INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

# *Project-Team ALCOVE*

# *Interacting with complex objects in collaborative virtual environments*

*Futurs*

THEME COG

Activity Report

2006

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# 2. Overall Objectives

## 2.1. Overall Objectives

**Keywords:** *3D framework*, *3D interfaces*, *HCI*, *cooperative virtual world*, *interaction models*, *physical modeling*, *virtual reality*.

Our project aims at defining new methods and tools for cooperative frameworks. This work is at the edge of several research areas : physical modeling, virtual reality, and HCI.

- Animation and physically-based simulation is a very active research field. Recent advances, to which our research work contributes, now allow users to interact with physically-based models. Surgical simulation is one of the areas that benefits from this research.
- During the last decade, numerous research works have been carried out that aim at immersing users into virtual worlds. Besides technological aspects (VR devices, ..), these new tools require new kinds of interaction between the users and the environment, as classical WIMP interfaces are no longer suited. It is now clear that many applications do not require the user to be fully immersed into the environment, thus opening a new research area : finding the best compromise between immersion-based realism and new models that allow to navigate in and to interact with the virtual world.
- Graphical Human-Computer Interfaces are now a basic part of any computer. However, they are not well suited to current applications like communication and collaborative work. New research is beeing carried out in order to make them more user-friendly in cooperative environments (Collaborative Virtual Environment, Tangible User Interface).

Our project deals with these three research areas. In the animation and simulation field, we aim at defining virtual objects behaving like real ones. As far as Virtual Reality is concerned, we focus on providing the users with natural interaction with the computer models. Last, we contribute to the HCI community by proposing and experimenting new interaction models and 3D interfaces between the users and the computer objects. Our team has been developping for several years a non-immersive 3D environment mimicking a meeting room. A group of users, each one using its own computer, can meet in a virtual office and work together. Such a concept involves new problems, like manipulating virtual objects inside a cooperative framework (how to model real objects ? how to interact with these models ?).

Our research currently focuses on fives subjects: one on physical models, one on Collaborative Virtual Environments and three around interactions : 3D HCI, tactile actuators and interaction between models and a main application area: medical simulation.

# 3. Scientific Foundations

## 3.1. 3D Human Computer Interface

**Keywords:** *3D desktop interaction*, *HCI*.

**Participants:** Géry Casiez, Christophe Chaillou, Samuel Degrande, Nicolas Martin, Qing Pan, Patricia Plénacoste, Luciana Provenzano, Johann Vandromme, Radu Vatavu.

Since more than 20 years, the fundamental concepts of the computer's desktop environments did not really evolve. Windows, Icons, Mouse, Pointer (WIMP) are always the 2D metaphors used by humans to interact with applications. The 2D window remains the medium of interaction for all 2D and 3D applications. Current windowing systems tend to use the 3D capabilities of modern computer's video cards, but only to add some specific visual effects, such as transparency or shadows.
In our daily activities, we use simultaneously more and more applications, and we display more and more windows on the same screen. In the meantime, there is a growing number of domains requiring applications to work on 3D objects while displaying and working with 2D information. However, the 2D windowing environments are not well adapted to the display and the interaction with such a great amount of information. Some studies did show that the use of a 3D space to organize information can ease the user's activity for the organization of 2D windows. In the case of the concurrent interaction with 3D objects and 2D information, the WIMP highlights its limits and addresses the need for the development of new interaction techniques and input devices. Consequently, the computer-human interfaces must evolve, and we think that the far future computer's desktop systems will be specific 3D environments, seamlessly incorporating collaborative features.

At a low level, virtual tools or action metaphors are needed in collaborative virtual environment to let the user focus on her/his activity rather than on the manipulation of the physical devices [33]. This should be done by matching the interaction technique with the physical properties of the input device. Useless interactions should be removed or replaced with high level virtual tools. Those tools are used to transpose the user intentions, and in a collaborative framework, each public action is to be represented in the remote user's environments, to let them understand the ongoing global activity.
At a higher level, the concept of "3D application" must be defined. A 3D desktop should be able to allow the user to interact simultaneously with several 3D applications, such as 2D windowing systems let users interact with several 2D applications at the same time. A 3D application is roughly a set of 3D objects and 3D tools. Handling several 3D applications thus means that the 3D desktop has to manage several sets of objects and tools, which are not necessarily spatially related. The 3D desktop must also provide specific tools to handle those 3D applications.
We are working on the software and the ergonomic parts needed to create such an environment.

## 3.2. New forms of Collaborative Virtual Environments

**Keywords:** *cooperative virtual environments*.

**Participants:** Christophe Chaillou, Samuel Degrande, Sylvain Gaeremynck, Nicolas Martin, Patricia Plénacoste, Jeremy Ringard, Johann Vandromme.

Traditionally, virtual environments are used in teaching domains, to simulate physical phenomena or to represent objects taken from the natural environment, notably in such domains as medicine, nuclear industry (EDF), transport industry (SNCF, military or civil aviation). Their goal is to reproduce the environment and the objects as they are in reality, by integrating the natural properties of the objects, physical behaviors and environmental constraints. Our proposal is appreciably different. Indeed, we have chosen to consider co-operative activities of small groups of actors around virtual 2D or 3D objects. Our goal is to provide them with a virtual environment which uses classical computers and input devices, and which could be considered as an extension of their current working environment in the broad sense.
At first, we focus on user's activity centered environments. This implies that the CVE should be built around the activity, bringing to the user all the facilities she needs to organize her environment, simply manipulate objects without unneeded interactions, achieve her task as quickly as possible. This notion is in opposite to any other multi-users 3D virtual environments that we are aware of, those propositions being world-centered, trying to mimic the real world by placing a user 'inside' a common shared world without any possibility to adapt it to her personal needs or work's habits. The OpenMASK framework from SIAMES is in this category. We are now shifting our researches to group's activity centered environments, to enable group-to-group collaborations. Two situations are studied : co-localization, where all members of a group are situated in front of a common interaction device, and open collaborative spaces (or *war-rooms*), where the members of a group can use several distinct interaction devices inside a room.
Our second focus is on software architecture. We aim at studying and providing an innovative software framework (from network communication channels, to 3D components), enabling to easily create complex collaborative applications, through the definition of dynamically adaptable interaction components. There are some researches on this topic in the Human-Computer Interface scientific community (in the In Situ project, for example), however they focus on 2D windowing interfaces, and the current findings are not easily transposable to 3D interfaces.
Our activity is at the intersection between the HCI community and the Web3D community.

