INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team i3D

3D Interaction and Virtual Reality

Grenoble - Rhône-Alpes

THEME COG

Activity Report

2007

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1. Team

Head of the team
Sabine Coquillart [Research Director (DR) INRIA, HdR]

Administrative assistants
Caroline Ouari [Secretary INRIA - part time from October 2006 to mid-January 2007]
Stephanie Berger [Secretary INRIA - part time from Mid-January 2007 to end-January 2007]
Marlyse Felici [Secretary INRIA - part time from 1st February 2007 to 31st August 2007]
Annie Simon [Secretary INRIA - part time from 1st September 2007 to mid-October 2007]
Ahlem Zammit Boubaker [Secretary INRIA - part time since mid-October 2007]

Research scientists INRIA
Olivier Martin [Research Associate (CR) INRIA]

Technical staff
Thomas Amory [Junior technical staff INRIA]

Ph. D. students
Jérémy Bluteau [INPG/Région Rhône-Alpes scholarship]
Michaël Ortega [Univ. Lyon 1/CIFRE scholarship INRIA - PSA-Peugeot Citroën - until end-February 2007]
Andreas Pusch [INPG/Marie-Curie scholarship]
Inna Tsirlin [UPMF/Région Rhône-Alpes scholarship]
Yann Mazel [INPG/INRIA-ANR scholarship - since mid-October 2007]

Intern students
Ehwalid Brahim [Licence Computer Sciences IMA/UJF]
Adrien Brilhault [Licence Computer Sciences IMA/UJF]
Laura Zunarelli [Licence Computer Sciences IMA/UJF]

2. Overall Objectives

2.1. Introduction

The objective of the i3D research team is to contribute to making interaction in virtual worlds as simple and intuitive as in the real world.
To this end, three research axes are privileged:

- Interaction metaphors and paradigms
- Haptic feedbacks [1]
- Human factors study

Within these research axes, focus is put on:

- **Spatial approaches**: spatial input and output.
- **Immersive environments**: immersion of the user into the virtual world or immersion of the application into the user's real world.
- **Better exploitation of the user's various sensory channels** such as visual and haptic.

The research activities are based on both the **"Workbench"** and **"Video See-through HMDs"**. These systems have been chosen for their complementarity and their potentials in terms of interaction and their adequacy to the main approaches mentioned above (see 3.3).

[1] force or tactile feedback

Research of the i3D group is organized around three themes:

- **The study of interaction metaphors and paradigms**. Tasks apparently as simple as displacement inside a virtual scene or catching and repositioning an object are still difficult to realize in a virtual world today. The objective of this theme is to study new paradigms and metaphors of interaction using the approaches quoted above.
- **The study of haptic feedbacks**. There are several ways to return a haptic feedback: *active haptic feedback* (requiring the use of a haptic feedback device), *pseudo-haptic feedback* [25], [24], *passive haptic feedback* (makes use of a prop), and *sensory substitution*. The objective of this theme is to study these different approaches in order to have a better characterization of haptic feedback according to the completed task.
- **Human factors study**. In addition to the two previous themes, the research group aims at carrying out experiments whenever possible. These experiments are either carried out to provide a basis for the research, such as psychophysics experiments on human perception or the evaluation of existing techniques and peripherals, or the evaluation of approaches developed by the group.

The i3D group wishes to emphasize the genericity of the proposed solutions. The solutions are developed with the objective to integrate them into various applications within different application fields. However, concerning applications, the group currently focuses on the most promising applications in terms of industrial use for the Workbench:

- **Interactive exploration of complex data** such as data from scientific computation, fractal models or meshes.
- **Virtual prototyping**: virtual prototyping for industries such as automotive or aeronautic.

2.2. Highlights of the year

- Sabine Coquillart has been co-chair of IEEE 3DUI'07 (Charlotte, USA) and of the VR track of ISVC'07 (Reno, USA).
- Transfert to PSA Peugeot Citroën of Michaël Ortéga PhD results on the simulation of putty application.

