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Activity Report 2011

Team VR4I

Virtual Reality for Improved Innovative Immersive Interaction

RESEARCH CENTER
Rennes - Bretagne-Atlantique

THEME
Interaction and Visualization

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Team VR4I

Keywords: Virtual Reality, Interaction, Simulation, 3D Modeling, Brain Computer Interface

1. Members

Research Scientist
Anatole Lécuyer [Senior Researcher Inria, HdR]

Faculty Members
Bruno Arnaldi [Professeur, INSA Rennes, HdR]
Quentin Avril [ATER, UNIV RENNES I]
Georges Dumont [Team leader, Associate Professor, ENS Cachan, HdR]
Thierry Duval [Associate Professor, UNIV RENNES I]
Valérie Gouranton [Associate Professor, INSA Rennes]
Maud Marchal [Associate Professor, INSA Rennes]
Charles Pontonnier [ATER, ENS Cachan]

Technical Staff
Marwan Badawi [IE Recherche]
Laurent Bonnet [IE Dev]
Alain Chauffaut [Research Engineer, INRIA]
Rémi Félix [IJD, INRIA]
Ronan Gaugne [Research Engineer, UNIV RENNES I]
Jozef Legény [IE Dev]
Florian Nouviale [IE Recherche, INSA Rennes]
Laurent Aguerreche [INSA Rennes]

PhD Students
Jérôme Ardouin [ESIEA]
Rozenn Bouville Berthelot [CIFRE, France Telecom]
Fabien Danieau [CIFRE, Technicolor]
Cédric Fleury [INSA Rennes]
Pierre Gaucher [CIFRE, Orange labs]
Laurent George [INRIA]
Loeïz Glondu [ENS Cachan]
Thi Thuong Huyen Nguyen [INRIA]
Andrès Saraos-Luna [INSA Rennes]
Anthony Talvas [INSA Rennes]
Léo Terziman [INRIA]
Gabriel Cirio [INRIA]
Zhaoguang Wang [ENS Cachan]

Post-Doctoral Fellows
Fernando Argelaguet Sanz [INRIA]
David Gomez Jauregui [INRIA]

2. Overall Objectives

2.1. Introduction

The VR4i Project Team inherits from the Bunraku Project Team and, before, from the Siames Project Team. Its purpose is the interaction of users with and through virtual worlds.

Virtual Reality can be defined as a set of models, methods and algorithms that allow one or several users to interact in a natural way with numerical data sensed by means of sensory channels. Virtual Reality is a scientific and technological domain exploiting computer science and sensory-motor devices in order to simulate in a virtual world the behavior of 3D entities in real time interaction with themselves and with one or more users in pseudo-natural immersion using multiple sensory channels.

Our main research activity is concerned with real-time simulation of complex dynamic systems, and we investigate real-time interaction between users and these systems. Our research topics address mechanical simulation, control of dynamic systems, real-time simulation, haptic interaction, multimodal interaction, collaborative interaction and modeling of virtual environments.

2.2. Highlights

2.2.1. A new Virtual Reality room

This year, our virtual reality room is renewed. It is composed of a new wall with four faces (front, two sides and ground), an ART tracker to track user position and a Yamaha sound rendering system linked to Genelec speakers with 10.2 format sound controlled by the user position. The dimension is 9.6 m wide, 2.9 m deep and 3.1 m high. This new equipment allowed us to become a key partner of the VISIONAIR european project which aims at creating a European infrastructure that should be a unique, visible and attractive entry towards high-level visualization facilities open to a wide set of research communities..

2.2.2. Runner-up award at IEEE 3DUI

Jérôme Ardouin, PhD student, obtained the 2nd best short paper award for his paper entitled "Design and Evaluation of Methods to Prevent Frame Cancellation in Real-Time Stereoscopic Rendering", presented at the IEEE 3DUI conference 2011 [10].

2.2.3. Two presentations at Siggraph E-Tech

The Joyman [33] has been demonstrated in Siggraph Asia while the Virtual Crepe Factory has been presented in Siggraph [14].

3. Scientific Foundations

3.1. Panorama

Our main concern is to allow real users to interact naturally within shared virtual environments as interaction can be the result of an individual interaction of one user with one object or a common interaction of several users on the same object. The long-term purpose of the project is to propose interaction modalities within virtual environments that bring **acting in Virtual Reality as natural as acting in reality**.

Complex physically based models have to be proposed to represent the virtual environment, complex multi-modal interaction models have to be proposed to represent natural activity and complex collaborative environments have to be proposed to ensure effective collaborative interactions.

The long term objectives of VR4i are:

- Improving the accuracy of the virtual environment representation for more interactivity and better perception of the environment;
- Improving the multi-modal interaction for more natural interactions and better perception of the activity;
- Improving the use of virtual environments for real activity and open to human science for evaluation and to engineering science for applications.

Thus, we propose three complementary research axes:

- Physical modeling and simulation of the environment
- Multimodal immersive interaction
- Collaborative work in Collaborative Virtual Environments (CVE)

3.2. Physical modeling and simulation

The first aspect is the modeling and the simulation of the virtual world that represents properly the physical behavior of the virtual world that sustains a natural interaction through the different devices. The main challenge is the search of the trade-off between accuracy and performance to allow effective manipulation, in interactive time, by the user. This trade-off is a key point while the user closes the interaction loop. Namely, the accuracy of the simulation drives the quality of the phenomenon to perceive and the performance drives the sensori-motor feelings of the user. Proposing new controlled algorithms for physical based simulation of the virtual world is certainly a key point for meeting this trade-off. We believe that the mechanical behavior of objects as to be more studied and to be as close as possible to their real behavior. The devices may act as a both way filter on the action and on the perception of the simulated world, but improving the representation of rigid objects submitted to contact, of deformable objects, of changing state object and of environments that include mixed rigid and deformable objects is needed in order to compute forces and positions that have a physical meaning. The interaction between tools and deformable objects is still a challenge in assembly applications and in medical applications. The activity of the user in interaction with the immersive environment will allow to provide method to qualify the quality of the environment and of the interaction by proposing a bio-mechanical user's Alter Ego. We believe that the analysis of the forces involved during an immersive activity will give us keys to design more acceptable environments. As the goal is to achieve more and more accurate simulation that will require more and more computation time, the coupling between physical modeling and related simulation algorithms is of first importance. Looking for genericity will ensure correct deployment on new advanced hardware platforms that we will use to ensure adapted performance. The main aim of this topic is to improve the simulation accuracy satisfying the simulation time constraints for improving the naturalness of interactions.

3.3. Multimodal immersive interaction

The second aspect concerns the design and evaluation of novel approaches for multimodal immersive interaction with virtual environments.

We aim at improving capabilities of selection and manipulation of virtual objects, as well as navigation in the virtual scene and control of the virtual application. We target a wide spectrum of sensory modalities and interfaces such as tangible devices, haptic interfaces (force-feedback, tactile feedback), visual interfaces (e.g., gaze tracking), locomotion and walking interfaces, and brain-computer interfaces. We consider this field as a strong scientific and technological challenge involving advanced user interfaces, but also as strongly related to user's perceptual experience. We promote a perception-based approach for multimodal interaction, based on collaborations with laboratories of the Perception and Neuroscience research community.

The introduction of a third dimension when interacting with a virtual environment makes inappropriate most of the classical techniques used successfully in the field of 2D interaction with desktop computers up to now. Thus, it becomes successfully used to design and evaluate new paradigms specifically oriented towards interaction within 3D virtual environments.

We aim at improving the immersion of VR users by offering them natural ways for navigation, interaction and application control, as these are the three main tasks within 3D virtual environments. Here we consider interactions as multimodal interactions, as described in the previous section. We also want to make the users forget their physical environment in benefit of the virtual environment that surrounds them and contribute to improve the feeling of immersion and of presence. To achieve this goal, we must ensure that users can avoid collisions with their surrounding real environment (the screens of the rendering system, the walls of the room) and can avoid lost of interaction tracking (keeping the user within the range of the physical interaction devices). To do that, we propose to take into account the surrounding real physical environment of the user and to include it in the virtual environment through a virtual representation. This explicit model of the real environment of the users will help users to forget it: throughout this model, the user will be aware (with visual, auditive or haptic feedback) of these virtual objects when he comes near their boundaries. We also have to investigate which physical limitations are the most important ones to perceive, and what are the best ways to make the users aware of their physical limitations.

3.4. Collaborative work in CVE's

The third aspect is to propose Collaborative Virtual Environments for several local or distant users. In these environments, distant experts could share their expertise for project review, for collaborative design or for analysis of data resulting from scientific computations in HPC context. Sharing the virtual environment is certainly a key point that leads to propose new software architectures ensuring the data distribution and the synchronization of the users.

In terms of interaction, new multi-modal interaction metaphors have to be proposed to tackle with the awareness of other users? activity. Here it is important to see a virtual representation of the other users, of their activity, and of the range of their action field, in order to better understand both their potential and their limitation for collaboration: what they can see, what they can reach, what their interaction tools are and which possibilities they offer.

Simultaneous collaborative interactions upon the same data through local representations of these data should be tackled by new generic algorithms dedicated to consistency management. Some solutions have to be proposed for distant collaboration, where it is not possible any more to share tangible devices to synchronize co-manipulation: we should offer some new haptic rendering to enforce users' coordination. Using physics engines for realistic interaction with virtual objects is also a challenge if we want to offer low latency feedback to the users. Indeed, the classical centralized approach for physics engines is not able to offer fast feedback to distant users, so this approach must be improved.