## 3.3. Tactile actuator

**Keywords:** *normal and tangential strain*, *tactile device*.

**Participants:** Melissande Biet, Christophe Chaillou, Frédéric Giraud, François Martinot, Gaston Mboungui, Patricia Plénacoste, Betty Lemaire-Semail, Zheng Dai.

Since several years, research dealing with touch parameters in interaction situation plays an increasing role in the fields of robotics and haptics since fast development in sensors and actuators miniaturizations could allow studying and reproducing touch at small scale. So, one of the main interests in haptics applied to virtual reality is to find a general purpose desktop I/O device that could enhance virtual touch interactions by stimulating the finger pulp.

To achieve that, we first need a better biomechanical knowledge of touching process - and lateral touch more particularly. In the research field, the influence of the friction dynamics used to perceive still remains unclear. First, the action is not sufficiently characterized. Second, there is no existing description of vibratory sources at contact. And finally, frictional and tactile role of fingerprint ridges in roughness estimation is an open research question. Using measurement and signal processing techniques, we analyze the in vivo mechanical behaviour of limbs, pulp and dermatoglyphs of the finger. We look forward finding exploration strategies which will result in new design guidelines for kinaesthetic and tactile displays.

Our team proposes then new technological solutions for fine textures simulation. On the one hand, we are designing high frequency vibratory devices that can output smooth or braking sensation as a function of the amplitude of vibration. Moreover, by using a position sensor, an amplitude modulation of the vibration is achieved in the bandwidth of the mechanoreceptors, so as to excite alternatively shear forces on the surface of the substrate; stimulation is then synchronised on the fingertip's position. This modulation gives rise to simulation of various rippled surface which could be compared with some gratings. On the other hand, in collaboration with the IEMN laboratory (AIMAN) we participate to the study of a dense pin array based either on electromagnetic technology, or pulse air micro-valve technology. Work, based on the guidelines defined above, has to be carried out in order to apply the "good" stimuli on the fingertip so as to improve the sensations. Moreover, we have to take into account ergonomic considerations in the design of devices; for example, we are designing a 2-dof tactile device which enables tactile exploration with a free motion.

Further to touch interactions, force feedback is also needed to reach deeper immersion in virtual environment. Motors used in kinaesthetic devices are often electromagnetic ones, but piezo-electric Ultrasonic Motors are good challengers in these applications because they can be much smaller for the same output torque, or available for multi dof. However their control is not straightforward. This is why we are designing specific control schemes for those motors. Our goal is to build a 3-D haptic device with force feedback, actuated by three Piezo-electric motors. This prototype should depict how much bulk size reduction can be expected.

## 3.4. Physical models for real-time simulation

**Keywords:** *3D virtual environment*, *Physically-based simulation*, *adaptive models*, *computer graphics*, *computer vision*, *dynamic control*, *hysteresis*, *inverse modeling*, *inverse rendering*, *mechanical simulation*, *multi-models*, *multi-resolution*, *physical parameter identification*, *rendering*.

**Participants:** Fabrice Aubert, Samuel Boivin, Laurent Grisoni, Cédric Syllebranque, Adrien Theetten.

The global activity of the project in real-time simulation is mostly targeted toward surgical simulators. The key activity of the team is to provide complex, integrated surgical protocols, involving several models and surgical aspects. This activity seems complementary, in our opinion, to most of classical simulation research, where results mostly deal with very specific aspects, i.e. collision detection, haptic, or mechanical models. In particular, our activity relates to that of EVASION project (on general-purpose simulation) and ASCLEPIOS project (research on organ mechanical models). We consider to be at the state-of-the-art level for mechanical modeling of deformable 1D models.

About cloth simulation, we have created a new nonlinear model of fabrics. This model is able to automatically integrate the measurements coming from the Kawabata machine, which defines the mechanical behavior of a real garment. Although many research teams work on cloth simulation, we consider our model to be unique because it no longer requires the tuning of physical parameters to create synthetic animations of garments. Two years ago, we have also started a new activity about the mechanical identification of volumetric models from videos. To our knowledge, this research area is poorly studied in the world and no other team has really started to work on similar problems under the same assumptions and physical constraints as ours.

## 3.5. Interaction between models

**Keywords:** *3D virtual environment*, *Interaction*, *collision*, *interaction with haptic devices*, *physically-based simulation*.

**Participants:** Jérémie Dequidt, Christian Duriez, Laurent Grisoni, Damien Marchal.

We have been working on mechanical models, but also on the more global question to know how to mix together algorithmically sophisticated mechanical system: although this question is, to our knowledge, barely studied by other research groups (we can note some early attempts though by Baraff, also SIAMES project), we consider this to be a key point for being able to provide complex surgical protocols in the near future. This aspect, among other, has allowed us to initiate, along with the CIMIT simulation group, the SOFA project, that now turns into international level.

This work includes dealing with contact and friction between deformable bodies [15] that have a big impact on mechanical behavior of models. Contact models are often solved with simplified method with real-time constraint. However these simplified method could lead to false behaviors. This is not acceptable in the medical simulation context [17] where we try to use interactive simulation for planning. Thus, we propose an active research on models for contact and friction between deformable objects and on efficient solvers.

