Activity Report 2012

Team VR4I

Virtual Reality for Improved Innovative Immersive Interaction

IN COLLABORATION WITH: Institut de recherche en informatique et systèmes aléatoires (IRISA)
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Team VR4I

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

Creation of the Team: January 01, 2011.

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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 of the Year

#### 2.2.1. Best paper award

The paper "Combining Brain-Computer Interfaces and Haptics: Detecting Mental Workload to Adapt Haptic Assistance" [22] has obtained the best paper award at Eurohaptics 2012.

#### 2.2.2. Honorable mention

The paper "Efficient Collision Detection for Brittle Fracture" [23] has obtained the honorable mention at Symposium on Computer Animation (SCA-2012).

#### 2.2.3. Inauguration of Immersia

The Immersia platform has been officially inaugurated the 20th of June 2012, by Bertrand Braunschweig, Inria Rennes, Bretagne Atlantique director, Claude Labit, vice-president of the Rennes 1 University scientific council, Antoine Petit, Inria deputy managing director, with Jean Le Traon, research and technology regional deputy director, Bernard Pouliquen, vice-president of the regional council, Clotilde Tascon-Mennetrier, vice-president of the general council, and Daniel Delaveau, Mayor of Rennes and president of Rennes Metropole. The platform is currently extended with the installation of the two lateral screens, improving the sensation of immersion in the VR applications.

### 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 multimodal 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 and for scientific visualization (ANR Part@ge and ANR Collaviz 7.1.2), 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 7.1.3 and FUI SIFORAS 7.1.1). 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, Marwan Badawi.
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. OpenMASK is well suited to develop applications in our new immersive room as ergonomics studies, including immersion, interaction, physic and haptic.

5.2. GVT : Generic Virtual Training

Participants: Bruno Arnaldi, Valérie Gouranton [contact], Florian Nouviale, Thomas Lopez, Andrés 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 modelled 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 7.1.3 and in the FUI SIFORAS 7.1.1, 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. Real-time mechanical simulation of brittle fracture

Participants: Loeiz 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 computationally expensive. Thus, physically-based simulation of brittle fracture in real-time is still challenging for interactive applications. We have worked on a physically-based approach for simulating realistic brittle fracture in real-time. Our method is mainly composed of two parts: (1) a fracture initiation method based on modal analysis, (2) a fast energy-based fracture propagation algorithm. Results that emphasize the "real-time" part of this method have been published in [9]. Collision detection plays a key role in simulation performance. This is particularly true for fracture simulation, where multiple new objects are dynamically created. We proposed algorithms and data structures for collision detection in real-time brittle fracture simulations. We build on a combination of well-known efficient data structures, namely distance fields and sphere trees, making our algorithm easy to integrate on existing simulation engines. We proposed novel methods to construct these data structures, such that they can be efficiently updated upon fracture events and integrated in a simple yet effective self-adapting contact selection algorithm. Altogether, we drastically reduce the cost of both collision detection and collision response. We have evaluated our global solution for collision detection on challenging scenarios, achieving high frame rates suited for hard real-time applications such as video games or haptics [23]. Moreover, a common weathering effect is the appearance of cracks due to material fractures. We introduced a method to exemplar-based modeling that creates weathered patterns on synthetic objects by matching the statistics of fracture patterns in a photograph. A user study was proposed to determine which statistics are correlated to visual similarity and how they are perceived by the user. A revised physically-based fracture model capable of producing a wide range of crack patterns at interactive rates has been proposed whose parameter can be determined by a Bayesian optimization to produce a pattern with the same key statistics as an exemplar [10]. This work was the subject of the PhD thesis of Loeiz Glondu that has been successfully defended [3].
6.1.2. Collision detection in large scale environments with High Performance Computing