4. Application Domains

4.1. Panorama

The research topics of the VR4i team are related to applications of the industrial, training and education domains.

The applications to the industrial domain are very promising. For instance, the PSA Automotive Design Network, which is a new design center, groups all the tools used for automotive design, from classical CAD systems to Virtual Reality applications. The coupling of virtual reality and simulation algorithms is a key point and is the core of VR4i simulation activities. Major issues in which industrials are strongly involved are focussing on collaborative tasks between multiple users in digital mockups (FUI EMOA 7.1.1) and for scientific visualization (ANR Part@ge and ANR Collaviz 7.1.3), tackling the challenging problem of training in Virtual Reality by providing interactive scenario languages with realists actions and reactions within the environment (GVT Project, ANR Corvette 7.1.4 and FUI SIFORAS 7.1.2). In this context, we are tackling the problem of using Virtual Reality environments for improving the ergonomics of workstations. Collaborative work is now a hot issue for facing the question of sharing expertise of distant experts for project review, for collaborative design or for analysis of data resulting from scientific computations (FP7-Infra VISIONAIR project 7.2.1) where we propose new software architectures ensuring the data distribution and the synchronization of the users (Figure 1).

5. Software

5.1. OpenMASK: Open-Source platform for Virtual Reality

Participants: Alain Chauffaut [contact], Ronan Gaugne [contact], Georges Dumont, Thierry Duval, Laurent Aguerreche, Florian Nouviale.

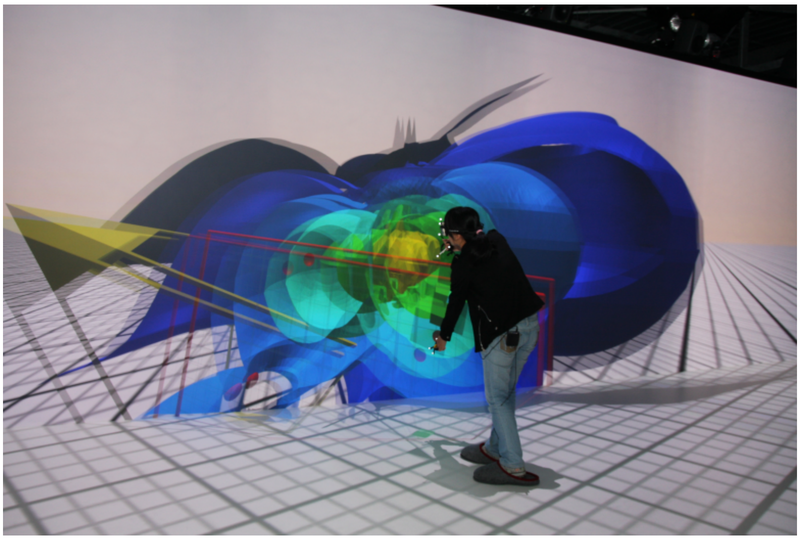

Figure 1. Collaboration between VR4i team in Immersia Room 6.4 and UCL on shared analysis of earthquake simulation within VISIONAIR project 7.2.1

OPENMASK (Open Modular Animation and Simulation Kit) is a federative platform for research developments in the VR4i team. Technology transfer is a significant goal of our team so this platform is available as OpenSource software (http://www.openmask.org).

OpenMASK is a C++ software platform for the development and execution of modular applications in the fields of animation, simulation and virtual reality. The main unit of modularity is the simulated object (OSO) which can be viewed as frequential or reactive motors. It can be used to describe the behavior or motion control of a virtual object as well as input devices control like haptic interfaces. Two OSO communicate with synchronous data flows or with asynchronous events.

We provide Model Driven Tools to help building OpenMASK applications without tedious and repeated coding and to improve reusability. Within Eclipse environment we offer an editor and a C++ code generator to design and build objects classes. The current OpenMASK 4.2 release is now based on MPI for distribution service, Ogre3D for visualisation service. One can benefit of new interaction tools for local or remote collaborative applications.

5.2. GVT : Generic Virtual Training

Participants: Bruno Arnaldi, Valérie Gouranton [contact], Florian Nouviale, Andrès Saraos-Luna.

The aim of GVT software is to offer personalized VR training sessions for industrial equipments. The most important features are the human and equipment security in the VR training (in opposition to the real training), the optimization of the learning process, the creation of dedicated scenarios, multiple hardware configurations: laptop computer, immersion room, distribution on network, etc.

The actual kernel of GVT platform is divided into two main elements that rely on innovative models we have proposed: LORA and STORM models.

- A Behavior Engine. The virtual world is composed of behavioral objects modeled with STORM (Simulation and Training Object-Relation Model).

- A Scenario Engine. This engine is used to determine the next steps of the procedure for a trainee, and its state evolves as the trainee achieves actions. The scenario is written in the LORA language (Language for Object-Relation Application).

A commercialized version of GVT, which includes a pedagogical engine developed in CERV laboratory, proposes training on individual procedures. A prototype is also available that enables users to train on collaborative procedures with one another or with virtual humans.

In the ANR Corvette 7.1.4 and in the FUI SIFORAS 7.1.2, new features of GVT Software are proposed.

5.3. OpenViBE Software

Participants: Anatole Lécuyer [contact], Laurent Bonnet, Jozef Legény, Yann Renard.

OpenViBE is a free and open-source software devoted to the design, test and use of **Brain-Computer Interfaces**.

The OpenViBE platform consists of a set of software modules that can be integrated easily and efficiently to design BCI applications. Key features of the platform are its modularity, its high-performance, its portability, its multiple-users facilities and its connection with high-end/VR displays. The "designer" of the platform enables to build complete scenarios based on existing software modules using a dedicated graphical language and a simple Graphical User Interface (GUI).

This software is available on the INRIA Forge under the terms of the LGPL-V2 licence, and it was officially released in June 2009. Since then, the OpenViBE software has already been downloaded more than 300 time, and it is used by numerous entities worldwide.

Our first international tutorial about OpenViBE was held at the International BCI Meeting in June 2010 (Monterey, US), with around 30 participants.

More information, downloads, tutorials, documentation, videos are available on OpenViBE website : http://openvibe.inria.fr

6. New Results

6.1. Physical modelling and simulation

6.1.1. Modal analysis for haptic manipulation of deformable models

Participants: Zhaoguang Wang, Georges Dumont [contact].

Real-time interaction between designer and deformable mock-up in VR (Virtual Reality) environment is a natural and promising manner to evaluate designing feasibility. Using finite element method (FEM) for solving this issue leads to high fidelity simulation but to simulation rates that do not meet the requirements (1000Hz) of real time haptic applications. We have proposed a two-stage method based on linear modal analysis. In this method, different modal subspaces, related to use scenarios, are pre-computed offline. These data are then combined online with respect to a simulation division scheme to obtain real time deformations of the parts with respect to the modal response. Two main features are developed in the method. First, we apply an adapted meshing method during the pre-computation process. This method allows to automatically switch between different modal subspaces depending on the interaction region. Second, we divide the real time deformation computation into two separate modules by extracting sub-matrixes from the pre-computed modal matrixes. This separates the haptic simulation loop from the whole deformation computation an thus preserves the haptic response. This work was presented in WINVR 2011 conference [31] is accepted for publication [8] and was the subject of the PhD Thesis of Zhaoguang Wang, that was defended in june 2011 [3].

6.1.2. Real-time mechanical simulation of brittle fracture

Participants: Loeïz Glondu, Georges Dumont [contact], Maud Marchal [contact].

Simulating brittle fracture of stiff bodies is now commonplace in computer graphics. However, simulating the deformations undergone by the bodies in a realistic way remains computationaly expensive. Thus, physically-based simulation of brittle fracture in real-time is still challenging for interactive applications. We are currently working on a new physically-based approach for simulating realistic brittle fracture in real-time. Our method is composed of two main original parts: (1) a fracture initiation model based on modal analysis and a new contact force model and (2) a fracture propagation model based on a novel physically-based algorithm (Figure 2). First results of this method have been published in [32].

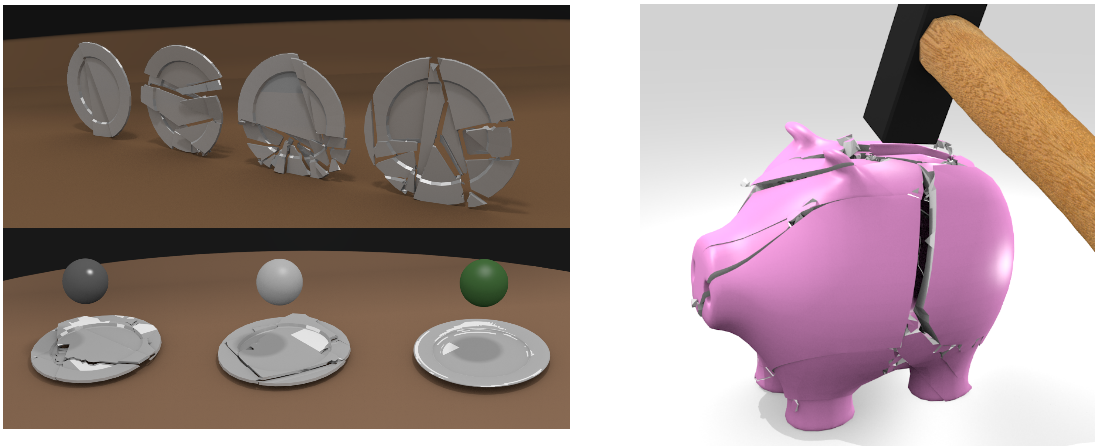

Figure 2. Different steps of the simulation (top-left), Different fracture patterns for different stiffness of the impactor (bottom-left), Haptic control of a hammer (Right)

Adding physical properties to objects within a virtual world can not generally be handled in real-time during a simulation. For that reason, it is still difficult nowadays to physically simulate fragments of fractured objects or parts of teared/cut objects. We have proposed a method for handling the real-time physical simulations of arbitrary objects that are represented by their surface mesh. Our method is based on a pre-computed shape database in which physical data are stored for a wide variety of objects. When a query object needs to be physically simulated in the virtual world, a similarity search is performed inside the database and the associated physical data are extracted. Our approach proposes to compare three different similarity search methods that fit with our real-time needs. Our results show that our approach has a great potential for the physical simulation of arbitrary objects in interactive applications. These results have been published in the Eurographics International Workshop on Virtual Reality Interaction and Physical Simulation (Vriphys) [21].