# 4. Application Domains

## 4.1. Medical simulation

**Keywords:** *health*.

Medical simulation has been a very active research field for the past ten years. The ultimate goal is to provide medical students with realistic simulators that reacts like actual human patients.

One of the most challenging task in medical simulation is to realistically model soft organs and tissues, and their interaction with surgical instruments, requiring real-time solutions to complex problems like physical modeling, collision detection, ...

We continue our contribution to the development of medical simulators. We have recently concentrated our effort on the design of a cataract surgery simulator in ophthalmology. The first step of the operation (namely capsulhorexis) has been modeled. We now have a realistic real-time behavior of the capsule and its interaction with the surgical instruments. The next step will be the realistic modeling of the lens. A first approach based on finite-element modeling has been investigated. It allows for an accurate simulation of the phacoemusification procedure (breaking of the lens).
We began a collaboration with Magritt project at INRIA on the realistic simulation of brain aneurysm embolization. A first project, named "‘simple"’ was proposed for ARC. We wish to shear our knowledges about medical image processing for Magritt and physically based simulation for Alcove. We would like to propose simulation as a tool, not only for education, but also for planning.

Following our first experience with the SPORE real-time simulation engine, we have started the development of a next generation engine (called SOFA) that will be more flexible than the previous one. This development is a joint-effort between Alcove, Asclepios (INRIA Sophia), Evasion (INRIA Grenoble) and the Sim group@CIMIT (Boston, USA). Our purpose is also to collaborate with other worldwide research teams involved in simulation.

# 5. Software

## 5.1. Spin 3D

**Participants:** Samuel Degrande, Damien Fournier, Sylvain Gaeremynck, Nicolas Martin, Luciana Provenzano, Ahmed Tahar, Julien Vandaele.

Spin|3D is a synchronous collaborative software platform, which implements the Collaborative Virtual Environment concepts presented in 4.1. Spin|3D is developed in collaboration with France Telecom R&D (Lannion's site). A multi-disciplinary team (computer scientists and psychologists) composed of a dozen of members (one half in Lille, one half in Lannion) works on that project. We aim at providing a complete software environment to ease the development of collaborative applications.
For that purpose, Spin|3D is built on a core layer which can be extended with dynamically loaded external modules. Two kind of external modules can be plugged : viewer plugins, to display objects not directly handled by the core layer (such as an HTML plugin, for example), or autonomous external applications which communicate with the core through a local Corba bus (with that mechanism, a legacy software such as a CAD modeler can be connected to Spin|3D, without needing any heavy cross-integration).

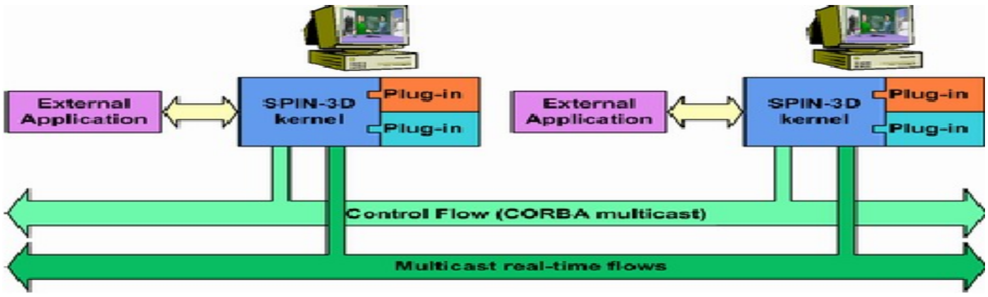



*Figure 1. Architecture of an application based on Spin|3D*

Until mid-2004, the LIFL worked, mainly, on "low level" layers, furnishing the communication framework and the object handling layer. Since then, we work on providing genericity and configurability to all platform's layers. We are, also, developing an authoring tool to help designers write a Spin|3D application. We lead researches on other based component approach [26] [25]. France Télécom, on its side, studies human/human communications through the development of avatars, the integration of video-communications, free-hand interactions and works on the definition of end-users applications.

*Figure 2. A terminal view of a Spin|3D application*

The main target applications are digital project reviews, support for medical diagnostics, virtual laboratory works and network games. France Télécom, with the IRCAD, has developed, during 2003, a prototype of a medical diagnostic application, called Argonaute 3D. An improved version of this application is currently being developed for the Odysseus European project.
Spin|3D will be used in the context of Part@ge, a national project funded by the ANR. Some technologies used in Spin|3D are also being transferred to a local small company. Some other applications, in the digital project review domain, are in preparation.

## 5.2. SOFA

**Participants:** Pierre-Jean Bensoussan, Stéphane Cotin, Jérémie Dequidt, Sylvère Fonteneau, Sylvain Karpf, Laurent Grisoni, Damien Marchal.

We are currently involved in an open-source, real-time simulation plateform project. The SOFA project is the result of a collaboration between the CIMIT Simulation group (Harvard Medical school, leader Stephane Cotin), and INRIA projects EVASION (leader Marie-Paule Cani, INRIA Rhônes-Alpes) and ASCLEPIOS (leader Nicolas Ayache, Sophia-antipolis). This project was born when it appeared CIMIT and ALCOVE project, separately, had started quite the same work: propose a framework flexible enough so that people would reuse algorithmic blocks, and change, for a given object, collision representation, visual and mechanic representation, as independently as possible. We chose to join effort, and after EVASION and ASCLEPIOS joined us in this work, INRIA supported this project by providing 2 engineers, for 2 years, for this project. The alpha version of the SOFA plateform should be made public soon. It provides multi-threaded support for simulation algorithmic (not only for drawing and/or haptic control), proper handling of group (for collision and constraints), and software structure that provides enough flexibility and genericity for people to consider functional blocks as exchangeable, and semantically start to build their own simulator efficiently.