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

We propose [14] a novel and efficient GPU-based parallel algorithm to cull non-colliding objects pairs in very large scale dynamic simulations. It allows to cull objects in less than 25ms with more than 100K objects. It is designed for many-core GPU and fully exploits multi-threaded capabilities and data-parallelism. In order to take advantage of the high number of cores, a new mapping function is defined that enables GPU threads to determine the objects pair to compute without any global memory access. These new optimized GPU kernel functions use the thread indexes and turn them into a unique pair of objects to test. A square root approximation technique is used based on Newton’s estimation, enabling the threads to only perform a few atomic operations to cull non-colliding objects. We present a first characterization of the approximation errors that enables the fixing of incorrect computations. Input and output GPU streams are optimized using binary masks. The implementation and evaluation is made on large-scale dynamic rigid body simulations. The increase in speed is highlighted over other recently proposed CPU and GPU-based techniques. The comparison shows that our system is, in most cases, faster than previous approaches.

6.1.3. Simulation evaluations for ergonomics in VR

**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.

For example, one of our study assessed 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 analyze their variation when some of the workstation design parameters are changing.

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.

With regard to the design parameters, that are the table height and the cutting direction, trends of recorded muscles activations were defined in order to be compared to computed ones issued from a musculoskeletal simulation performed with the AnyBody modeling system (AnyBody, Aalborg, Denmark). Results showed that an optimal set of design parameters can be obtained [27], whereas motor control strategies are highly dependent to the subject’s experience and morphology.

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). Furthermore, the fidelity of the VR simulator has to be evaluated (see Figure 2). For example, a simulator for assembly task has been evaluated in comparing different types of interaction: real, virtual and virtual + force feedback [28]. Objective and subjective metrics of discomfort led to highlight the influence of the environment on motor control and sensory feedback, changing more or less deeply the way the task is performed. Those change have to be taken into account to enable the use of such simulators for ergonomics purposes.

6.2. Multimodal immersive interaction

6.2.1. Immersive Archaeology

**Participants:** Bruno Arnaldi, Georges Dumont, Ronan Gaugne [contact], Valérie Gouranton [contact].
We propose a workflow of tools and procedures to reconstruct an existing archaeological site as a virtual 3D reconstitution in a large scale immersive system [35]. This interdisciplinary endeavor, gathering archaeologists and virtual reality computer scientists, is the first step of a joint research project with three objectives: (i) propose a common workflow to reconstruct archaeological sites as 3D models in fully immersive systems, (ii) provide archaeologists with tools and interaction metaphors to exploit immersive reconstitutions, and (iii) develop the use and access of immersive systems to archaeologists. In this context, we present [21] results from the immersive reconstitution of Carn’s monument central chamber, in Finistere, France, a site currently studied by the Creaah archaeology laboratory. The results rely on a detailed workflow we propose, which uses efficient solutions to enable archaeologists to work with immersive systems. In particular, we proposed a procedure to model the central chamber of the Carn monument, and compare several softwares to deploy it in an immersive structure. We then proposed two immersive implementations of the central chamber, with simple interaction tools.

6.2.2. Novel 3D displays and user interfaces

**Participants:** Anatole Lécuyer [contact], David Gomez, Fernando Argelaguet, Maud Marchal, Jerome Ardonin.

We describe hereafter our recent results in the field of novel 3D User Interfaces and, more specifically, novel displays and interactive techniques to better perceive and interact in 3D. This encloses: (1) Novel interactive techniques for interaction with 3D web content, and (2) A novel display for augmented 3D vision.

6.2.2.1. Novel interactive techniques for 3D web content

The selection and manipulation of 3D content in desktop virtual environments is commonly achieved with 2D mouse cursor-based interaction. However, by interacting with image-based techniques we introduce a conflict between the 2D space in which the 2D cursor lays and the 3D content. For example, the 2D mouse cursor does not provide any information about the depth of the selected objects. In this situation, the user has to rely on the depth cues provided by the virtual environment, such as perspective deformation, shading and shadows.