6.1.3. Collision detection in large scale environments with High Performance Computing

Participants: Quentin Avril, Valérie Gouranton [contact], Bruno Arnaldi.

Virtual reality environments are becoming increasingly large and complex and real-time interaction level is becoming difficult to stably insure. Indeed, because of their complexity, detailed geometry and specific physical properties, these large scale environments create a critical computational bottleneck on physical algorithms. Our work focused on the first step of the physical process : the collision detection. These algorithms can sometimes have a quadratic complexity. Solving and simplifying the collision detection problem is integral to alleviating this bottleneck. Hardware architectures have undergone extensive changes in the last few years that have opened new ways to relieve this computational bottleneck. Multiple processor cores offer the ability to execute algorithms in parallel on one single processor. At the same time, graphics cards have gone from being a simple graphical display device to a supercomputer. These supercomputers now enjoy attention from a specialized community dealing solely with physical simulation. To perform large scale simulations and remain generic on the runtime architecture, we proposed unified and adaptive mapping models between collision detection algorithms and the runtime architecture using multi-core and multi-GPU architectures. We have developed innovative and effective solutions to significantly reduce the computation time in large scale environments while ensuring the stability and reproducibility of results (cf. Figure 3). We proposed a new pipeline of collision detection with a granularity of parallelism on multicore processors or multi-GPU platforms[11]. It enables simultaneous execution of different stages of the pipeline and a parallel internal to each of these steps. This was the subject of the PhD thesis of Quentin Avril [1].

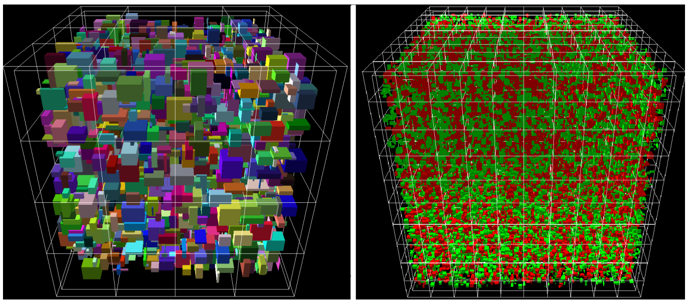

*Figure 3. Simulation of moving objects with varying size. Our approach enables to perform the Broad phase step in interactive time using optimized spatial brute force algorithm. (**Left: 2.000 Objects** - **Right: 50.000 Objects**.*

6.1.4. Assessment of inverse dynamics method for muscle activity analysis

Participants: Georges Dumont [contact], Charles Pontonnier.

The use of virtual reality tools for ergonomics applications is a very important challenge. In order to improve the design of workstations, an estimation of the muscle forces involved in the work tasks has to be done. Several methods can lead to these muscle forces. In this study, we try to assess the level of confidence for results obtained with an inverse dynamics method from real captured work tasks. The chosen tasks are meat cutting tasks, well known to be highly correlated to musculoskeletal troubles appearance in the slaughter industry.

The experimental protocol consists in recording three main data during meat cutting tasks, and analyse their variation when some of the workstation design parameters are changing [26].

1. External (cutting)force data : for this purpose, a 3D instrumented knife has been designed in order to record the force applied by the subject during the task;
2. Motion Capture data : for this purpose, we use a motion capture system with active markers (Visualeyez II, Phoenix Technologies, Canada);
3. EMG data : several muscle activities are recorded using electromyographic electrodes, in order to compare these activities to the ones obtained from the inverse dynamics method.

Then the motion is replayed in the AnyBody modeling system (AnyBody, Aalborg, Denmark) in order to obtain muscle forces generated during the motion. A trend comparison is then done [27], comparing recorded and computed muscle activations. Results show that most of the computed activations are qualitatively close from the recorded ones (similar shapes and peaks), but quantitative comparison leads to major differences between recorded and computed activations (the trend followed by the recorded activations in regard of a workstation design parameter, such as the table height, is not obtained with the computed activations). We currently explore those results to see if the fact that co-contraction of single joints muscles is badly estimated by classical inverse dynamics method can be a reason of this issue. We also work on the co-contration simulation in order to improve the results [28].

This work has been done in collaboration with the Center for Sensory-motor Interaction (SMI, Aalborg University, Aalborg, Denmark), particularly Mark de Zee (Associate Professor) and Pascal Madeleine (Professor). Charles Pontonnier spent a 9 months post-doctoral fellowship at SMI from December 2010 to August 2011.

6.2. Multimodal immersive interaction

6.2.1. Brain-Computer Interaction based mental state

Participants: Anatole Lécuyer [contact], Bruno Arnaldi, Laurent George, Yann Renard.

In [20], presented at IEEE EMBS conference, we have explored the use of electrical biosignals measured on scalp and corresponding to mental relaxation and concentration tasks in order to control an object in a video game as illustrated in Figure 4. To evaluate the requirements of such a system in terms of sensors and signal processing we compared two designs. The first one used only one scalp electroencephalographic (EEG) electrode and the power in the alpha frequency band. The second one used sixteen scalp EEG electrodes and machine learning methods. The role of muscular activity was also evaluated using five electrodes positioned on the face and the neck.

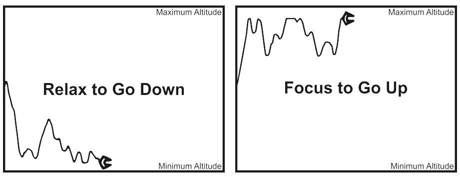

Figure 4. Video game application with feedback during the two different phases (relaxation and concentration for going respectively Down and Up)

Results show that the first design enabled 70% of the participants to successfully control the game, whereas 100% of the participants managed to do it with the second design based on machine learning. Subjective questionnaires confirm these results: users globally felt to have control in both designs, with an increased feeling of control in the second one. Offline analysis of face and neck muscle activity shows that this activity could also be used to distinguish between relaxation and concentration tasks. Results suggest that the combination of muscular and brain activity could improve performance of this kind of system. They also suggest that muscular activity has probably been recorded by EEG electrodes.

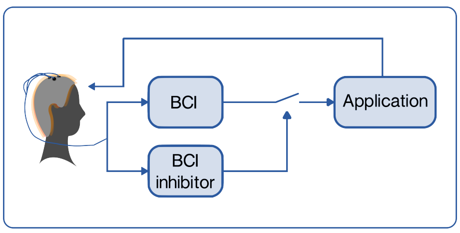

Figure 5. BCI inhibitor concept

In [19],presented in the 5th International Brain-Computer Interface Conference, we introduce the concept of Brain-Computer Interface (BCI) inhibitor, which is meant to standby the BCI until the user is ready, in order to improve the overall performance and usability of the system. BCI inhibitor can be defined as a system that monitors user's state and inhibits BCI interaction until specific requirements (e.g. brain activity pattern, user attention level) are met.

We conducted a pilot study to evaluate a hybrid BCI composed of a classic synchronous BCI system based on motor imagery and a BCI inhibitor (Figure 5). The BCI inhibitor initiates the control period of the BCI when requirements in terms of brain activity are reached (i.e. stability in the beta band).

Preliminary results with four participants suggest that BCI inhibitor system can improve BCI performance.

6.2.2. Navigating in virtual worlds using a Brain-Computer Interface

Participants: Anatole Lécuyer [contact], Jozef Legény.

When a person looks at a light flickering at a constant frequency, we can observe a corresponding electrical signal in their EEG. This phenomenon, located in the occipital area of the brain is called Steady-State Visual-Evoked Potential (SSVEP).

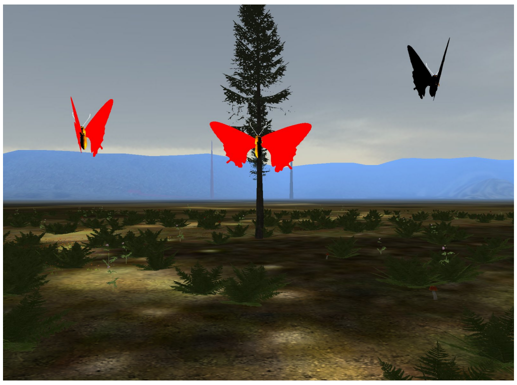

Figure 6. Animated flickering butterflies being used as stimulators for an SSVEP BCI

In [7] we introduce a novel paradigm for a controller using SSVEP. Compared to the state-of-the-art implementations which use static flickering targets, we have used animated and moving objects. In our example applications we have used animated butterflies flying in front of the user as show in Figure 6. A study has revealed that, at the cost of decreased performance, this controller increases the personal feeling of presence.

These results show that integrating visual SSVEP stimulation into the environment is possible and that further study is necessary in order to improve the performance of the system.