3. Scientific Foundations

3.1. Virtual Reality

Keywords: *Virtual reality*.

We begin by explaining the expression **virtual reality**. We are not going to propose a $n+1^{th}$ definition. Instead, we propose to position Virtual Reality by reference to the image synthesis field which is older, better specified but which is nowadays too often confused with virtual reality.

Image synthesis gathers all the techniques leading to the production of images (fixed or animated) representing a numerical model, a scene or a virtual world. To simplify, one can say that image synthesis is a reproduction of a virtual scene through a photo album (fixed image) or a film (animated images). Virtual reality makes it possible to enrich perception of the virtual scene by enabling a person to interact with this scene.

It is proposed to him/her to move from a passive role to an active role, to "live" the virtual experiment instead of being satisfied to view it. By taking again the preceding analogy, virtual reality can be compared with the visit of a country while going on the spot as opposed to the photo report or documentary film. However, contrary to the real case, where the photo report or the documentary film are quite distinct from living the experience, in the virtual world there is a continuum between graphic applications and virtual reality. It is mainly the position of this border which is prone to discussions.

A first brief reply could be given by consulting the various definitions of virtual reality. The concept most usually associated to the expression virtual reality is that of immersion. One speaks about virtual reality when the interaction is sufficiently realistic to get a feeling of immersion, communion, fusion between the person and the application. This concept of immersion remains quite subjective. Should we specify it ? Or isn't it rather prone to a slow evolution accompanying virtual reality research progresses ? We chose the second solution and would like to list some factors improving immersion, such as stereoscopic visualization, visualization on large screens, head tracking, spatial interaction, two-handed interaction, multi-sensory interaction, real-time control, not forgetting the most important factor, and often considered as required [17]: the first-person point of view.

3.2. 3D Interaction

Keywords: *3D interaction*.

The importance of 3D interaction in virtual reality (see 3.1 for a description of virtual reality) coupled with the immaturity of the field, makes 3D interaction one of the most important **open problems** of virtual reality. In spite of its major importance, the human-application[2] interface is currently far from providing the same level of satisfaction as other computer graphics sub-domains [19].

In computer graphics, the race towards realism engaged over the last twenty years has led to impressive results where the virtual world is sometimes not easy to distinguish from the real one. Who did not hesitate while seeing certain images of complex scenes, with most realistic illumination effects ? Most of us have once doubted while seeing an image or a sequence of images which he/she did not know how to classify: real or virtual ? At the inverse, this feeling of doubt is unlikely as soon as there is interaction. Conversely, it is often a feeling of faintness or awkwardness which dominates. Indeed, the processes of interaction with the virtual worlds are still often very poor. The large majority of the systems is developed on 2D workstations. Even if using 3D configurations, the user interface is frequently inspired by 2D interfaces. The WIMP concept (Windows, Icons, Menu, and Pointing) is often used. As an example, operations as simple as navigation inside virtual 3D scenes, or the handling (displacement) of entities in a virtual 3D scene, are still open research problems. The relative poverty of the interaction with virtual worlds is even more poorly perceived because the real world, in which we live and which we are used to interact with, is a very rich world. Any machine, with some complexity, (car, bicycle, television, telephone, musical instrument...) has its own mode of interaction adapted to the task to perform.

On the other hand, some configurations and some recent approaches are very promising. These approaches are more specifically 3 dimensional or are proposing a better use of the various sensory channels.

In short, the current situation is as follows. One can identify:

- **a well identified need:** increasingly demanding users and a growing number of applications.
- **an unsatisfactory situation:** poor interfaces, primarily 2D, with a strong under-utilization of the human-application bandwidth.
- **strong potentials:** very promising configurations and approaches to study or to conceive.