# 6. New Results

## 6.1. A specific metaphor for Private Point of View

**Participants:** Johann Vandromme, Samuel Degrande, Nicolas Martin, Patrica Plénacoste, Luciana Provenzano.

In some collaborative activities, such as the manipulation of complex objects, different users can work on distinct parts of a shared object. This implies that each user has her own viewpoint on the object. Viewpoint awareness is then necessary both to coordinate each other and to understand remote users' activity during the execution of the collaborative task. We propose a combination of several metaphors to provide a remote viewpoint awareness in a 3D collaborative desktop in which multiple shared objects can be independently positioned and manipulated [32].

## 6.2. Dynamic adaptation of instrumental interaction

**Participants:** Nicolas Martin, Samuel Degrande, Ahmed Tahar.

The concept of instrumental interaction, introduced by Beaudouin-Lafon, is used in post-wimp interfaces to implement modern interaction mechanisms. However, in current implementations, the interaction tools are static ones, and are not able to adapt themselves to the interaction context, nor to the objects they are acting on. We propose an extension of the instrumental interaction concept, based on interaction rules, that is able to dynamically adapt the behavior of an interaction tool, through modification, augmentation, or deletion of its internal state, depending of the interaction context [28].

## 6.3. Interactive Accurate Simulation of Cables

**Participants:** Adrien Theetten, Laurent Grisoni, Christophe Chaillou, Brian Barsky, Xavier Merlhiot, Claude Andriot.

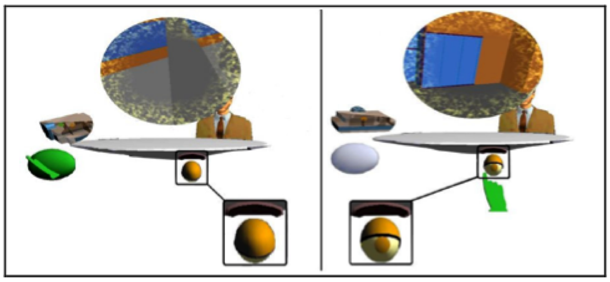


*Figure 3. Metaphors used to manage private point of views*

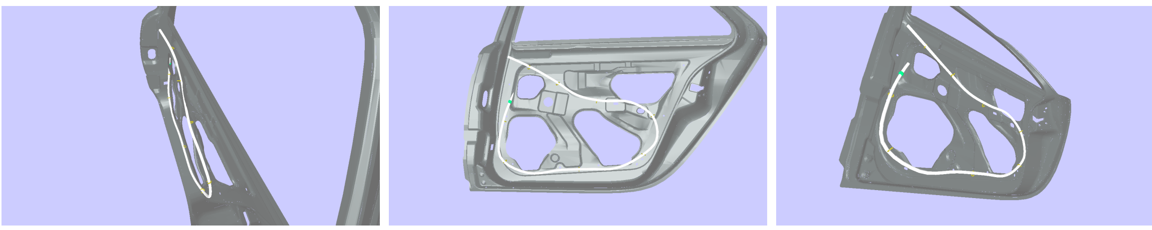


*Figure 4. Virtual cable positioning on a car door.*

We have proposed a complete model handling physical simulation of deformable 1D objects. The formulation of continuous expressions for stretching, bending and twisting energies has provided mechanically rigorous and geometrically exact simulations. We have also handled both elastic and plastic deformations to simulate a wide range of materials. We have then validated our model on several classical test configurations. The use of geometrical exact energies with dynamic splines has provided very accurate results as well as interactive simulation time, which has shown the suitability of the model for constrained CAD applications. We have illustrated the application potential of the proposed model by describing a virtual system for cable positioning 4, that can be used to test compatibility between planned fixing clip positions, and mechanical cable properties. More details are available in our research report [34].

## 6.4. Cutting and suture of deformable objects

**Participants:** Laurent Grisoni, Damien Marchal, Christophe Guerbert.

This work takes place in the context of our surgical simulator activities (see SPORE and SOFA). To simulate cutting operation, we proposed new algorithms based on Meshless methods. The approach is based on the Shape-Matching method. This method is used to animate object deformations and has the strong advantage to be unconditionally stable. Compared to more classical FEM based approaches, where the underlying tetrahedral mesh has to be well conditioned, the stability of the Shape-Matching approach a more easy cutting procedure. The main drawback of the Shape-Matching approach is that it is based on the object segmentation. We proposed a new algorithm that is fast enough to be used in real-time while the object is cut. First results of this work have been presented in Damien Marchal's PhD thesis [13] and during the poster session at the SCA conference [27]. In the following of this work we start, with Christophe Guebert, a new PhD thesis on suturing .

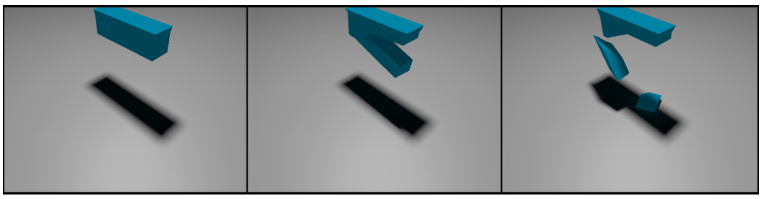


*Figure 5. An exemple of the cutting of an object. The object is composed of 7000 tetrahedras, animation of the deformation is in real-time.*

## 6.5. Substructure Analysis

**Participants:** Christian Duriez, Stéphane Cotin, Julien Lenoir.

We have proposed in [14] a series of novel approaches that have lead to the development of a high-fidelity simulation system for interventional neuroradiology. It combined a real-time incremental Finite Element Model, an optimization strategy based on substructure decomposition, and a new method for handling collision response in situations where the number of contacts points is very large.