6.2.3. Walking-in-place in virtual environments

Participants: Anatole Lécuyer [contact], Maud Marchal [contact], Léo Terziman, Bruno Arnaldi, Franck Multon.

The Walking-In-Place interaction technique was introduced to navigate infinitely in 3D virtual worlds by walking in place in the real world. The technique has been initially developed for users standing in immersive setups and was built upon sophisticated visual displays and tracking equipments. We have proposed to revisit the whole pipeline of the Walking-In-Place technique to match a larger set of configurations and apply it notably to the context of desktop Virtual Reality. With our novel "Shake-Your-Head" technique, the user has the possibility to sit down, and to use small screens and standard input devices for tracking. The locomotion simulation can compute various motions such as turning, jumping and crawling, using as sole input the head movements of the user (Figure 7).

Figure 7. Shake-Your-Head and walk in place

In a second study [29] we analyzed and compared the trajectories made in a Virtual Environment with two different navigation techniques. The first is a standard joystick technique and the second is the Walking-In-Place (WIP) technique. We proposed a spatial and temporal analysis of the trajectories produced with both techniques during a virtual slalom task. We found that trajectories and users' behaviors are very different across the two conditions. Our results notably showed that with the WIP technique the users turned more often and navigated more sequentially, i.e. waited to cross obstacles before changing their direction. However, the users were also able to modulate their speed more precisely with the WIP. These results could be used to optimize the design and future implementations of WIP techniques. Our analysis could also become the basis of a future framework to compare other navigation techniques.

6.2.4. Improved interactive stereoscopic rendering : SCVC

Participants: Jérôme Ardouin, Anatole Lécuyer [contact], Maud Marchal [contact], Eric Marchand.

Frame cancellation comes from the conflict between two depth cues: stereo disparity and occlusion with the screen border. When this conflict occurs, the user suffers from poor depth perception of the scene. It also leads to uncomfortable viewing and eyestrain due to problems in fusing left and right images.

In [10], presented at the IEEE 3DUI conference, we propose a novel method to avoid frame cancellation in real-time stereoscopic rendering. To solve the disparity/frame occlusion conflict, we propose rendering only the part of the viewing volume that is free of conflict by using clipping methods available in standard real-time 3D APIs. This volume is called the Stereo Compatible Volume (SCV) and the method is named Stereo Compatible Volume Clipping (SCVC).

Black Bands, a proven method initially designed for stereoscopic movies is also implemented to conduct an evaluation. Twenty two people were asked to answer open questions and to score criteria for SCVC, Black Bands and a Control method with no specific treatment. Results show that subjective preference and user's depth perception near screen edge seem improved by SCVC, and that Black Bands did not achieve the performance we expected.

At a time when stereoscopic capable hardware is available from the mass consumer market, the disparity/frame occlusion conflict in stereoscopic rendering will become more noticeable. SCVC could be a solution to recommend. SCVC's simplicity of implementation makes the method able to target a wide range of rendering software from VR application to game engine.

6.2.5. Six degrees-of-freedom haptic interaction

Participants: Anatole Lécuyer [contact], Maud Marchal [contact], Gabriel Cirio.

Haptic interaction with virtual objects is a major concern in the virtual reality field. There are many physically-based efficient models that enable the simulation of a specific type of media, e.g. fluid volumes, deformable and rigid bodies. However, combining these often heterogeneous algorithms in the same virtual world in order to simulate and interact with different types of media can be a complex task.

In [5], published at IEEE Transactions on visualization and Computer Graphics, we propose a novel approach that allows real-time 6 Degrees of Freedom (DoF) haptic interaction with fluids of variable viscosity. Our haptic rendering technique, based on a Smoothed-Particle Hydrodynamics (SPH) physical model, provides a realistic haptic feedback through physically-based forces. 6DoF haptic interaction with fluids is made possible thanks to a new coupling scheme and a unified particle model, allowing the use of arbitrary-shaped rigid bodies. Particularly, fluid containers can be created to hold fluid and hence transmit to the user force feedback coming from fluid stirring, pouring, shaking or scooping. We evaluate and illustrate the main features of our approach through different scenarios, highlighting the 6DoF haptic feedback and the use of containers.

The Virtual Crepe Factory [14] illustrates this approach for 6DoF haptic interaction with fluids. It showcases a 2-handed interactive haptic scenario: a recipe consisting in using different types of fluid in order to make a special pancake also known as "crepe". The scenario (Figure 8) guides the user through all the steps required to prepare a crepe: from the stirring and pouring of the dough to the spreading of different toppings, without forgetting the challenging flipping of the crepe. With the Virtual Crepe Factory, users can experience for the first time 6DoF haptic interactions with fluids of varying viscosity.

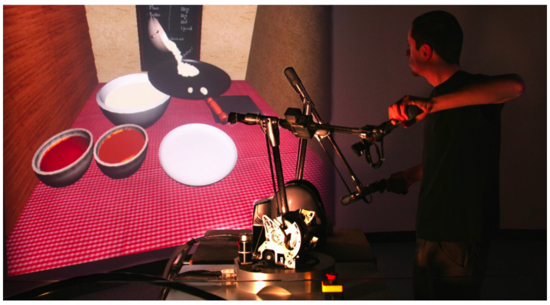

Figure 8. A complete use-case of our approach: a virtual crepe preparation simulator. The user manipulates a bowl (left hand, left haptic device) and a pan (right hand, right haptic device).

In [15], presented at the IEEE Virtual Reality Conference, we propose the first haptic rendering technique for the simulation and the interaction with multistate (Figure 9) media, namely fluids, deformable bodies and rigid bodies, in real-time and with 6DoF haptic feedback. The shared physical model (SPH) for all three types of media avoids the complexity of dealing with different algorithms and their coupling. We achieve high update rates while simulating a physically-based virtual world governed by fluid and elasticity theories, and show how to render interaction forces and torques through a 6DoF haptic device.

6.2.6. Joyman: a human-scale joystick for navigating in virtual worlds

Participants: Maud Marchal [contact], Anatole Lécuyer, Julien Pettré.

We have proposed a novel interface called Joyman (Figure 10), designed for immersive locomotion in virtual environments. Whereas many previous interfaces preserve or stimulate the users proprioception, the Joyman aims at preserving equilibrioception in order to improve the feeling of immersion during virtual locomotion

Figure 9. 6DoF haptic interaction in a medical scenario. Fluid blood pours from the deformable intestine when the user penetrates it with the rigid probe.

tasks. The proposed interface is based on the metaphor of a human-scale joystick. The device has a simple mechanical design that allows a user to indicate his virtual navigation intentions by leaning accordingly. We have also proposed a control law inspired by the biomechanics of the human locomotion to transform the measured leaning angle into a walking direction and speed - i.e., a virtual velocity vector. A preliminary evaluation was conducted in order to evaluate the advantages and drawbacks of the proposed interface and to better draw the future expectations of such a device.

This principle of this new interface was published at international conference IEEE 3DUI [25] and a patent has been filed for the interface. A demonstration of this interface was proposed at ACM Siggraph Asia Emerging Technologies [33].

Figure 10. Prototype of the "Joyman"

6.2.7. Interactions within 3D virtual universes

Participants: Thierry Duval [contact], Valérie Gouranton [contact], Bruno Arnaldi, Laurent Aguerreche, Cédric Fleury, Thi Thuong Huyen Nguyen.

Our work focuses upon new formalisms for 3D interactions in virtual environments, to define what an interactive object is, what an interaction tool is, and how these two kinds of objects can communicate together. We also propose virtual reality patterns to combine navigation with interaction in immersive virtual environments.

We have worked upon generic interaction tools for collaboration, based on multi-point interaction. In that context we have studied the efficiency of one instance of our Reconfigurable Tangible Device, the RTD-3, for collaborative manipulation of 3D objects compared to state of the art metaphors [9]. We have setup an experiment for collaborative distant co-manipulation (figure 1) of a clipping plane inside for remotely analyzing 3D scientific data issued from an earthquake simulation .

6.3. Collaborative work in CVE's

6.3.1. The immersive interactive virtual cabin (IIVC)

Participants: Thierry Duval [contact], Valérie Gouranton [contact], Alain Chauffaut, Bruno Arnaldi, Cédric Fleury.

We are still improving the architecture of our Immersive Interactive Virtual Cabin to improve the user's immersion with all his real tools and so to make the design and the use of 3D interaction techniques easier, and to make possible to use them in various contexts, either for different kinds of applications, or with different kinds of physical input devices.

The IIVC is now fully implemented in our two VR platforms: OpenMASK 5.1 and Collaviz 7.1.3.

6.3.2. Generic architecture for 3D interoperability

Participants: Thierry Duval [contact], Valérie Gouranton, Cédric Fleury, Rozenn Bouville Berthelot, Bruno Arnaldi.

Our goal is to allow software developers to build 3D interactive and collaborative environments without bothering with the 3D graphics API they are using. This work is the achievement of the IIVC software architecture. We have proposed PAC-C3D (Figure 11), a new software architectural model for collaborative 3D applications, in order to provide a higher abstraction for designing 3D virtual objects, and in order to provide interoperability, making it possible to share a virtual universe between heterogeneous 3D viewers [17], [16].