3.3. Virtual/Augmented/Mixed Reality Configurations, Workbench and See-Through HMD

Keywords: *CAVE*, *HMD*, *flat or cylindrical wall*, *immersion*, *see-through HMD*, *virtual/augmented/mixed reality*, *workbench*.

[2] one will speak about human-application interface instead of human-machine interface, as one would tell in 2D, because the objective is to make the machine transparent and to give the impression to the user to interact directly with the application

Until 2004, much of the research work and especially of the developments of the i3D group were dictated by the **Workbench** Virtual Reality configuration installed at the end of 1999. Last year, the i3D group has acquired a complementary augmented reality configuration, the **Video See-Through HMD** This paragraph briefly describes these configurations and positions them within the set of other configurations of the same class.

Virtual reality has been identified for a while with head mounted displays (HMDs). HMDs isolate the user from its real environment and require the use of avatars.
Currently, projection-based virtual environments often take the place of HMDs. More recent, less invasive and offering better characteristics, these configurations take several forms. In this class, one finds the CAVE^{TM}, the flat or cylindrical walls and the Workbenchs. See [18] for a more detailed introduction of this class of configurations.
The CAVE^{TM} [3] [21] is probably the best known of these configurations. It is also the most expensive and the most complex to install and maintain. It appears as a room of approximatively 3 meters on each side with the virtual world back-projected on 4 (three walls and the ground) to 6 (for some recent configurations) of the faces of the room. This configuration provides a good feeling of immersion thanks to the screens which "surround" the person, to stereoscopic visualization and to head tracking. This configuration is very well adapted to navigation inside large spaces (for example, a visit of a virtual scene such as architecture, an amusement park, or a driving simulation).
The wall is a large flat or cylindrical screen on which the virtual world is visualized generally with the assistance of 3 video projectors. The fact that people sit in front of the screen, without head tracking, makes this configuration more passive. It is a nice configuration for presenting projects to a group of approximately 20 persons, like project reviews for example.
The Workbench (or Responsive Workbench^{TM}[4] [20], by reference to the first developed system [23], [22]) is the "lightest" configuration (see Figure 1). Often less known than the CAVE^{TM}, this configuration is, from many points of view, far from being less attractive. With a horizontal screen (plus, possibly, a second vertical one providing a wider field of view) which represents a tabletop, the Workbench makes it possible to visualize a virtual scene within the reaching area, in front of the observer. A video projector, after reflexion on one or more mirrors, back-projects the image on the screen representing the surface of the table. 3D effects are provided thanks to stereoscopic visualization with shutter glasses. As with the CAVE^{TM}, head-tracking is provided.

The form of the Workbench predestines it with manual manipulations on a table. This configuration is also characterized by a strong potential for interaction. Its head tracking feature allows a superposition of the visualization and the manipulation spaces (virtual and real spaces) and opens the way to simpler and more intuitive interactions. In addition, whereas a maximum immersion of the person into the virtual world was preached a long time, in particular with the HMDs, this configuration introduces the opposite approach, which is more comfortable: the immersion of the application into the user's (real) environment. This configuration is thus integrated into the users real world, providing him with very pleasant feelings, close to what he/she is used to when manipulating objects on a table in the real world. It is thus quite natural that the applications of this configuration are those where the user observes and handles data or numerical mock-ups which rest in front of him, within the range of hands.

Projection-based configurations only allow a limited mixing of the real and the virtual worlds. The real world has to be in front of the virtual one. Optical see-through HMD overcome this limitation but introduces the inverse one, the virtual world has to be in front of the real one. The only VR/VA configuration allowing for a free mixing of the real and the virtual worlds is the video see-through HMD. The video see-through HMD is an HMD configuration equipped with two small cameras, one in front of each eye. The cameras are capturing the real world which is mixed together with the virtual one within the computer and then, the mixed world is displayed onto the HMD. Even if presently, the characteristics of see-through HMD in terms of resolution, field

[3]CAVE is a trademark of the university of Illinois
[4]"Responsive Workbench" is a trademark of GMD