In [24], we have explored new metaphors to improve the depth perception when interacting with 3D content. Our approach focus on the usage of 3D cursors controlled with 2D input devices (the Hand Avatar and the Torch) and a pseudo-motion parallax effect. The additional depth cues provided by the visual feedback of the 3D cursors and the motion parallax are expected to increase the users’ depth perception of the environment.

The evaluation of proposed techniques showed that users depth perception was significantly increased. Users were able to better judge the depth ordering of virtual environment. Although 3D cursors showed a decrease of selection performance, it is compensated by the increased depth perception.
6.2.2.2. FlyVIZ: A novel display for providing humans with panoramic vision

Have you ever dreamed of having eyes in the back of your head? In [12], we have presented a novel display device called FlyVIZ which enables humans to experience a real-time 360-degree vision of their surroundings for the first time.

To do so, we combined a panoramic image acquisition system (positioned on top of the user’s head) with a Head-Mounted Display (HMD). The omnidirectional images are transformed to fit the characteristics of HMD screens. As a result, the user can see his/her surroundings, in real-time, with 360 degree images mapped into the HMD field of view.

We foresee potential applications in different fields where augmented human capacity (an extended field-of-view) could benefit, such as surveillance, security, or entertainment. FlyVIZ could also be used in novel perception and neuroscience studies.

6.2.3. Brain-Computer Interfaces

Participants: Anatole Lécuyer [contact], Laurent George, Laurent Bonnet, Jozef Legeny.

Brain-computer interfaces (BCI) are communication systems that enable to send commands to a computer using only the brain activity. Cerebral activity is generally sensed with electroencephalography (or EEG). We describe hereafter our recent results in the field of brain-computer interfaces and virtual environments: (1) Novel signal processing techniques for EEG-based Brain-Computer Interfaces, and (2) Design and study of Brain-Computer Interaction with real and virtual environments.

6.2.3.1. Novel signal processing techniques for EEG-based Brain-Computer Interfaces

A first part of the BCI research conducted in the team is dedicated to EEG signal processing and classification techniques applied to cerebral EEG data.

To properly and efficiently decode brain signals into computer commands the application of efficient machine-learning techniques is required.

In [5] we could introduce two new features for the design of electroencephalography (EEG) based Brain-Computer Interfaces (BCI): one feature based on multifractal cumulants, and one feature based on the predictive complexity of the EEG time series. The multifractal cumulants feature measures the signal regularity, while the predictive complexity measures the difficulty to predict the future of the signal based on its past, hence a degree of how complex it is. We have conducted an evaluation of the performance of these two novel features on EEG data corresponding to motor-imagery. We also compared them to the gold standard features used in the BCI field, namely the Band-Power features. We evaluated these three kinds of features and their combinations on EEG signals from 13 subjects. Results obtained show that our novel features can lead to BCI designs with improved classification performance, notably when using and combining the three kinds of feature (band-power, multifractal cumulants, predictive complexity) together.

Evolutionary algorithms have also been increasingly applied in different steps of BCI implementations. In [29], we could then introduce the use of the covariance matrix adaptation evolution strategy (CMA-ES) for BCI systems based on motor imagery. The optimization algorithm was used to evolve linear classifiers able to outperform other traditional classifiers. We could also analyze the role of modeling variables interactions for additional insight in the understanding of the BCI paradigms.

6.2.3.2. Brain-Computer Interaction with real and virtual environments

A second part of our BCI research is dedicated to the improvement of BCI-based interaction with real and virtual environments. We have first initiated research on Combining Haptic and Brain-Computer Interfaces.

In [22], we have introduced the combined use of Brain-Computer Interfaces (BCI) and Haptic interfaces. We proposed to adapt haptic guides based on the mental activity measured by a BCI system. This novel approach has been illustrated within a proof-of-concept system: haptic guides were toggled during a path-following task thanks to a mental workload index provided by a BCI. The aim of this system was to provide haptic assistance only when the user’s brain activity reflects a high mental workload.
A user study conducted with 8 participants showed that our proof-of-concept is operational and exploitable. Results showed that activation of haptic guides occurs in the most difficult part of the path-following task. Moreover it allowed to increase task performance by activating assistance only 59 percents of the time. Taken together, these results suggest that BCI could be used to determine when the user needs assistance during haptic interaction and to enable haptic guides accordingly.