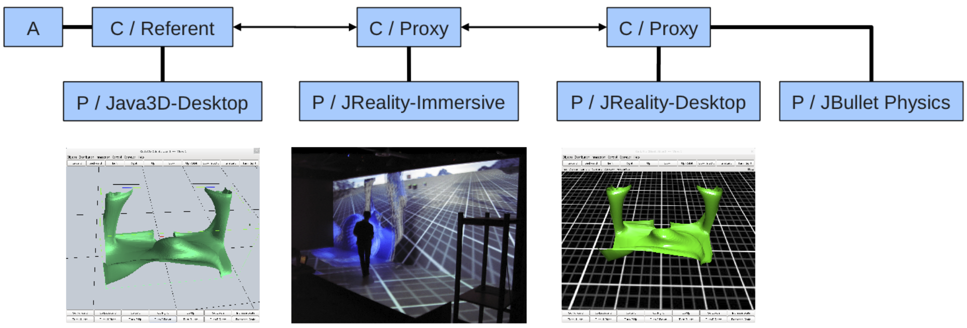

Figure 11. The PAC-C3D software architectural model makes interoperability possible between heterogeneous 3D viewers

We also study how to offer interoperability between virtual objects that are loaded in the same virtual environment but that are described using different formats. This is why we have proposed a generic architecture for enabling interoperability between 3D formats (Figure 12), the Scene Graph Adapter [12]. Our SGA is now able to allow events coming from a 3D format to act upon data provided in another format, such as X3D events operating on Collada data [4].

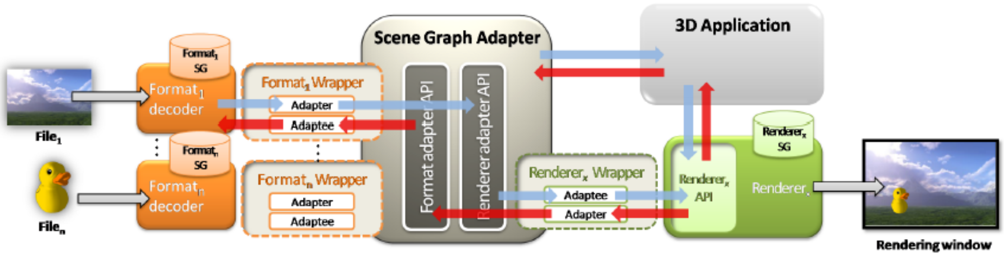

Figure 12. Our architecture allows the loading of any 3D graphics format simultaneously in any available rendering engine. The scene graph adapter is an interface that adapts a scene graph (SG) of a given format into a renderer scene graph and which also allows the rendering part to request this scene graph.

6.4. Immersia Virtual Reality room

Participants: Georges Dumont [contact], Alain Chauffaut [contact], Ronan Gaugne [contact], Rémi Félix, Marwan Badawi, Bruno Arnaldi, Thierry Duval, Valérie Gouranton.

The team was the first in France to host a large-scale immersive virtual reality equipment known as Immersia. This platform, with full visual and sound immersion, is dedicated to real-time, multimodal (vision, sound, haptic, BCI) and immersive interaction. The Immersia platform is a key node of the european transnational VISIONAIR infrastructure and will be open in 2012 to the access of foreign research projects. It will accommodate experiments using interactive and collaborative virtual-reality applications that have multiple local or remote users. Our new wall has four faces: a front, two sides and a ground. Dimensions are 9.6 m wide, 2.9 m deep and 3.1 m hight. The visual reproduction system combines eight Barco Galaxy NW12 projectors and three Barco Galaxy 7+ projectors. Visual images from Barco projectors are rendered on glass screens. They are adjusted for the user's position, and this, together with their high resolution and homogeneous coloring, make them very realistic. The ART localization system, constituted of 16 ART-track2 cameras, enables real objects to be located within the U-shape. Sound rendering is provided by a Yamaha processor, linked either to Genelec speakers with 10.2 format sound or Beyer Dynamic headsets with 5.1 virtual format sound, controlled by the user's position.

7. Partnerships and Cooperations

7.1. National Initiatives

7.1.1. EMOA project

Participants: Georges Dumont [contact], Zhaoguang Wang.

EMOA project [2007-mid2011] of the competitiveness cluster ID4CAR is funded by The french ministry of industry. This project involves seven industrial partners (PSA as project manager, ARCELOR, CETIM, ESI Group, Gruau, Cerizay, E. Leclerc) and five academic partners (CROMEP, UBS, ENS Cachan, IrCCyN, IRISA-ENS Cachan). The goal of this project is to improve the quality of stamped parts of car bodies. We are involved in the work package 11 with the purpose of proposing quality validation methods based on virtual reality project reviews. This could allow the industrial partners to verify and to improve the stamping tools design. The aim of Zhaoguang Wang PHD thesis [3] was to propose models and simulation methods for computation of the parts deformation in interactive time compatible with haptic manipulation by the user. This method is based on modal analysis and mode recombination.

7.1.2. FUI SIFORAS

Participants: Valérie Gouranton [contact], Bruno Arnaldi [contact].

SIFORAS (Simulation for training and assistance), based on GVT 5.2, aims to propose Instructional Systems Design to answer the new objectives of training (Intelligent Tutorial System, mobility, augmented reality, high productivity).

SIFORAS involves Academic partners 4 (INSA Rennes, ENIB, CEA-List, ENISE) and 9 Industrial partners (Nexter Training, Delta CAD, Virtualys, DAF Conseils, Nexter Systems, DCNS, Renault, SNCF, Alstom).

In this project, INSA Rennes-VR4i aims ensuring consistency with respect to CORVETTE project (see section 7.1.4) in particular for the global architecture based on STORM and LORA models.

7.1.3. ANR Collaviz

Participants: Thierry Duval [contact], Valérie Gouranton [contact], Cédric Fleury, Laurent Aguerreche.

Collaviz is an innovative multi-domain remote collaborative platform (project ANR-08-COSI-003-11 funded by the french national research agency) for the simulation-based design applications.

Collaviz involves 6 Academic partners (ECP, EGID, INPT, INSA Rennes, LIRIS, Scilab) and 11 Industrial partners (Artenum, BRGM, Distene, EDF, Faurecia, Medit, MCLP Consulting, NECS, Oxalya, TechViz, Teratec)

The major value brought by Collaviz to the scientific and industrial community is to make remote analysis and collaboration easily available and scalable. Web-based technologies, on the top of shared high-performance computing and visualization centers, will permit researchers and engineers handling very large data sets, including 3D data models, by using a single workstation, wherever in the world. Just a "standard" internet connexion will be needed. The classical approach is not adapted anymore: simulation-based design applications tend to generate Terabytes and even Petabytes of data.

We are leading the WP4 about Collaborative Virtual Environments and Techniques, whose aim is to manage the 3D collaborative interactions of the users. During 2011 we contributed to the second Collaviz prototype by providing the final version of a collaboration service, and by building upon it new collaborative interaction metaphors. We also improved the Collaviz software architecture in order to provide interoperability, making it possible to share a virtual universe between heterogeneous 3D viewers.

Scientific contributions are presented in [17], [16].

We have also deployed the Collaviz framework between London (in the immersive room of the University College of London) and Rennes (in our Immersia room). We setup an experiment of collaborative manipulation of a clipping plane inside 3D scientific data within VISIONAIR project. This first real deployment of Collaviz is a success, it has allowed efficient co-manipulation of a shared 3D object between two really distant users.

7.1.4. ANR Corvette

Participants: Bruno Arnaldi [contact], Valérie Gouranton [contact], Florian Nouviale, Andrès Saraos-Luna.

Corvette (COllaboRative Virtual Environment Technical Training and Experiment) aims to propose a set of scientific innovations in industrial training domain (maintenance, complex procedures, security, diagnostic, ...) exploiting virtual reality technologies. This project has several scientific axes : collaborative work, virtual human, communication and evaluation.

Corvette involves 3 Academic partners (INSA Rennes, ENIB, CEA-List) and 3 Industrial partners (Nexter Training, Virtualys, Golaem). We (INSA Rennes) are leading the ANR Corvette.

The project seeks to put in synergy a number of scientific axes:

- Collaborative work that can handle representative complex scenarios of industrial training
- Virtual Human for its ability to embody the user as an avatar and acting as a collaborator during training
- Natural communication between users and virtual humans for task-oriented dialogues
- Methodology in cognitive psychiology for the assement of the effectiveness of the collaboration of users and virtual humans to perform complex cooperative tasks in a virtual environment.

Some directions are emerging to address the projects goals. We define the specifications to achieve the creation of our new architecture for training applications. We also study the states of the art in the fields : collaborative work, virtual human, communication, scenarios. We specify the two industrial scenarios of the project. We propose an architecture that permits the solutions of the main breakthroughs to be integrated.

For further information: http://corvette.irisa.fr/

7.1.5. ANR Acoustic

Participant: Maud Marchal [contact].

The main objective of the project ACouStiC is to develop an innovative strategy based on models for helping decision-making process during surgical planning in Deep Brain Stimulation. Models rely on different levels involved in the decision-making process; namely multimodal images, information, and knowledge. The project aims at developing methods for 1) building generic and patient specific models and 2) automatically computing optimal electrodes trajectories from these models taking into account possible simulated deformations occurring during surgery. VR4i is involved in the project with Shaman INRIA project-team and aims at providing models of deformations of the cerebral structures and electrodes for the surgical planning. The objective is to propose a biomechanical approach to model the brain and electrode deformations and also their mutual interaction.

7.1.6. ANR Open-ViBE2

Participants: Laurent Bonnet, Alain Chauffaut, Thierry Duval, Laurent George, Anatole Lécuyer [contact], Jozef Legény.