## 6.6. Inverse dynamics

**Keywords:** *computer graphics*, *computer vision*, *inverse modeling*, *inverse rendering*, *mechanical simulation*, *physical parameter identification*, *rendering*.

**Participants:** Cédric Syllebranque, Samuel Boivin.

We propose a new method for estimating the physical properties of complex objects from an image sequence. Actually, we want to approximate the mechanical properties of a deformable object directly from a real video. We have been working on a new algorithm being able to recover the parameters of a deformable solid simulated by a finite element method, directly from a real image sequence: a user applies a force on a deformable solid using a special device that we created for this purpose (see left picture of figure 6). This device has been achieved past year, and we have been realizing many experiments to validate it. Indeed, it appears that because of friction issues, we had to enhance some details for ensuring a valid estimation of the external forces captured by this device. At the same time, we have also developed a complete environment that includes real-time acquisition of video sequences, automatic calibration of cameras and rerendering of synthetic sequences.

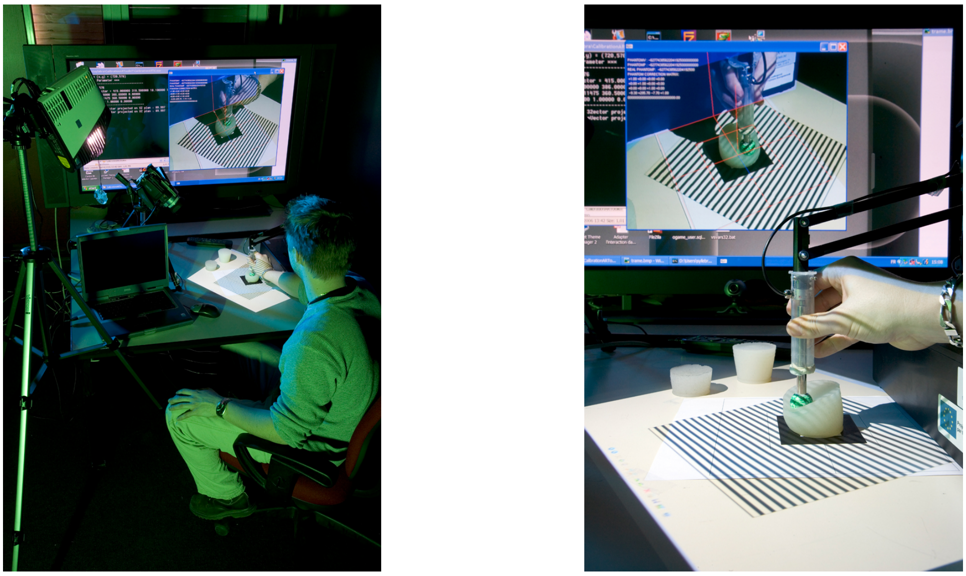


*Figure 6. Left: our device for real-time capturing of external forces applied on an object. Right: A closer look at the system.*

For estimating the physical properties of a soft bodies, we capture the whole scene using a camera, and we project a specific pattern on the real object using a regular video projector. The whole scene is reconstructed in computer graphics and the physical parameters (the Young modulus and the Poisson coefficient) are now estimated from the real image sequence using an iterative technique minimizing the error between the real and the synthetic videos (see figure 7).

We use Christian Duriez's FEM simulator to reproduce the soft body in computer gaphics. Our main algorithm has been designed for automatically recovering the Young modulus and the Poisson Coefficient only using our device and a video sequence of the deformable body. Therefore we have achieved a full study of these two parameters and their impact on the generated image sequences. It appears that the Poisson coefficient does not vary very much for very different silicons even if their hardness is extremely different. That is why we have decided to extend our technique to other materials such as cleaning sponges for example. The error metric used in the comparison between real and synthetic images seems to work well but we definitely need to further validate it. Once all these techniques will have been validated on simple deformable solids, we will work on recovering the parameters of more complex objects such as real human organ.

## 6.7. Nonlinear cloth simulation

**Keywords:** *cloth simulation*, *hysteresis*, *nonlinear deformation*, *numerical computation*, *parameter identification*, *physically based modeling*, *solid friction*.

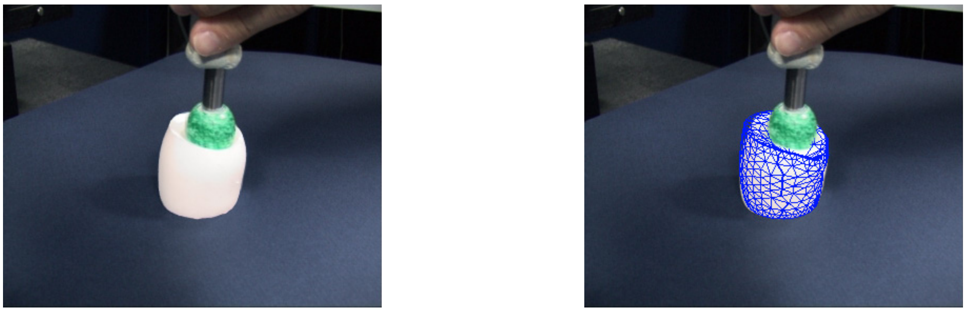


*Figure 7. Left: original video. Right: Projection of the deformable solid simulated using the recovered parameters from the original video.*

**Participants:** Cyril Ngo-Ngoc, Samuel Boivin.

We have developed a new cloth model that is based on the Kawabata Evaluation System (KES). It reproduces the behavior of a cloth using the parameters coming from direct measurements on real clothes. Therefore we propose an identification procedure to compute all the physical parameters of our model directly from the KES curves. Since many textile manufacturers use this KES to design their fabrics, we are able to accurately simulate their real fabrics in computer graphics using the manufacturer's parameters. We are currently working on the production of a high quality movie with a famous special effects company. We have filmed a fashion show with a real mannequin wearing complex clothes, and we are reproducing this video in computer graphics by creating a virtual fashion identical to the original one using our cloth model. This work is very hard to achieve and we are still working on different details in order to validate our physical model. We have also recently decided to try to recover the KES parameters videos of real fabric samples using the a similar technique than the one we used for deformable bodies (see section 6.6).