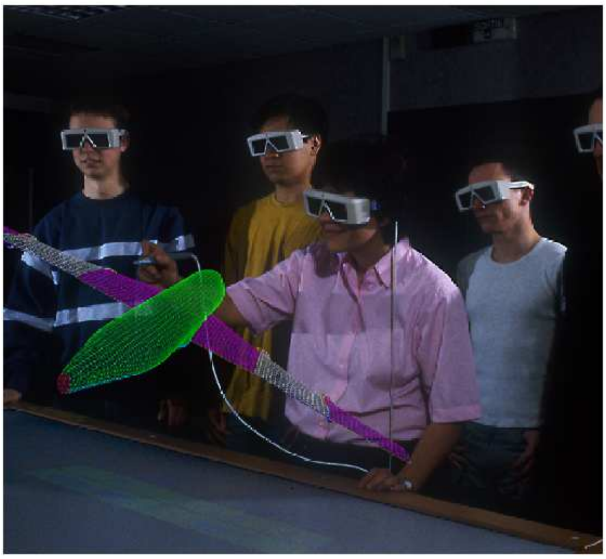

Figure 1. The INRIA Workbench (with special effects)

of view etc... are not sufficient for some industrial applications, acquiring expertise on these configurations is of great interest because they potentially allow unique applications.

4. Application Domains

4.1. Application Domains

In 3D interaction, applications are of a great interest. In addition to their significant role regarding industrial transfer, they are essential for our research. They make it possible to validate our work, to make the Workbench more known, and to cause new interaction problems therefore new research problems.
We are concentrating on applications for which the use of the Workbench (more recently, we also focus on applications for the see-through HMD) seems particularly promising to us. These applications include:

- the visualization and analysis of complex data (geological data, fractal models, complex meshes, graphs...),
- virtual prototyping (assembling/disassembling...),
- neuroscience applications.

On the other hand, we do not set any constraint on the domain to which we apply our results.

5. Software

5.1. Panorama

In 2005 the i3D software development effort was mainly dedicated to the move of the i3D MiniOSG platform from SGI Onyx to a PC cluster. In 2006, the development of the MiniOSG platform continued mainly toward the integration of the see-through HMDs and associated functionalities. In 2007, this effort continued in three ways: cleaning and simplification of the core of the software platform, development of new functionnalities, transfert of Onyx demos.

5.2. MiniOSG

Participant: Thomas Amory.

Due to the migration from SGI Onyx to PC clusters as well as new configurations like see-through head mounted displays, the development of a new software platform named MiniOSG has started in 2004.

According to the work done in previous years[5], OpenSG has been chosen as the basis of our virtual reality platform: MiniOSG. The main advantage of OpenSG resides in that visual rendering can be done over a cluster of PCs quite easily. So, our efforts have not been wasted in questions like the synchronization of the scenegraph in a distributed environment. This year, the main developments have focus on:

- Core of the software platform miniOSG.

  The core of the software platform has been cleaned up. Too specific software parts have been removed. An HMD module has also been created to simplify the core of the platform and to gather HMDs specific treatment. The main objective is to obtain a full flexible and configurable platform running independently on workbench, HMDs and workstation.
- Video see-through HMDs.

[5] cf. Activity Report 2004: http://ralyx.inria.fr/2004/Raweb/i3d/uid0.html

In 2007, in the continuation of the developments realized in 2006, several types of visualisation have been added with video see-through HMDs: pure virtual scene, real images, virtual scene without hand occlusion, virtual scene with hand occlusion.

- ShadowVolume.

  The shadowvolume algorithm developed for workbench applications has been extended to be available on monoscopic display devices (workstation, HMDs).

- Geoclay demo.

  Due to the migration from SGI Onyx to PC clusters, old workbench demos had to be transfered on the new software platform miniOSG. This year, the Geoclay demo has been transfered. The core of the demo has been adapted and integrated by Ehwalid Brahiman, internship student, and other functionalities such as a menu, rendering options, and scene manipulation tools have been recently developped. The new application Geoclay has been shown for two days in a row for the "Fête de la Science".

