INRIA

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

2007

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2. Overall Objectives

2.1. Introduction

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 in physical simulation. We focus on the medical field as main application area. We target tools (both numerical and hardware) for medical simulation, as well as for improval of patient rehabilitation .

2.2. Highlights of the year

- Thanks to Christophe Chaillou sabbatical leave, our team starts this year new collaborations with two teams, one in Institute of automation, Chinese Academy of Science conducted by Pan Chunhong and one in School of Mechanical Engineering and Automation, Beihang University leaded by Zhang Yuru.
- Virtual reality room: a VR room has been built (project lead: S. Boivin). This room is composed of some immersive cylindrical display system, combined with AR-track infra-red acquisition system for user gesture. This room will first allow us to promote VR tools in the academic and industrial field; also we plan to investigate further into gesture real-time analysis. The planned application fields are free-hand interaction, and gesture qualification for patient rehabilitation (ANR TecSan Reactive project)

- This year has seen the publication of a full paper in a major conference in the field of HCI: the 20th ACM Symposium on User Interface Software and Technology (acceptance rate = 17%). This work presents the RubberEdge technique that combines position and rate control with elastic feedback to reduce clutching (see section 6.4 for more details).
- During the MMVR 2007 international conference we organized a workshop to present SOFA and released the first public version of the code. This first release came with a series of examples as well as a prototype of an ophthalmology simulation system. This simulator focused on retinal reattachment surgery involving diabetic traction and retinal tears. The prototype included a detailed anatomical model of the eye, deformable models of the retina and circular fibovascular membrane within the retina. Initial cutting algorithms were also integrated in this simulation to simulate the action of a blade instrument. Images of the simulator are shown in Section 5.2

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, Quan Xu, Jean-Philippe Deblonde.

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 [32]. 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, Nicolas Martin, Patricia Plénacoste, Jeremy Ringard, Johann Vandromme, Haibo Wang, Damien Fournier.

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 he needs to organize her/his environment, simply manipulate objects without unneeded interactions, achieve her/his 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/his 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, Gaston Mboungui, Patricia Plénacoste, Betty Lemaire-Semail, Zheng Dai, Mohamad Abdolvahab.

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.
Our team proposes then new technological solutions (like, this year [14], [17], [11], [21]) 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 synchronized 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.

But work has to be carried out in order to apply the "good" stimuli on the fingertip so as to improve the sensations. To achieve that, we first need a better biomechanical knowledge of touching process - and lateral touch more particularly. In this 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 appropriate modelings taking into account those characteristics, we look forward describing physical phenomena located at the contact point between a fingertip and an explored surface in order to deduce the lateral stress field induced by touch movement. At the end, stimuli variation will be found by inverting this modelling.
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: Jérémie Allard, Samuel Boivin, Laurent Grisoni, Cédric Syllebranque, Adrien Theetten, Christophe Guébert, Guillaume Saupin, Olivier Comas, Pierre-Jean Bensoussan, Juan-Pablo de la Plata Alcalde, Stéphane Cotin.

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 Allard, Jérémie Dequidt, Christian Duriez, Laurent Grisoni, Stéphane Cotin, Pierre-Jean Bensoussan, Juan-Pablo de la Plata Alcalde.

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 that have a big impact on mechanical behavior of models [13]. 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 where we try to use interactive simulation like the one presented in [25] 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*, *planning*, *simulation*, *soft organ models*, *training*.

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 react 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 [25] [19] [33]. 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.

4.2. Virtual Rehabilitation

Keywords: *Cerebral Vascular Accident*, *health*, *rehabilitation*, *simulation*, *stroke*.

We started this year some research on patient rehabilitation. This activity is supported by the ANR TecSan Reactive project, that will start in january 2008. This project is lead by the HOPALE fundation (medical institute, specialized in medical rehabilitation), and also involves the CEA, as well as Idees3com company.

Reactive addresses rehabilitation for patient that have suffered cerebral vascular accident (CVA). It aims at proposing new VR-based tools for rehabilitation, that would:

- improve patient involvement into her/his own rehabilitation, by proposing attractive training exercices;
- increase transfer of recovered skills, from exercices to real-life situations.

The proposed tools integrate tactile interfaces, including grabbing task analysis. We also plan to study how to evaluate some gesture quality: in the long term, this activity would open way to accurate exercice efficiency evaluation. Also, Human-Computer interfaces that integrate gesture analysis are hopefully reachable in a reasonnable range.

4.3. Commercial Industries

During the year we participate to meetings of the PICOM "Pôle de compétitivité industries du commerce". We worked on a pre-project study, targeted toward virtual design of shops. We collaborate with Idées3com company, that proposes web-based interface for shopping. In the PICOM context, we currently identify several research fields that could be of practical interest for the ALCOVE project. We think shop design, and also possibly virtual shops for client could provide interesting testbed for advanced interaction techniques.