## 6.8. The impact of control-display gain on user performance in pointing tasks

**Participant:** Géry Casiez.

We theoretically and empirically examine the impact of control-display gain (CD) on mouse pointing performance. Two techniques for modifying CD gain are considered: constant-gain (CG) where CD gain is uniformly adjusted by a constant multiplier, and pointer acceleration (PA) where CD gain is adjusted using a non-uniform function depending on movement characteristics. Both CG and PA are evaluated at various levels of relationship between mouse and cursor movement: from low levels which have a near one-to-one mapping, through to high levels that aggressively amplify mouse movement. We further derive a model predicting the modification in motor-space caused by pointer acceleration. Experiments are then conducted on a standard desktop display and on a very large high-resolution display, allowing us to measure performance in high index of difficulty tasks where the effect of clutching may be pronounced. The evaluation apparatus was designed to minimize device quantization effects, and also used accurate 3D motion tracking equipment to analyze users' limb movements.

On both displays, and in both gain techniques, we found that low levels of CD gain had a marked negative effect on performance, largely due to increased clutching and maximum limb speeds. High gain levels had relatively little impact on performance, with only a slight increase in time when selecting very small targets at high levels of constant gain. On the standard desktop display, pointer acceleration resulted in 3.3% faster pointing than constant gain, and up to 5.2% faster with small targets. This supported the theoretical prediction of motor-space modification, but fell short of the theoretical potential, possibly because PA caused an increase in target overshooting. Both techniques were accurately modeled by Fitts' law in all gain settings. From our results, we derive a usable range of CD gain settings between thresholds of speed and accuracy given the capabilities of a pointing device, display, and the expected range of target widths and distances.

## 6.9. Microscopic aspects in the dynamic exploration of fine haptic textures.

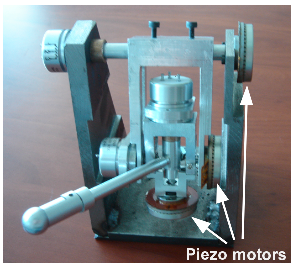
**Participants:** Melisande Biet, Christophe Chaillou, Betty Lemaire-Semail, François Martinot, Patrica Plénacoste.

For given exploration tasks of haptic textures, we found a random strategy in directed motion [31]. Measurement campaigns also allowed to conclude on a lack of consistent relationships between the texture relief and vibratory phenomena at contact [31][30][29]. This was explained by the tribologic complexity of touch at a microscopic scale induced by the presence of epidermal ridges. Even if macroscopic phenomena mainly explain perception, we suggest that it is important to consider the micromechanics of touch [29]. Thus, we showed the importance of the interlocking between surface states to perceive the fine texture [29]. To quantify the roughness intensity, we have to explore whether the shape of the skin texture conforms to the relief of the haptic texture in order to perceive the micro texture [24]: the fingerprint pattern justifies then the control of the voluntary motion. This feature applies in the case of fine texture. New design guidelines emerged for kinaesthetic and tactile displays [20].

## 6.10. Achieving virtual stiff walls with a force feedback device based on piezo-electric motor

**Participants:** Frédéric Giraud, Betty Lemaire-Semail, Zheng Dai.

The rotor of the piezo-electric motors is propelled by friction by a bending wave at the surface of the stator. They have then a high holding torque if not supplied because in that condition rotor is locked on stator. This feature can be used to simulate very stiff walls on a 1-dof force feedback device [23]: if the device's lever is at the position of the virtual wall, the supply voltages of the motor are set to zero, otherwise the motor is controlled in an elastic mode (figure 8). The main advantage is that the wall mode ensures passivity of the interface because no energy is supplied to the motor. This strategy is specific to this kind of motors[18]. Finally, a torque estimator has been designed; it can help to remove the torque sensor of the test setup [16].



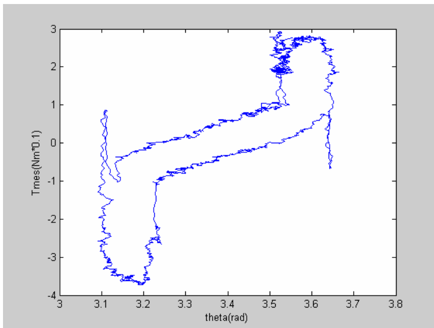




*Figure 8. Force-feedback using piezo-electric travelling wave ultrasonic motor - left - prototype of the 3-dof digitracker and its 3 piezo motors -Right - stiff wall operations removing motor's supply*

## 6.11. Simulating fine textured surfaces

**Participants:** Frédéric Giraud, Betty Lemaire-Semail, François Martinot, Melisande Biet.

Using a stator of Travelling Wave Ultrasonic Motors and a linear position encoder [21], we have demonstrated that it is possible to simulate various rippled surfaces with a high frequency vibrating device. Comparison tests with striated layouts etched on a copper printed circuit board have been carried out, and show a good percentage of correct recognition for those specific rough textures [20]. Then to derive some prerequisite for the design of a new tactile display based on this principle, we suggested carrying out a study to investigate the use of ultrasonic transducer to understand determinants of friction at contact (figure 9). Results give the vibration amplitude which is necessary to make a fine textured surface significantly smoother than it is actually. Moreover, we showed that this threshold is larger if the directed movement is done along the epidermal ridges than across [19]. This suggests that tactile perception of texture really depends on the bearing exerted by the surface state on the skin.