This work paves the way to novel passive BCI applications such as medical training simulators based on passive BCI and smart guides. It has received the Best Paper Award of Eurohaptics 2012 conference, and was nominated for the BCI Award 2012.

6.2.4. Natural Interactive Walking in Virtual Environments

Participants: Anatole Lécuyer [contact], Maud Marchal [contact], Gabriel Cirio, Tony Regia Corte, Sébastien Hillaire, Léo Terziman.

We describe hereafter our recent results obtained in the field of "augmented" or "natural interactive" walking in virtual environments. Our first objective is to better understand the properties of human perception and human locomotion when walking in virtual worlds. Then, we intend to design advanced interactive techniques and interaction metaphors to enhance, in a general manner, the navigation possibilities in VR systems. Last, our intention is to improve the multisensory rendering of human locomotion and human walk in virtual environments, making full use of both haptic and visual feedback.

6.2.4.1. Perception of ground affordances in virtual environments

We have evaluated the perception of ground affordances in virtual environments (VE).

In [11], we considered the affordances for standing on a virtual slanted surface. Participants were asked to judge whether a virtual slanted surface supported upright stance. The objective was to evaluate if this perception was possible in virtual reality (VR) and comparable to previous works conducted in real environments. We found that the perception of affordances for standing on a slanted surface in virtual reality is possible and comparable (with an underestimation) to previous studies conducted in real environments. We also found that participants were able to extract and to use virtual information about friction in order to judge whether a slanted surface supported an upright stance. Finally, results revealed that the person’s position on the slanted
surface is involved in the perception of affordances for standing on virtual grounds. Taken together, our results show quantitatively that the perception of affordances can be effective in virtual environments, and influenced by both environmental and person properties. Such a perceptual evaluation of affordances in VR could guide VE designers to improve their designs and to better understand the effect of these designs on VE users.

6.2.4.2. Novel metaphors for navigating virtual environments

Immersive spaces such as 4-sided displays with stereo viewing and high-quality tracking provide a very engaging and realistic virtual experience. However, walking is inherently limited by the restricted physical space, both due to the screens (limited translation) and the missing back screen (limited rotation).

In [7], we proposed three novel locomotion techniques that have three concurrent goals: keep the user safe from reaching the translational and rotational boundaries; increase the amount of real walking and finally, provide a more enjoyable and ecological interaction paradigm compared to traditional controller-based approaches.

We notably introduced the “Virtual Companion”, which uses a small bird to guide the user through VEs larger than the physical space. We evaluated the three new techniques through a user study with travel-to-target and path following tasks. The study provided insight into the relative strengths of each new technique for the three aforementioned goals. Specifically, if speed and accuracy are paramount, traditional controller interfaces augmented with our novel warning techniques may be more appropriate; if physical walking is more important, two of our paradigms (extended Magic Barrier Tape and Constrained Wand) should be preferred; last, fun and ecological criteria would favor the Virtual Companion.

6.2.4.3. Novel sensory feedback for improving sensation of walking in VR: the King-Kong Effects

Third, we have designed novel sensory feedbacks named “King-Kong Effects” to enhance the sensation of walking in virtual environments [33].

King Kong Effects are inspired by special effects in movies in which the incoming of a gigantic creature is suggested by adding visual vibrations/pulses to the camera at each of its steps (Figure 4).

Figure 4. Concept of the King Kong Effects: Visual and Tactile vibrations inspired by special effects in movies enhance the sensation of walking in VE. Visual and Tactile feedbacks are generated at each step made in the VE.