5. Software

5.1. Spin 3D

Participants: Samuel Degrande [correspondant], Damien Fournier, Nicolas Martin, Luciana Provenzano, Ahmed Tahar, Julien Vandaele.

Spin|3D is a synchronous collaborative software platform, which implements the Collaborative Virtual Environment concepts presented above. 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).

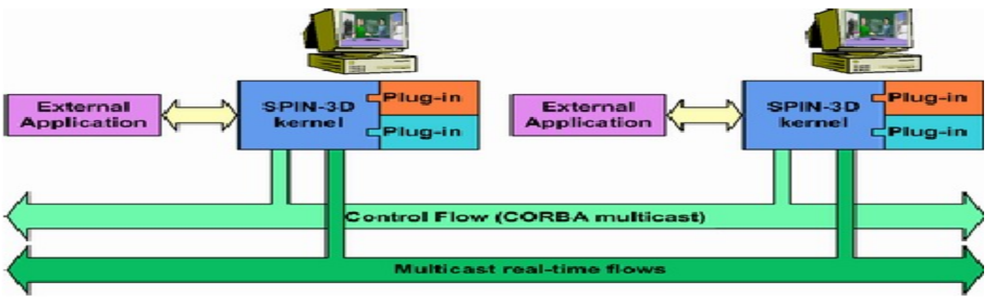


Figure 1. Architecture of an application based on Spin|3D

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 component based approach. 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.

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 was being developed for the Odysseus European project.

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

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: Jérémie Allard [correspondant], Pierre-Jean Bensoussan, Stéphane Cotin [correspondant], Jérémie Dequidt, Laurent Grisoni, Christian Duriez, Juan Pablo de la Plata Alcalde.

This research outlines a plan to build a foundation for a potential interoperability standard for Medical Simulation. Theoretically, such a framework should be generic, platform-independent, public domain, open source, and extendible. ALCOVE has been working on this concept for the past few years and with the assistance of several INRIA projects (EVASION, ASCLEPIOS) and CIMIT simulation group at Boston. We have assembled a beginning prototype that we demonstrated at Medicine Meets Virtual Reality (MMVR). We wanted to extend and refine this prototype with the aim of publicly releasing it to the medical simulation research community. Essentially, SOFA (Simulation Open Framework Architecture) is a flexible core framework which will allow independently developed algorithms to interact together within a common simulation while minimizing the development time required for integration. The main objective of SOFA is to foster collaboration among research groups. Rather than a centralized toolkit for Medical Simulation, our approach focuses on the development of a core technology that will support the integration of modules using a plug-in system. It is our hope that SOFA will simplify the developmental time for simulators, reduce production costs, and provide a means to share components through a common interface.

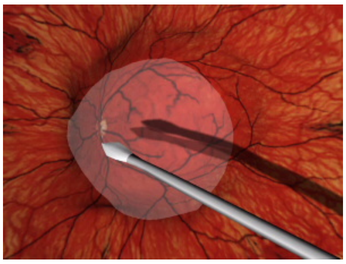
Framework Improvements

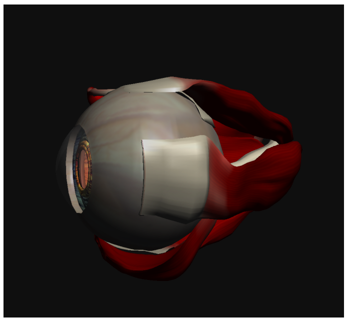
Framework Improvements include (but is not limited to...)

- Cutting

  The initial focus of the SOFA framework was on collision detection, deformation, collision response, and visual feedback since they are the current foci of the medical simulation research. Other simulation components such as cutting, physiology, haptics, multi-processing, etc can be required depending on the application requirements. Of these, cutting poses the greatest challenge since it changes the topology of all of an object's mapped representations such a visual, behavioral, collision and other possible future representations. As a result, a variety of cutting interface proposals were put forth so that this action could be simulated within SOFA framework before it matured too much.

- Multi-Processing





(a) (b)

Figure 3. Application using SOFA: surgical procedure in ophthalmology

Because of their complexity, realism demands and interactive requirements, medical simulators often strain their computing and rendering capabilities. With decreasing hardware costs, multiple central processing units (CPUs) and more efficient graphics processing units (GPUs) are becoming more affordable. The SOFA framework has now the capability to take advantage of these multi-processing computing environments.

- Contact processing

  SOFA framework includes new algorithms for the collision response based on unilateral constraints and non-linear friction constraints based on Coulomb's law. The contact equations are solved using Gauss-Seidel iterative solver.

The number of downloads of the project from its web site (www.sofa-framework.org) after its initial release is close to 5,000. SOFA was presented during the MMVR 2007 conference [16] and during Surgetica [20]. We were present at Siggraph Emerging Technologies with an interactive demo integrating SOFA in the GrImage realtime multi-cameras 3D acquisition platform.