- Conclusion

  MiniOSG is currently used in different projects. It works not only on the Stringed Haptic Workbench but also on workstations and with the Spidar together with the new video see-through HMDs.

  This platform is configurable and evolutive enough to allow future researches and the integration of other devices.

6. New Results

6.1. Panorama

This year has been marked by a continuation of the researches on the Stringed Haptic Workbench and associated industrial applications. It has also been marked by an increase of the video see-through HMDs activity.

6.2. Evaluation of the Prop-based Stringed Haptic Workbench

Participants: Michaël Ortega, Sabine Coquillart, Olivier Martin.

In 2005, i3D, in collaboration with PSA Peugeot Citroën, has proposed the prop-based Stringed Haptic Workbench [26], an extension of the Stringed Haptic Workbench [27] proposed 2 years earlier, and has developed on top of it an automotive application for simulating putty application [26]. This application also benefits from the generalization to the six degree-of-freedom God-Object method [3]. In 2006, an evaluation of the putty application has started. Formal evaluations comparing the putty application in real and in virtual, started in 2006, have been completed. Twelve subjects performed the putty application task in real and in virtual. Completion time and trajectories have been recorded, in order to analyze the hand movement under each of the two conditions. Results show that the movements are quite similar under each conditions, but a little bit slower in virtual (see [8] for more details).
Figure 2 represents the initial posture of a subject, the prototyping environment and the junction to be done.

6.3. Study of a New Pseudo-Haptic Solution

Participants: Andreas Pusch, Sabine Coquillart, Olivier Martin.

In 2007, i3D started the study of a new pseudo-haptic (see [2]) solution based on Augmented Reality see through HMDs. The purpose is to propose an interaction paradigm allowing to make a user fill haptic (forces) without an active force feedback device. This new approach is first studied in the context of force field simulation.

(a) (b)

*Figure 2. **Evaluation**. The putty application gesture is compared in two conditions: real or virtual prototyping configuration.*

6.4. Study of Hemispatial Neglect

Participants: Inna Tsirlin, Sabine Coquillart.

In 2007, i3D started a collaboration with Theophile Ohlmann and Eve Dupierrix from LPNC-Grenoble (Psychology and Neuro Cognition Laboratory) on the utilization of Virtual Reality (VR) for the study and rehabilitation of Hemispatial Neglect (HN). HN is a disabling disorder of spatial perception, which frequently occurs after right hemisphere stroke. An experimental setup based on the Stringed Haptic Workbench (see [7] has been developped and formal experiments are now being conducted.

6.5. Evaluation of Haptic guidance for the visuo-manual tracking of trajectories

Participants: Jérémy Bluteau, Sabine Coquillart.

Within the framework of the PRESENCE ISLE cluster, i3D started in 2007 a collaboration with Edouard Gentaz from LPNC-Grenoble (Psychology and Neuro Cognition Laboratory) and Yohan Payan from TIMC-Grenoble (Techniques for Biomedical Engineering and Complexity Management Laboratory) on the influence of haptic feedback on visuo-manual tracking of trajectories. This study will compare the visuo-manual tracking of trajectories with and without haptic feedback. Both spatial and temporal user performance will be considered.

In 2007, a first experiment has been conducted on handwriting ie. visuo-manual tracking of 2D trajectories. An experimental setup has been designed. It provides a realistic way of returning haptic feedback during the writing task. Psycho-experimental experiments were conducted in order to:

- assess the impact of level of guidance using proportional derivative controller (widely used in the literature).

- evaluate the respective benefits of two types of haptic guidance (haptic guidance in force and haptic guidance in position). This study is conducted on two types of 2D trajectories: Ellipses and Arabic/Japanese Letters.