OpenViBE2 is a 3-year project funded by the French National Agency for Research. The objective of OpenViBE2 is to propose a radical shift of perspective about the use of Brain-Computer Interfaces (BCI). First, in OpenViBE2 we consider the possibility to merge a BCI with traditional peripherals such as joysticks, mice and other devices, all being possibly used simultaneously in a virtual environment. Therefore, BCI is not seen as a replacement but as a complement of classical HCI. Second, we aim at monitoring brain cognitive functions and mental states of the user in order to adapt, in real-time and in an automated fashion, the interaction protocol as well as the content of the remote/virtual environment (VE).

One major strength of OpenViBE2 consortium relies on the fact that four partners were already involved in the previous ANR project OpenViBE1 (2005-2009): INRIA, INSERM, GIPSA-LAB, CEA. In addition, six partners have joined OpenViBE2 to bring their complementary expertise required by the scope of our proposal: CHART, CLARTE, UBISOFT, BLACK SHEEP, and KYLOTONN.

In parallel, the OpenViBE2 consortium contributes to the free and open-source software OpenViBE, which is devoted to the design, test and use of Brain-Computer Interfaces (see Section 5.3).

7.1.7. BRAINVOX

Participants: Anatole Lécuyer [contact], Jozef Legény [contact].

The BRAINVOX project is a project funded by Brittany region in the frame of the CREATE call. It is a 4 year-project (2008-2012), on the topic of Brain-Computer Interfaces.

The "blue-sky" vision of the BrainVox project is a "mental language", more elaborated, and richer, for BCI applications. We want to study the possibility for a single user to exploit various mental activities, in order to achieve more varied operations in the BCI-based application within novel hybrid BCI schemes. In the end, this novel mental language would enable a practice of BCI richer and more intuitive, with more potential actions in the real world. This should improve the spreading of BCI technologies in numerous applications such as multimedia and video games, but also assistance to disabled people.

7.1.8. NIEVE

Participant: Anatole Lécuyer [contact].

The collaborative research initiative (ARC) NIEVE aims at:

- Studying the modulation of emotion in audiovisual VEs, focusing on the case of phobia of dogs in the iCube.
- Studying appropriate representations, view combinations/transitions and auditory feedback for effective navigation in VEs
- Developing novel immersive audiovisual interfaces for navigation in VEs
- Developing an innovative emotion-based methodology for the evaluation of immersive navigation interfaces.

This research initiative involves two INRIA teams, REVES and VR4i, and IRCAM. It is supported by DREAM service at INRIA Sophia-Antipolis.

7.1.9. ADT Loic

Participant: Anatole Lécuyer [contact].

This ADT is a collaboration on OpenViBE software between two INRIA teams: VR4i team at INRIA Rennes and Cortex team at INRIA Nancy 5.3.

7.2. European Initiatives

7.2.1. INFRA-FP7: VISIONAIR

Participants: Georges Dumont [contact], Bruno Arnaldi, Valérie Gouranton, Thierry Duval, Alain Chauffaut, Ronan Gaugne.

Our actual Virtual Reality systems allowed us to be a key partner within the European Project VISIONAIR (http://www.infra-visionair.eu/) that began in February 2011 in the infrastructure call of FP7. Our Immersia (see section 6.4) Virtual Reality room is now, in Europe, a key place for virtual reality. We are leading the Work Package 9 on Advanced methods for interaction and collaboration of this project and are deeply involved in the directory board and in the scientific piloting committee. The VISIONAIR project's goal is to create a European infrastructure that should be a unique, visible and attractive entry towards high level visualization facilities. These facilities will be open to the access of a wide set of research communities. By integrating our existing facilities, we will create a world-class research infrastructure enabling to conduct frontier research. This integration will provide a significant attractiveness and visibility of the European Research Area. The partners of this project have proposed to build a common infrastructure that would grant access to high level visualization and interaction facilities and resources to researchers. Indeed, researchers from Europe and from around the world will be welcome to carry out research projects using the visualization facilities provided by the infrastructure [6]. Visibility and attractiveness will be increased by the invitation of external projects.

This project is built with the participation of 26 partners, INPG ENTREPRISE SA IESA France , Institut Polytechnique de Grenoble France, University of Patras LMS Greece, Cranfield University United Kingdom, Universiteit Twente Utwente Netherlands, Universitaet Stuttgart Germany, Instytut Chemii Bioorganicznej Pan Psnc Poland, Université De La Méditerranée D'aix-Marseille II France, Consiglio Nazionale Delle Ricerche CNR Italy, Institut National de Recherche en Informatique et en Automatique INRIA France, Kungliga Tekniska Hoegskolan Sweden, Technion - Israel Institute of Technology Israel, Rheinisch-Westfaelische Technische Hochschule Aachen RWTH Germany, Poznan University of Technology Poland, Arts et Métiers ParisTech AMPT France, Technische Universitaet Kaiserslautern Germany, The University of Salford United Kingdom, Fraunhofer-gesellschaft zur foerderung der Angewandten Forschung Germany, fundacio privada I2CAT Spain, University of Essex United Kingdom, Magyar Tudomanyos Akademia Szamitastechnikai Es Automatizalasi Kutato Intezet Hungary, École Centrale de Nantes France, University College of London United Kingdom, Politecnico di Milano Polimi Italy, European Manufacturing and Innovation Research Association (cluster leading excellence).

7.2.2. STREP: NIW

Participants: Gabriel Cirio, Anatole Lécuyer [contact], Maud Marchal, Léo Terziman.

The Natural Interactive Walking Project (NIW) is a 3-year project funded by the European Commission under the FET Open STREP call. NIW involves 5 partners: INRIA/VR4i (Bunraku), University of Verona (leader), University of Aalborg, University of Paris 6, and McGill University. The Natural Interactive Walking (NIW) project aims at taking advantage of multisensory information about the ground to develop knowledge for designing walking experiences. This will be accomplished through the engineering and perceptual validation of human-computer interfaces conveying virtual cues of everyday ground attributes and events. Such cues may be conveyed by auditory, haptic, pseudo-haptic, and visual augmentation of otherwise neutral grounds. The project is focused on creating efficient and scalable display methods across these modalities that can be easily and cost-effectively reproduced, via augmented floors and footwear.

It is expected that the NIW project will contribute to scientific knowledge in two key areas. First, it will reinforce the understanding of how our feet interact with surfaces on which we walk. Second, it will inform the design of such interactions, by forging links with recent advances in the haptics of direct manipulation and in locomotion in real-world environments. The methods that will be created could impact a wide range of future applications that have become prominent in recently funded research within Europe and North America. Examples include floor-based navigational aids for airports or railway stations, guidance systems for the visually impaired, augmented reality training systems for search and rescue, interactive entertainment, and physical rehabilitation.

7.2.3. ADT-Mixed Reality Technological Development: VCore

Participants: Georges Dumont [contact], Thierry Duval, Valérie Gouranton, Alain Chauffaut [contact], Ronan Gaugne [contact], Rémi Félix.

The Mixed Reality Project is a shared collaboration between Fraunhoffer IGD and five INRIA research centers: Rennes, Grenoble, Sophia, Lille and Saclay. On the INRIA side, the project started in october 2011, with a four years outlook, as an ADT with two IJDs, one in Rennes and one in Sophia. The goal of the project is to build a modular shared source software framework, fostering the development of new and unique research topics and application areas, which can be used alike by research teams and innovative companies. The goal is to make it a de facto standard, favoring interoperability between various developments in the mixed reality area. Research teams will get a sound software base that helps them focus their efforts on innovative software libraries or applications. Companies will benefit from implementations of state-of-the-art algorithms as well as a full-fledged framework strongly connected with 3D-related emerging standards like Collada, X3D and WebGL.

8. Dissemination

8.1. Scientific Community Animation

- B. Arnaldi: **Director** of IRISA (UMR 6074), **Vice-President** of Scientific Committee of INSA, **Member** of the Selection Committee (CSV) of the Competitiveness Cluster "Media and Networks" (http://www.images-et-reseaux.com/) since 2005, **Member** of the Managment Committee of "Métivier action of Rennes 1 University Foundation", **Vice-President** of AFRV, **Responsible** of the organization of scientific presentation during the annual days of the association AFRV, **Chair** of the white ANR SIMI2 committee.
- G. Dumont: **Head** of Media and Interaction department of IRISA (UMR 6074), **Leader** of WP9 of VISIONAIR european project [2011-2014], member of its Directory Board and member of its scientific committee, **Member** of the Selection Committee (CSV) of the Competitiveness Cluster "Media and Networks" (http://www.images-et-reseaux.com/), **Member** of Executive Board of international Journal IJIDeM. **Member** of the international scientific committee of ASME WINVR2011, of CASA2011, **Reviewer** for ASME WINVR2011, CASA2011, Improve2011, Haptics Symposium 2012 and JIMSS, **Member** of the AFRV, bf Reviewer for one PhD Defense.
- T. Duval: **Member** of ACM, AFIHM, AFRV and IEEE, **Reviewer** for IEEE VR 2011, JVRC 2011 and IHM 2011, **Member** of the International Program Committee of JVRC 2011.
- V. Gouranton: **member** of AFRV, **reviewer** of IEEE Virtual Reality 2011 conference, co-leader of ANR CORVETTE.
- A. Lécuyer: **Associate editor** of ACM Transactions on Applied Perception, **Associate editor** of International Journal on Human-Computer Studies, **Secretary** of the French Association for Virtual Reality, **Secretary** of the IEEE Technical Committee on Haptics, **Member of Selection Committee of ANR CONTINT Call for Project**, **Co-organizer of Course** at ACM SIGGRAPH ASIA 2011 "Walking through virtual environments" (Co-organizers: F. Steinicke from Munster Univ., Germany, and B. Mohler from MPI, Germany), **Program Committee member** of international conferences in 2011 : IEEE VR, IEEE 3DUI, JVRC, Augmented Human, VRIC, **Reviewer** of journals in 2011 : IEEE TVCG, ACM TAP **Reviewer of conferences** in 2011 : Eurographics.
- M. Marchal: **Reviewer of international journals in 2011**: Presence, International Journal of Computer-Human Studies, **Reviewer of international conferences in 2011:** MICCAI, IEEE EMBS, IEEE Virtual Reality, IEEE 3DUI, ACM SIGCHI, Eurographics, Pacific Graphics, Worldhaptics **Member** of AFRV and AFIG, **Program Committee member** of international conferences: IEEE VR, IEEE 3DUI.