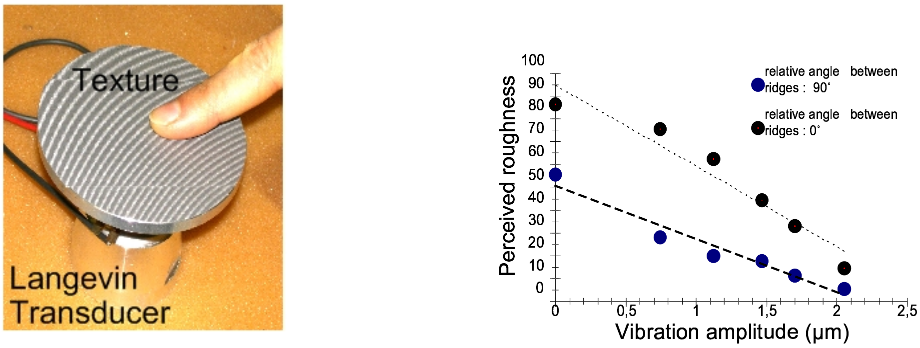



*Figure 9. Investigation of determinants of friction at contact - left - Langevin transducer with its thin disc glued on its top and surfaced by the grooved surface - right - Geometric mean magnitude estimate as functions of the vibration amplitude of the disc.*

# 7. Contracts and Grants with Industry

## 7.1. France Télécom R&D

We work in collaboration with France Télécom since 1994. In a first period, from 1994 to 1997, a CTI contract was established to develop a first prototype of a collaborative work interface, called Spin. Two PhD thesis were defended in the LIFL, one of them being supported by the contract.

In 1999, France Télécom showed its interest in our research by creating a project-team in its Lannion's site, recruiting the first PhD student who was on the CTI contract, and supporting a third PhD student who defended his thesis in 2001 on the articulation between action and communication in non-immersive virtual environments.

In order to jointly develop a pre-industrial framework, based on the first prototype studies, a second contract (External Research Contract) was signed between the University of Lille 1 and France Télécom in 2000, for 2 years, for a global amount of 1,1MF HT. Since 2001, the Spinl3D team in France Télécom is composed of 5 full-time members.

In 2003, two other contracts have been signed between the University of Lille 1, the INRIA and France Télécom. The first one, for an amount of 240kEuros HT, concerns the finalization of the core framework, and the integration of some new features. The second one supports one half of Nicolas Martin's PhD thesis, the other half being financed by INRIA.

A new contract started in 2005 in order to integrate Nicolas Martin's results into the SPIN framework. This work is done by Ahmed Tahar.
We are currently collaborating in two projects : Odysseus, a Eureka project, and Part@ge, an ANR funded project.

## 7.2. CEA

We are collaborating with Claude Andriot (LIST Team, CEA, Fontenay-Aux-Roses) through a co-funded PhD Thesis (Adrien Theetten). This work aims at modeling slightly deformable 1D objects for CAD applications (simulation of the behavior of large cables) in urban projects, building design, ...

Partnership with the laboratory of CEA-LIST Fontenay aux Roses :

- CEA gave the university direction to Laurent Grisoni and Christian Duriez for the PhD thesis of Guillaume Saupin. This thesis is completely financed by CEA.
- M. Hafez is copromoter of the PhD thesis of R. Demerssemann who works on magneto-rheological fluids in order to design a tactile display. This study has begun in November 2005.

## 7.3. GPUTech

GPUtech is a french start-up specialized in GPU-based rendering software. They now want to investigate the use of GPUs for physic-based simulation engines. We have just started a first collaboration (GPU-based implementation of our dynamic 1-D Spline model).

# 8. Other Grants and Activities

## 8.1. National initiatives

- Part@ge (ANR 2006 - RNTL - Partners : INSA Rennes, INRIA (Alcove, I3D), CNRS (LaBRI, Mouvement et Perception), ESIEA, FT R&D, CEA-LIST, VIRTOOLS, HAPTION, CLARTE, RENAULT, THALES, SOGITEC).

  This project aims to propose a software platform for collaborative work, studying it from the point of view of a human interacting in collaboration inside a 3D environment. Part@ge will use a multi-criteria analysis in order to propose several innovative solutions:

  - functions associated with collaboration in a 3D environment: starting from technical design up to maintenance skill acquisition, the need to communicate and collaborate around 3D digital models is a major stake for the industry.
  - technical infrastructures helping collaboration: there is a great diversity of technical platforms needed for collaborative 3D activities: from PDAs to *war-rooms*. Each of them has specific features that are more suited to specific applications.
  - tools to spread 3D collaborative activities : to maximize the spread of Part@ge's innovative tools, three platforms already developed by some of the partners will be used : OpenMask, Spin and Virtools.
  - scientific and technical new solutions: the heart of the project is composed by several research studies which intend to solve some current scientific and technical problems : models for CVE, communication and presence, advanced collaboration, usage of collaboration.

  The INRIA is involved in a large part of this project.

- VORTISS (ANR 2006, programme "Masse de Données et Connaissances Ambiantes" Partners : LSIIT, IRCAD, SIS. This project is leaded by Laurent Grisoni.).

  This project aims at designing a robust and unified model which allows a faithful restitution of the shape and behaviour of organs in surgical simulators. This model relies on a coupling between several components: a precise geometric and visually realistic model of the organ which is reconstructed from medical images, a rigorous topological model allowing incisions, cuttings, tearings and destruction while assuming the structure consistency, a hybrid mechanical model and an interaction model which is adapted to deformable bodies with variable topology and allows the control of haptic devices. To deal with the precision vs computation speed compromise, the four components are necessarily multiresolution. The resolution of each model is chosen independently even if the model control remains highly connected to the other components.

- STIC-ASIE

  we did participate to the STIC-ASIE project, funded by CNRS. This project aimed at structuring potential collaborations between france and Asia, about Virtual Reality. Several workshops have been organized in france and asia (japan and Korea).