We thus proposed to add artificial visual or tactile vibrations (King-Kong Effects or KKE) at each footstep detected (or simulated) during the virtual walk of the user. The user can be seated, and our system proposes to use vibrotactile tiles located under his/her feet for tactile rendering, in addition to the visual display. We have designed different kinds of KKE based on vertical or lateral oscillations, physical or metaphorical patterns, and one or two peaks for heal-toe contacts simulation.
We have conducted different experiments to evaluate the preferences of users navigating with or without the various KKE. Taken together, our results identify the best choices in term of sensation of walking for future uses of visual and tactile KKE, and they suggest a preference for multisensory combinations. Our King-Kong effects could be used in a variety of VR applications targeting the immersion of a user walking in a 3D virtual scene.

6.2.5. Haptic Interaction

Participants: Fernando Argelaguet, Fabien Danieau, Anatole Lécuyer [contact], Maud Marchal, Anthony Talvas.

6.2.5.1. Pseudo-Haptic Feedback

Pseudo-haptic feedback is a technique meant to simulate haptic sensations in virtual environments using visual feedback and properties of human visuo-haptic perception. Pseudo-haptic feedback uses vision to distort haptic perception and verges on haptic illusions. Pseudo-haptic feedback has been used to simulate various haptic properties such as the stiffness of a virtual spring, the texture of an image, or the mass of a virtual object.

In [13], we focused on the improvement of pseudo-haptic textures. Pseudo-haptic textures allow to optically-induce relief in textures without a haptic device by adjusting the speed of the mouse pointer according to the depth information encoded in the texture. In this work, we have presented a novel approach for using curvature information instead of relying on depth information. The curvature of the texture is encoded in a normal map which allows the computation of the curvature and local changes of orientation, according to the mouse position and direction.

A user evaluation was conducted to compare the optically-induced haptic feedback of the curvature-based approach versus the original depth-based approach based on depth maps. Results showed that users, in addition to being able to efficiently recognize simulated bumps and holes with the curvature-based approach, were also able to discriminate shapes with lower frequency and amplitude.

6.2.5.2. Bi-Manual Haptic Feedback

In the field of haptics and virtual reality, two-handed interaction with virtual environments (VEs) is a domain that is slowly emerging while bearing very promising applications.

In [32] we could present a set of novel interactive techniques adapted to two-handed manipulation of objects with dual 3DoF single-point haptic devices (see Figure 5). We first proposed the double bubble for bimanual haptic exploration of virtual environments through hybrid position/rate controls, and a bimanual viewport adaptation method that keeps both proxies on screen in large environments. We also presented two bimanual haptic manipulation techniques that facilitate pick-and-place tasks: the joint control, which forces common control modes and control/display ratios for two interfaces grabbing an object, and the magnetic pinch, which simulates a magnet-like attraction between both hands to prevent unwanted drops of that object.

An experiment was conducted to assess the efficiency of these techniques for pick-and-place tasks, by comparing the double bubble with viewport adaptation to the clutching technique for extending the workspaces, and by measuring the benefits of the joint control and magnetic pinch.

6.2.5.3. Haptic Feedback and Haptic Seat for Enhancing AudioVisual Experience

This work aims at enhancing a classical video viewing experience by introducing realistic haptic feelings in a consumer environment.

First, in [16] a complete framework to both produce and render the motion embedded in an audiovisual content was proposed to enhance a natural movie viewing session. We especially considered the case of a first-person point of view audiovisual content and we propose a general workflow to address this problem. This latter includes a novel approach to both capture the motion and video of the scene of interest, together with a haptic rendering system for generating a sensation of motion. A complete methodology to evaluate the relevance of our framework was finally proposed and could demonstrate the interest of our approach.
Second, leveraging on the techniques and framework introduced previously, in [17] we could introduce a novel way of simulating motion sensations without calling for expensive and cumbersome motion platforms. The main idea consists in applying multiple force-feedbacks on the user’s body to generate a sensation of motion while seated and experiencing passive navigation. A set of force-feedback devices are therefore arranged around a seat, as if various components of the seat could apply forces on the user, like mobile armrests or headrest. This new approach is called HapSeat (see Figure 6). A proof-of-concept has been designed within a structure which relies on 3 low-cost force-feedback devices, and two models were implemented to control them.