The first set of experiments did not give any convincing results due to subjects variability. But the second set is giving interesting psycho-cognitive results.

7. Contracts and Grants with Industry

7.1. PSA Peugeot Citroën

PSA Peugeot Citroën and i3D have collaborated within a CIFRE contract.

7.2. INRIA

- **Bunraku Project**: Several collaborations are running with the Bunraku Project. As they all involve other partners, they are presented in the section on "National" or "International" actions.
- **Alcove and iPARLA Projects**: i3D is collaborating with both the Alcove project and the iPARLA projects within the framework of the Part@ge project. As this project involves other partners, it is presented in the section on "National" actions.

7.3. Regional

- i3D is collaborating with Theophile Ohmann from LPNC-Grenoble (Psychology and Neuro Cognition Laboratory) on possible VR applications for studying neural disorders. Funding through région Rhône-Alpes white projects.
- i3D is collaborating with Edouard Gentaz from LPNC-Grenoble and Yohan Payan from TIMC-Grenoble on the influence of haptics on manual trajectory drawings. Funding through Presence Cluster ISLE.

7.4. National

- **PERF-RV2** i3D is participating to the ANR platform "PERF-RV2" on Virtual Humans at Work. i3D is involved in researches on immersive haptic feedback for industrial applications.
- **PART@GE** i3D is participating to the ANR platform "PART@GE" on Collaborative Interaction. i3D is involved in researches on Local Collaboration with Augmented Reality.

7.5. International

- Collaboration with Sato-Koike research group from the Tokyo Institute of Technology. Collaborations on the Spidar system.
- Within the Sixth European Framework Programme, i3D together with Bunraku-Rennes is in the core group of the "Intuition" Virtual Reality Network of Excellence. i3D and Bunraku are the INRIA representatives.

8. Dissemination

8.1. Contribution to the Scientific Community

- Sabine Coquillart is a member of the EUROGRAPHICS Executive Committee and of the EUROGRAPHICS Working Group and Workshop board.
- Sabine Coquillart is a member of the Editorial Board of the "Computer Graphics Forum" journal.
- Sabine Coquillart is a member of the Editorial Board of the journal of "Virtual Reality and Broadcasting".
- Sabine Coquillart has been a member of the evaluation committee of the FP6- HAPTEX project.
- Sabine Coquillart has been a member of the Review Board of the book "Interactive Visualisation" by Springer Verlag, Advanced Information and Knowledge Processing series, 2007.
- Sabine Coquillart has co-chaired IEEE 3DUI'07, Charlotte, USA.
- Sabine Coquillart has co-chaired the Virtual Reality track of ISVC'07, Reno, USA.

8.2. Courses

- **Master 2R I3 University Paris-Sud-Orsay**, Sabine Coquillart is teaching in the "Virtual Environments and Advanced Interfaces" module.
- **Master 2R Ingénierie du Virtuel et Innovation, Laval**, Sabine Coquillart is teaching the 3D Interaction module.
- **ENSIMAG 3rd Year**, Course on Virtual Reality and Augmented Reality Systems, Sabine Coquillart and Jérémy Bluteau.

8.3. Conference and Workshop Committees, Invited Conferences

- Sabine Coquillart has been a member of the International Program Committee of the following conferences: IEEE 3DUI'07, Afrigraph'07, Cyberworlds'07, EG'07 short papers, IPT-EGVE'07, Grapp'07, Haptex'07, IADIS-CGV'07, ICAT'07, IHM'07, Intuition'07, ISVC'07, IEEE VR'07, ISVC'06, Laval'07, Pacific Graphics'07, SCCG'07, VRST'07, WSCG'07.
- Sabine Coquillart has reviewed articles for the following journals: ACM Transactions on Applied Perception, Presence journal.

8.4. Invited Conferences

- Sabine Coquillart, "A First Person Visuo-Haptic Environment", Invited conference at HCI'07, Beijing, China.

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Miscellaneous

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