## 8.2. European initiative

- Odysseus (Eureka - Partners : IRCAD (Strasbourg), France Telecom, Storz (Germany), SimSurgery (Norway), INRIA (Alcove, Evasion, Asclepios)).

  The three main objectives of this project are :

  - develop an operational patient 3D-reconstruction tool or commercial service
  - develop a 3D tele-diagnosis software based on the SPIN platform
  - develop a urology and liver-surgery simulator

  We are involved in the last two sub-projects.

## 8.3. Chinese collaboration

Christophe Chaillou is in sabbatical leave in LIAMA for 2006-2007 year. With professor Pan Chunhong, we start a new collaboration about communication in collaborative 3D environment. We work to find a good representation for the person on the distant computers (mixing video and avatar) for collaborative work. Two chinese students are working on the subjet.

## 8.4. Visiting scientists

### *8.4.1. Pr. Brian Barsky*

Following an initiative by S. Boivin, Pr. Brian Barsky from Berkeley is visiting us for one year, starting september 2005. He is working on two of our projects : real-time simulation of 1D-Splines based objects, and modeling of the eye for a corneal transplant simulator. We hope this will lead to a strong collaboration between Alcove and the University of Berkeley.

### *8.4.2. Dr Stéphane Cotin*

Dr Stéphane Cotin, lead of the Simulation Group at CIMIT (Boston, USA), has been part-time researcher in the Alcove team in 2005, in order to lead the SOFA project. He also came 2 months in 2006 (january and may).

# 9. Dissemination

## 9.1. Leadership within scientific community

- Alcove co-organized a workshop at Eurohaptics 2006 on tactile subject.
- Alcove attented the '13èmes Rencontres INRIA-Industrie" with Inserm: "'Les Sciences et Technologies de lInformation et de la Communication au service de la Médecine"' at Rocquencourt in January 2006. We presented a demonstration about eye surgical simulation and Christophe Chaillou had a talk about surgical simulation with a presentation of SOFA "'Simulateurs Chirurgicaux : du moteur de simulation à l'application "' <resumes/interventions.fr.html#chaillou>,.
- Alcove attended the "ZOOM Sciences et Technologies : Technologies émergentes des TIC" organized by the University of Lille in December 2005 during the NET 2005 meeting, with a demonstration about Interacting with Deformable Virtual Objects.
- Betty Lemaire-Semail participate to external PhD committees: 7 since 2003 (5 rapporteur, 1prd, 1 mb), Congress reviewer : EPE, EPE-PEMC, Euro-PES 2005, IAS 2004 Journal reviewer : EPJ Applied Physics, IEEE trans. On Industrial Electronics, IEEE trans. On mechatronics, EPE journal, RIGE, journal of micromecanics and microengineering, EMPS, IEEE Trans on UFFC. An average of 4 papers reviewed each year. Member of the international Steering Committee of EPE since 2001 Chairman of an oral session at EPE-Toulouse (2003) and EPE-Dresde (2005)
- Frédéric Giraud participated to 1 internal PhD. Journal reviewer for Transactions on Ultrasonics, Ferroelectrics and Frequency Control since 2005. 3 papers reviewed. Chairman of an oral session at the Intenational conference on IEEE Industrial comminty (IECON'06 - Paris).
- Christophe Chaillou was reviewer for the French research network RNTL (2 projects reviewed) the French research network in Medical (2 projects reviewed) and ARA Masse de Données (1 project reviewed). He was also reviewer for 3 PhD Thesis. He is a member of the program committee of VRIC, Vriphys 06 (workshop on virtual reality interaction and physical simulation) and Eurohaptic 2006. He was invited for a talk to the 2nd Workshop on Computer Assisted Diagnosis and Surgery, Santiago (Chile)[22].
- Laurent Grisoni was reviewer for Eurographics 2006 and for the Journal of Graphic Tools. He was also examiner for the PhD Thesis of Laks Raghupathi.
- Géry Casiez was reviewer for the French research network RNTL (1 project reviewed). He was also examiner for one PhD Thesis and is reviewer for 3DUI, Eurohaptics and WorldHaptics.
- Christian Duriez was in the Organizing committee (Demo and Poster Chair) of Eurohaptics Conference (2006) and reviewer for Eurohaptics 2006 and WorldHaptics 2007.
- Francois Martinot reviewed 6 papers for the Haptic Symposium Conference. He defended his phD on October 10th 2006 [12].
- Damien Marchal reviewed 1 paper for IEEE Visualization 2005. He defended his phD on October 12th 2006 [13].

## 9.2. Teaching

- Master students (University of Lille I) :
  - Samuel Boivin : computer graphics (rendering and inverse rendering)
  - Christophe Chaillou : digital image processing.
  - Laurent Grisoni : computer graphics (Animation, geometric modeling)
  - Frédéric Giraud : Fundamentals of Piezo-electricity.
- Engineer students (Polytech'Lille)

- Géry Casiez : Haptic, HCI, GTK
- Christophe Chaillou : Computer Graphics, HCI, VR, Data and Image Compression
- Laurent Grisoni : Animation, Advanced Computer Graphics
- Sylvain Karpf : Computer architecture, Computer Graphics
- Patricia Plénacoste : HCI - Ergonomics
- Betty Lemaire-Semail : electromagnetism, piezo-electric control

- Engineer students (ENIC - Lille)
  - Géry Casiez : Haptics
- Faculty students (University of Lille I)
  - Fabrice Aubert : 3D Programmation, Introduction to Computer Graphics
  - Géry Casiez : 3D Programming, Pascal programming, Linear programming and graph theory
  - Patricia Plénacoste : HCI - Ergonomics.
  - Frédéric Giraud : Modeling and Control of electrical devices, Introduction to electrical engineering

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