Results of a first user study suggests that subjective sensations of motion can be generated by both approaches. Taken together, our results pave the way to novel setups and motion effects for consumer living-places based on the HapSeat.

6.2.6. Interactions within 3D virtual universes

Participants: Thierry Duval [contact], Thi Thuong Huyen Nguyen, Cédric Fleury.

We have proposed some new metaphors allowing a guiding user to be fully aware of what the main user was seeing in the virtual universe and of what were the physical constraints of this user. We made a first prototype that made it possible to participate to the 3DUI 2012 contest [26], then we made further experiments showing the interest of the approach, these results will be presented in [25].
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 are currently working about new multi-point interaction techniques to allow users to precisely manipulate virtual objects.

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, Thi Thuong Huyen Nguyen, Georges Dumont.

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 7.1.2.

We have used the IIVC in order to provide efficient collaboration between users in a guiding task, allowing a guiding user to be fully aware of what the main user was seeing in the virtual universe and of what were the physical constraints of this user. We made a first prototype that made it possible to participate to the 3DUl 2012 contest [26], then we made further experiments showing the interest of the approach, these results will be presented in [25]. We also proposed to use the IIVC to enhance the communication between users sharing a virtual universe by helping them to build a cognitive model of the other users’ environment [19]

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 7), 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.

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 8), the Scene Graph Adapter. 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, and makes also it possible to compose different format files [15].

6.3.3. Collaborative interaction model

**Participants:** Bruno Arnaldi, Valérie Gouranton [contact], Andrés Saraos Luna.

Our work ponders on collaborative interactions in Collaborative Virtual Environments for Training, with an emphasis on collaborative interactions between Real Humans and Virtual Humans working as a team. We propose [30] a new collaborative interaction model and from it construct a set of tools to describe and define such collaborative interactions [34].

6.4. Immersia Virtual Reality room

**Participants:** Georges Dumont [contact], Alain Chauffaut, Ronan Gaugne [contact], Marwan Badawi.
Figure 7. The PAC-C3D software architectural model makes interoperability possible between heterogeneous 3D viewers.

Figure 8. 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.
The team was the first in France to host a large-scale immersive virtual reality equipment known as Immersia (see figure 9). This platform, with full visual and sound immersion, is dedicated to real-time, multimodal (vision, sound, haptic, BCI) and immersive interaction. 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 high. The visual reproduction system combines ten 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 users position, and this, together with their high resolution and homogeneous colouring, make them very realistic. The ART localization system, constituted of 16 ARTtrack 2 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 users position.

The Immersia Virtual Reality room has been inaugurated on 2012, June, the 20th. We have hosted the project VR-GO, a Trans National Access VISIONAIR project in June 2012. The goal was to evaluate an assembly by comparing different types of interaction: real, virtual and virtual + force feedback [28].

![Figure 9. Immersia Virtual Reality Room](image)

### 7. Partnerships and Cooperations

#### 7.1. National Initiatives

##### 7.1.1. FUI SIFORAS

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

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 7.1.3) in particular for the global architecture based on STORM and LORA models.

##### 7.1.2. ANR Collaviz

Participants: Thierry Duval [contact], Valérie Gouranton [contact], Cédric Fleury, Van Viet Pham.
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 was involving 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 Collaviz ended at on 30th June 2012.

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 connection will be needed. The classical approach is not adapted anymore: simulation-based design applications tend to generate Terabytes and even Petabytes of data.