8.2. Teaching

- Bruno Arnaldi

  Master MR2I Computer sciences : Virtual and Augmented Reality (VAR) (with E. Marchand), level M2), Rennes 1 University and INSA of Rennes, France

  Master MR2I Computer sciences : Responsible for the Track Images and Interactions, level M2), Rennes 1 University and INSA of Rennes, France

- Georges Dumont

  Master2, mechatronics : Mechanical simulation in Virtual reality, 36h, level M2, Rennes 1 University and École Normale Supérieure de Cachan, France

  Master2, formation des enseignants du supérieur : Mechanics of deformable systems, 20h, level M2, école Normale Supérieure de Cachan, France

  Master2, formation des enseignants du supérieur : Vibrations in Mechanics, 6h, level M2, école Normale Supérieure de Cachan, France

  Master2, formation des enseignants du supérieur : Multibody Dynamics, 6h, level M2, école Normale Supérieure de Cachan, France

Master2 mechatronics : Responsible of the second year of the master, Rennes 1 University and école Normale Supérieure de Cachan, France

- Thierry Duval

  Master : Man-Machine Interfaces and Design of Interactive Applications, 32h, M2 (GL, Mitic, Miage), University of Rennes 1, France

  Master : Collaborative Virtual Environments, 32h, M2 (GL, Mitic), University of Rennes 1, France

  Master : Introduction to Computer Graphics, 20h, M1, University of Rennes 1, France

- Ronan Gaugne

  Master : Projects on Virtual Reality, 30h, M1, INSA of Rennes, FR.

  Master : Projects on Virtual Reality, 16h, M2, INSA of Rennes, FR.

- Valérie Gouranton

  Licence : Introduction to Virtual Reality, 6h, L2, INSA of Rennes, FR and responsible of this lecture.

  Licence : Project on Virtual Reality, 16h, L3, INSA of Rennes, FR and responsible of this lecture.

  Master : Virtual Reality, 8h, M2, INSA of Rennes, FR.

  Master : Projects on Virtual Reality, 40h, M1, INSA of Rennes, FR.

  Master **co-responsible** of M2 Computer Science of RENNES 1 University, INSA of Rennes, ENS CACHAN, Supelec, UBO, ENIB, ENSTA Bretagne, Télécom Bretagne, UBS.

- Anatole Lécuyer

  Master MNRV : Haptic Interaction, 7 hours, M2, University of Angers, France

  Master SIBM : Brain-Computer Interfaces and Haptic Interfaces, 3 hours, M2, University of Rennes 1, France

- Maud Marchal

  Licence : Programming Language C, 16h, L3, INSA Rennes, France;

  Master : Algorithms and complexity, 31h, M1, INSA Rennes, France; Object-Oriented Modeling and Programming, 43h, M1, INSA Rennes, France; Software Quality, 29h, M2, INSA Rennes, France; Modeling and Engineering in Biology and Health Applications, 48h, M2, INSA Rennes, France; Medical Simulation, 3h, M2, Master SIBM University of Rennes 1, France;

- Quentin Avril

  Licence : Sensibilisation Réalité Virtuelle, 20h eq. TD, L1, INSA de Rennes, France

  Master : Images Numériques, 28h eq. TD, M1, Université de Rennes1, France

  Master : Modélisation, Animation et Rendu 3D, 11h eq. TD, M2, Université de Rennes1, France

- Charles Pontonnier

  Master : Conception de systèmes mécatroniques, 20h, M1 Mécatronique, Antenne de Bretagne de l'ENS Cachan, France

  Master : Mécanique des milieux continus, 24h, M2 Formation à l'Enseignement Supérieur, Antenne de Bretagne de l'ENS Cachan, France

Master : Résistance des matériaux, 24h, M2 Formation à l'Enseignement Supérieur, Antenne de Bretagne de l'ENS Cachan, France

Master : Travaux pratiques d'automatique, 24h, M2 Formation à l'Enseignement Supérieur, Antenne de Bretagne de l'ENS Cachan, France

Master : Travaux pratiques d'analyse de systèmes mécaniques, 15h, M2 Formation à l'Enseignement Supérieur, Antenne de Bretagne de l'ENS Cachan, France

PhD : Zhaoguang Wang, Interactive project review of deformable parts through haptic interfaces in Virtual Reality, ENS Cachan, advised by Georges Dumont, Defense date 2011/06/22 [3].

PhD : Quentin Avril, Détection de Collision pour Environnements Large Echelle : Modèle Unifié et Adaptatif pour Architectures Multi-coeur et Multi-GPU, INSA of Rennes, Defense date 2011/09/16, advised by Bruno Arnaldi, co-advised by Valérie Gouranton [1].

PhD in progress : Gabriel Cirio, Multimodal feedback and interaction techniques for physically based and large virtual environments, INSA de Rennes, will be defended on 2011/12/02, advised by Anatole Lécuyer, co-advised by Maud Marchal.

PhD in progress: Laurent George, The use of Brain computer interface for implicit human-computer interaction with Virtual Environnements, start date 2009/11/01, advised by Anatole Lécuyer.

PhD in progress : Léo Terziman, Realistic walking navigation in virtual environments for training, start date 2009/10/01, advised by Anatole Lécuyer and Bruno Arnaldi.

PhD in progress : Jérôme Ardouin, See and Interact at 360 degree, start date 2011/01/14, advised by Anatole Lécuyer.

PhD in progress : Loeiz Glondu, Modélisation et simulation physique d'outils d'exploration pour des interactions en environnement virtuel, start date 2009/10/01, advised by Georges Dumont, co-advised by Maud Marchal.

PhD in progress : Fabien Danieau, Haptic interaction for multimedia, start date 2011/01/03, advised by Anatole Lécuyer.

PhD in progress : Anthony TALVAS, Two-handed haptic perception and interaction with virtual worlds, start date 2011/10/01, advised by Anatole Lécuyer, co-advised by Maud Marchal.

PhD in progress : Fleury Cédric, Outils pour l'exploration collaborative d'environnements virtuels 3D, start date 2008/10/01, advised by Bruno Arnaldi, co-advised by Thierry Duval and Valérie Gouranton.

PhD in progress : Thi Thuong Huyen Nguyen, Proposition de nouvelles techniques d'interaction 3D et de navigation 3D préservant l'immersion de l'utilisateur et facilitant la collaboration entre utilisateurs distants, start date 2011/10/01, advised by Thierry Duval.

PhD in progress : Saraos-Luna Andrès, Travail d'équipe entre individus réels ou virtuels pour réaliser un travail collaboratif adaptatif dans un environnement virtuel possiblement physicalisé, start date 2010/10/01, advised by Bruno Arnaldi, co-advised by Valérie Gouranton.

9. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses

[1] Q. AVRIL. *Détection de Collision pour Environnements Large Échelle : Modèle Unifié et Adaptatif pour Architectures Multi-coeur et Multi-GPU*, INSA de Rennes, September 2011, http://hal.inria.fr/tel-00642067/en.

[2] G. CIRIO. *Retour Multimodal et Techniques d'Interaction pour des Environnements Virtuels Basés Physique et Larges*, INSA de Rennes, December 2011, http://hal.inria.fr/tel-00652077/en.

[3] Z. WANG. *Interactive project review of deformable parts through haptic interfaces in Virtual Reality*, Université Rennes 1, June 2011, http://hal.inria.fr/tel-00608499/en.

Articles in International Peer-Reviewed Journal

[4] R. BOUVILLE BERTHELOT, T. DUVAL, J. ROYAN, B. ARNALDI. *Improving Reusability of Assets for Virtual Worlds while Preserving 3D Formats Features*, in "JVWR (Journal for Virtual World Research)", November 2011, vol. 4, n^{o} 3, http://hal.inria.fr/inria-00636145/en.

[5] G. CIRIO, M. MARCHAL, S. HILLAIRE, A. LÉCUYER. *Six Degrees-of-Freedom Haptic Interaction with Fluids*, in "IEEE Transactions on Visualization and Computer Graphics", December 2011, vol. 17, n^{o} 11, p. 1714-1727 [*DOI :* 10.1109/TVCG.2010.271], http://hal.inria.fr/hal-00642814/en.

[6] A. KOPECKI, U. WÖSSNER, D. MAVRIKIOS, L. RENTZOS, C. WEIDIG, L. ROUCOULES, O.-D. NTOFON, M. REED, G. DUMONT, D. BÜNDGENS, A. MILECKI, P. BARANYI, F. NOEL, C. MASCLET, M. ATTENE, F. GIANNINI, M. SPAGNUOLO. *VISIONAIR: VISION Advanced Infrastructure for Research*, in "SBC Journal on 3D Interactive Systems", November 2011, vol. 2, n^{o} 2, p. 40-43, http://hal.inria.fr/hal-00644745/en.

