

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