We were leading the WP4 about Collaborative Virtual Environments and Techniques, whose aim was to manage the 3D collaborative interactions of the users. During 2012 we contributed to the second Collaviz prototype 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. We added a JMonkeyEngine viewer dedicated to deploy Collaviz on mobile devices such as tablets. We also made a link with the VCoRE project by adding a C++ OpenSG viewer to the our Java Collaviz framework.

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 was a success, it has allowed efficient co-manipulation of a shared 3D object between two really distant users, and the experimental results have been presented in [20]. Collaviz has then been deployed in the Inria Sophia-Antipolis immersive system in the context of the VCoRE project.

7.1.3. ANR Corvette

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

Corvette (COllaboRative Virtual Environment Technical Training and Experiment) based on GVT 5.2, 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 4 Industrial partners (AFPA, 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 psychology for the assessment of the effectiveness of the collaboration of users and virtual humans to perform complex cooperative tasks in a virtual environment.

Unit contributions and technologies are demonstrated. Each partner has integrated global constraints of the project to produce the technical elements in relation to their contributions. The next step is to combine the components into a unified environment and have it validated by industrial use cases.

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

7.1.4. 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.

7.1.5. ANR Open-ViBE2

Participants: Laurent Bonnet, Laurent George, Anatole Lécuyer [contact], Jozef Legeny.

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).

7.1.6. ANR HOMO TEXTILUS

Participants: Anatole Lécuyer [contact], Jozef Legeny, Maud Marchal, Jonathan Mercier.

HOMO TEXTILUS is a 3-year project funded by the French National Agency for Research (2012-2015). The objective of HOMO TEXTILUS is to study what could be the next generation of smart and augmented clothes, and their influence and potential impact on behavior and habits of their users. The project is strongly oriented towards human science, with both user studies and sociological studies. The involvement of VR4i team in the project consists in contributing to the design of next-gen prototypes of clothes embedding novel kinds of sensors and actuators. Envisionned sensors relate to physiological measurements such as with EEG (electroencephalography and Brain-Computer Interfaces), EMG (muscular activity), GSR (galvanic skin response) or Heart Rate (HR). Envisionned actuators relate to new sensory stimulations such as vibrotactile displays or novel visual (eg LED) displays. These prototypes will thus be used in the various experiments planned in the project.

Partners of the project are: Inria, CHART, LIP6, TOMORROW LAND, RCP and potential end-user is Hussein Chalayan fashion creator.

7.1.7. ANR MANDARIN

Participants: Anatole Lecuyer [contact], Maud Marchal [contact], Merwan Achibet.

MANDARIN is a 3-year project funded by the French National Agency for Research (2012-2015). The objective of MANDARIN is to study the design of truly dexterous haptic peripherals allowing natural and intuitive mono or bi-manual interactions with force feedback in virtual environments. The design of an innovative and comfortable and high performance force feedback glove is planned in the project, based on accurate biomechanical models of the human hand. The involvement of VR4i team in the project consists in contributing to the design of novel multimodal 3D interactions techniques and metaphors allowing to deal with haptic gloves limitations and to assist the user in virtual applications requiring dexterous manipulation.
The scientific results will be evaluated with a representative industrial application proposed by Renault, that is not feasible currently with existing technologies (bi-manual manipulation of complex rigid objects and cables bundles).

Partners of the project are: Inria, CEA, UTC, Haption, Renault (potential end-user)

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 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. 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, Ecole 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.

More information can be found on Natural Interactive Walking project website: [http://www.niwproject.eu/](http://www.niwproject.eu/)

### 7.2.3. BRAINVOX

**Participants:** Anatole Lécuyer [contact], Jozef Legeny [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.

### 7.2.4. 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 Fraunhofer 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 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: Vice-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/](http://www.images-et-reseaux.com/)) since 2005, Member of the Management Committee of "Mé- tivier 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 Mechatronics department at École Normale Supérieure de Cachan, 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"
Team VR4I

Member of Executive Board of international Journal IJIDeM. Reviewer for ASME-ISFA2012, ASME-DETC2012, Haptic Symposium 2012, Member of the AFRV, Reviewer for three PhD Defense (two in Politechnico di Milano, one in École Centrale de Nantes).