[7] J. LEGÉNY, R. VICIANA ABAD, A. LÉCUYER. *Navigating in virtual worlds using a self-paced SSVEP-based Brain-Computer Interface with integrated stimulation and real-time feedback*, in "Presence: Teleoperators and Virtual Environments", December 2011, http://hal.inria.fr/hal-00646493/en.

[8] Z. WANG, G. DUMONT. *Haptic Manipulation of Deformable CAD Parts with a Two-stage Method*, in "International Journal on Interactive Design and Manufacturing", November 2011, vol. 5, n^{o} 4, p. 255-270 [*DOI :* 10.1007/S12008-011-0136-6], http://hal.inria.fr/hal-00642717/en.

International Conferences with Proceedings

[9] L. AGUERRECHE, T. DUVAL, A. LÉCUYER. *Evaluation of a Reconfigurable Tangible Device for Collaborative Manipulation of Objects in Virtual Reality*, in "Theory and Practice of Computer Graphics", Warwick, United Kingdom, September 2011, UK Eurographics Chapter, http://hal.inria.fr/inria-00608788/en.

[10] J. ARDOUIN, A. LÉCUYER, M. MARCHAL, E. MARCHAND. *Design and Evaluation of Methods to Prevent Frame Cancellation in Real-Time Stereoscopic Rendering*, in "IEEE Symposium on 3D User Interfaces, 3DUI 2011", Singapore, Singapore, 2011, p. 95-98, http://hal.inria.fr/hal-00639649/en.

[11] Q. AVRIL, V. GOURANTON, B. ARNALDI. *Dynamic Adaptation of Broad Phase Collision Detection Algorithms*, in "ISVRI, Conjunction with IEEE Virtual Reality (VR)", Singapore, 2011, 7p, http://hal.inria.fr/hal-00555720/en.

[12] R. BOUVILLE BERTHELOT, J. ROYAN, T. DUVAL, B. ARNALDI. *Scene Graph Adapter: An efficient Architecture to Improve Interoperability between 3D Formats and 3D Application Engines*, in "Web3D 2011 (16th International Conference on 3D Web technology, ACM)", Paris, France, June 2011, http://hal.inria.fr/inria-00586161/en.

[13] N. BRODU, F. LOTTE, A. LÉCUYER. *Comparative Study of Band-Power Extraction Techniques for Motor Imagery Classification*, in "IEEE Symposium on Computational Intelligence, Cogni-

tive Algorithms, Mind, and Brain (SSCI'2011 CCMB)", Paris, France, IEEE, April 2011, p. 1-6 [*DOI :* 10.1109/CCMB.2011.5952105], http://hal.inria.fr/inria-00609161/en.

[14] G. CIRIO, M. MARCHAL, S. HILLAIRE, A. LÉCUYER. *The Virtual Crepe Factory: 6DoF Haptic Interaction with Fluids*, in "SIGGRAPH Emerging Technologies", Vancouver, Canada, 2011, 17 [*DOI :* 10.1145/2048259.2048276], http://hal.inria.fr/hal-00645756/en.

[15] G. CIRIO, M. MARCHAL, A. LE GENTIL, A. LÉCUYER. *Tap, squeeze and stir the virtual world: Touching the different states of matter through 6DoF haptic interaction*, in "IEEE Virtual Reality Conference", Singapore, Singapore, March 2011, p. 123-126 [*DOI :* 10.1109/VR.2011.5759449], http://hal.inria.fr/hal-00642816/en.

[16] T. DUVAL, C. FLEURY. *Enabling Collaboration between Heterogeneous 3D Viewers through a PAC-C3D Modeling of the Shared Virtual Environment*, in "ICAT 2011 (The 21st International Conference on Artificial Reality and Telexistence)", Osaka, Japan, VRSJ, November 2011, http://hal.inria.fr/inria-00638638/en.

[17] T. DUVAL, C. FLEURY. *PAC-C3D: A New Software Architectural Model for Designing 3D Collaborative Virtual Environments*, in "ICAT 2011", Osaka, Japan, VRSJ, November 2011, http://hal.inria.fr/inria-00636143/en.

[18] F. FONTANA, F. MORREALE, T. REGIA-CORTE, A. LÉCUYER, M. MARCHAL. *Auditory recognition of floor surfaces by temporal and spectral cues of walking*, in "17th International Conference on Auditory Display", Budapest, Hungary, June 2011, http://hal.inria.fr/hal-00644249/en.

[19] L. GEORGE, L. BONNET, A. LÉCUYER. *Freeze the BCI until the user is ready: a pilot study of a BCI inhibitor*, in "5th International Brain-Computer Interface Workshop", Graz, Austria, September 2011, http://hal.inria.fr/inria-00634556/en.

[20] L. GEORGE, F. LOTTE, R. VICIANA ABAD, A. LÉCUYER. *Using Scalp Electrical Biosignals to Control an Object by Concentration and Relaxation Tasks: Design and Evaluation*, in "International Conference of the IEEE EMBS", Boston, United States, August 2011, http://hal.inria.fr/inria-00634549/en.

[21] L. GLONDU, B. LEGOUIS, M. MARCHAL, G. DUMONT. *Precomputed Shape Database for Real-Time Physically-Based Simulation*, in "Workshop on Virtual Reality Interaction and Physical Simulation - VRIPHYS 2011", Lyon, France, December 2011, http://hal.inria.fr/hal-00640578/en.

[22] T. HACHISU, G. CIRIO, M. MARCHAL, A. LÉCUYER, H. KAJIMOTO. *Pseudo-haptic feedback augmented with visual and tactile vibrations*, in "International Symposium on VR Innovations", Singapour, Singapore, March 2011, http://hal.inria.fr/hal-00644252/en.

[23] T. HACHISU, G. CIRIO, M. MARCHAL, A. LÉCUYER, H. KAJIMOTO. *Virtual Chromatic Percussions Simulated by Pseudo-Haptic and Vibrotactile Feedback*, in "ACM International Conference on Advances on Computer Entertainment Technology", Lisbon, Portugal, November 2011, http://hal.inria.fr/hal-00644246/en.

[24] A. LÉCUYER, M. MARCHAL, A. HAMELIN, D. WOLINSKI, F. FONTANA, M. CIVOLANI, S. PAPETTI, S. SERAFIN. *"Shoes-Your-Style": Changing Sound of Footsteps to Create New Walking Experiences*, in "Workshop on Sound and Music Computing for Human-Computer Interaction (CHItaly)", Alghero, Italy, September 2011, http://hal.inria.fr/hal-00644247/en.

[25] M. MARCHAL, J. PETTRÉ, A. LÉCUYER. *Joyman: a Human-Scale Joystick for Navigating in Virtual Worlds*, in "IEEE Symposium on 3D User Interfaces 2011 (3DUI)", Singapour, Singapore, March 2011, http://hal.inria.fr/inria-00567437/en.

[26] C. PONTONNIER, M. DE ZEE, A. SAMANI, G. DUMONT, P. MADELEINE. *Meat Cutting Tasks Analysis using 3D Instrumented Knife and Motion Capture*, in "15th Nordic-Baltic Conference on Biomedical Engineering and Medical Physics", Aalborg, Denmark, IFMBE Proceedings, Springer, June 2011, vol. 34, p. 144-147 [*DOI :* 10.1007/978-3-642-21683-1_36], http://hal.inria.fr/hal-00640202/en.

[27] C. PONTONNIER, M. DE ZEE, A. SAMANI, G. DUMONT, P. MADELEINE. *Trend Validation of a Musculoskeletal Model with a Workstation Design Parameter*, in "ISB Technical Group on Computer Simulation Symposium 2011", Leuven, Belgium, International Society of biomechanics, June 2011, http://hal.inria.fr/hal-00640206/en.

[28] C. PONTONNIER, G. DUMONT. *Using a Cocontraction Ratio to Predict Antagonistic Behavior During Elbow Motion*, in "International Society of Biomechanics 2011 Congress", Brussels, Belgium, July 2011, http://hal.inria.fr/hal-00640207/en.

[29] L. TERZIMAN, M. MARCHAL, F. MULTON, B. ARNALDI, A. LÉCUYER. *Comparing Virtual Trajectories Made in Slalom Using Walking-In-Place and Joystick Techniques*, in "EuroVR / EGVE Joint Virtual Reality Conference", Nottingham, United Kingdom, Eurographics, 2011, http://hal.inria.fr/hal-00641371/en.

[30] J. VANCE, G. DUMONT. *A Conceptual Framework to Support Natural Interaction for Virtual Assembly Tasks*, in "ASME 2011 World Conference on Innovative Virtual Reality (WINVR 2011)", Milan, Italy, ASME, June 2011, http://hal.inria.fr/hal-00640562/en.

[31] Z. WANG, G. DUMONT. *Interactive Design Validation of Deformable Parts Through Haptic Interface*, in "ASME 2011 World Conference on Innovative Virtual Reality (WINVR 2011)", Milan, Italy, ASME, June 2011, http://hal.inria.fr/hal-00640565/en.

National Conferences with Proceeding

[32] L. GLONDU, M. MARCHAL, G. DUMONT. *Simulation physique de fracture d'objets fragiles en temps réel*, in "Journées de l'association française d'informatique graphique", Biarritz, France, AFIG, October 2011, http://hal.inria.fr/hal-00644251/en.

Conferences without Proceedings

[33] J. PETTRÉ, M. MARCHAL, O. SIRET, J.-B. DE LA RIVIÈRE, A. LÉCUYER. *Joyman: an Immersive and Entertaining Interface for Virtual Locomotion*, in "ACM SIGGRAPH Asia Emerging Technologies", Hong-Kong, Hong Kong, December 2011, http://hal.inria.fr/hal-00644256/en.