- V. Gouranton: member of AFRV, co-leader of ANR CORVETTE and FUI SIFORAS.


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
  First year of mechatronics : Design project, 24h, École Normale Supérieure de Cachan, France
  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, 40h, level M2, école Normale Supérieure de Cachan, France
  Master2, formation des enseignants du supérieur : oral preparation to agregation competitive exam, 20h, level M2, école Normale Supérieure de Cachan, France
  Master2, formation des enseignants du supérieur : Vibrations in Mechanics, 10h, level M2, école Normale Supérieure de Cachan, France
  Master2, formation des enseignants du supérieur : Multibody Dynamics, 9h, level M2, école Normale Supérieure de Cachan, France
  Master2, formation des enseignants du supérieur : Finite Element method, 12h, 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 : Human-Computer Interaction 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
  Master : Introduction to 2D and 3D Human-Computer Interaction, 48h, M1, University of Rennes 1, France
• Ronan Gaugne
  Master : Virtual Reality presentation, 12h, M1, INSA of Rennes, FR.
  Master : Projects on Virtual Reality, 20h, M1, INSA of Rennes, FR.
  Master : Projects on Virtual Reality, 16h, M2, INSA of Rennes, FR.
• Valérie Gouranton
  Licence : Introduction to Virtual Reality, 13h, 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, 20h, M1, INSA of Rennes, FR.
  Master co-responsible of M2 Computer Science of RENNES 1 University, INSA Rennes, ENS CACHAN Antenne Bretagne, Supelec, UBO, ENIB, ENSTA Bretagne, Télécom Bretagne, UBS.
• Anatole Lécuyer
  Master IVI : Haptic Interaction, 7 hours, M2, ENSAM, France
  Master SIBM : Brain-Computer Interfaces and Haptic Interfaces, 3 hours, M2, University of Rennes 1, France
• Maud Marchal
  Licence : Programming Language C, 30h, L3, INSA Rennes, France;
  Master : Algorithms and complexity, 30h, M1, INSA Rennes, France; Object-Oriented Modeling and Programming, 43h, M1, INSA Rennes, France; Software Quality, 30h, 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;
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• 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

8.3. PhD

HDR : Thierry Duval, Models for design, implementation and deployment of 3D Collaborative Virtual Environments, defense date 2012/11/28.

PhD : Cédric Fleury, Outils pour l’exploration collaborative d’environnements virtuels 3D, INSA Rennes, defense 2012/06/15, advised by Bruno Arnaldi, co-advised by Thierry Duval and Valérie Gouranton [2].

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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.

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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.

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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 : Léo Terziman, Realistic walking navigation in virtual environments for training, start date 2009/10/01, advised by Anatole Lécuyer and Bruno Arnaldi. [4]

9. Bibliography

Publications of the year

Doctoral Dissertations and Habilitation Theses


**Articles in International Peer-Reviewed Journals**


**International Conferences with Proceedings**


National Conferences with Proceeding


Conferences without Proceedings

Scientific Books (or Scientific Book chapters)

[36] G. CIRIO, Y. VISELL, M. MARCHAL, A. LÉCUYER. *Multisensory and Haptic Rendering of Complex Virtual Grounds*, in "Walking with the Senses", Y. VISELL, F. FONTANA (editors), Logos Verlag, October 2012, [http://hal.inria.fr/hal-00766586](http://hal.inria.fr/hal-00766586).


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[39] L. TERZIMAN, G. CIRIO, M. MARCHAL, A. LÉCUYER. *Novel Interactive Techniques for Walking in Virtual Reality*, in "Walking with the Senses", Y. VISELL, F. FONTANA (editors), Logos Verlag, October 2012, [http://hal.inria.fr/hal-00766588](http://hal.inria.fr/hal-00766588).

Other Publications