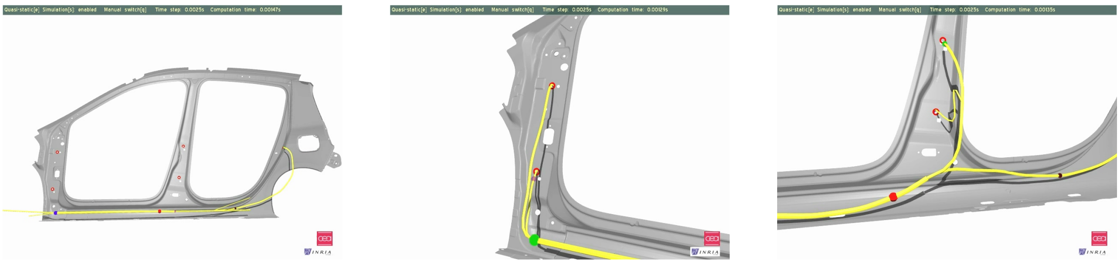
6. New Results

6.1. Interactive Accurate Simulation of Cables

Participants: Adrien Theetten, Laurent Grisoni, Christian Duriez, Christophe Chaillou, Xavier Merlhiot, Claude Andriot.

We are here interested in the deformations and the interactions of 1D objects with their environment. Our purpose is to reproduce and predict their behavior in a virtual world. Our model, called geometrically exact dynamic spline, may be used in many fields, such as robotics, biology and animation. To produce a model adapted to virtual reality, we conciliated accuracy, power of interaction and performance in our model.

We first focused on the accuracy and the validity of the deformations, including twisting and bending, under the large deformation assumption. Twisting is the sum of a geometrical component, the Frenet twisting, and a material component, the roll, expressed as a supplementary degree of freedom. We not only took account of reversible or elastic deformations, but we also proposed an algorithm for irreversible or plastic deformations, and break point detection. Moreover, we considered non circular cross-sections of 1D objects. They may be empty or full, with several different material layers, provided that they have two orthogonal axes of symmetry. Their dimensions may vary along the spline. To solve the equilibrium, we used the Lagrange equations. They are numerically expressed with a linearized backward Euler integration scheme, that we adapted to the spline



(a) (b) (c)

Figure 4. Cable beam positioning on a lateral car structure.

model. Since we get control point displacements at each time step integration, a dynamic solution as well as a quasi-static one is possible. A special effort was made to compute and factorize at most generalized forces, torques and stiffnesses. The time step computation time was very much reduced in this way. As we did not make any geometrical approximation, we can speak about *Geometrically Exact Spline*. We finally proposed a method to evaluate accuracy of spline and finite element blending functions. It is based on the approximation between a cercle and these functions. We proved that the most accurate spline is the B-Spline. We also established the required control point density of a spline for a desired accuracy. Most of the results on accuracy are about to be published in a special issue of Computer Aided Design [15].

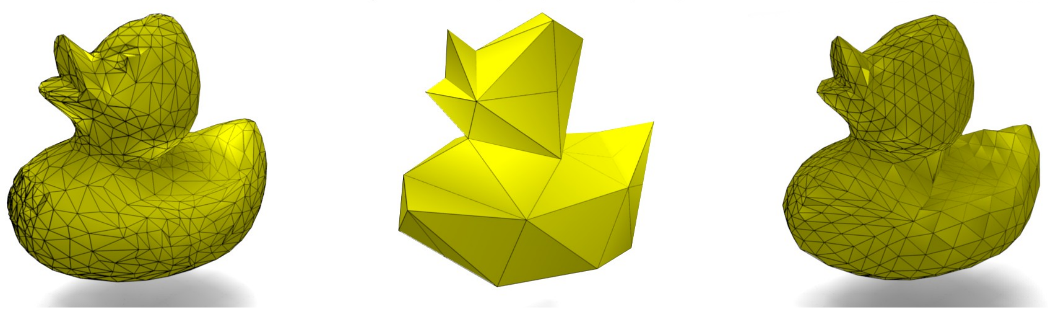
We contributed then to increase the power of manipulation of material splines. We reformulated Lenoir's lagrangian constraints to be usable with the linearized backward integration scheme: position, orientation, space limitation to a plane or an axis and sliding constraints, which make spline go through a fixed point. We also improved their violation purposes. We acquired more simple and more direct solving processes, since the Baumgarte scheme is now useless. We propose new constraints: distance constraint, oriented sliding constraint and particle constraint. A distance constraint keeps the distance between two spline point, or between a spline point and fixed point; the oriented sliding constraint, a sliding constraint with a constant orientation; and the particle constraint, a particle whose trajectory belongs to the spline, but that can also modify it. We proposed some complex application of these constraints: cable beams 4, DNA double helix and rope bridge, mechanical coupling and fixing clip.

Our last purpose was to provide a high-performance spline model for real-time simulation. We proposed an optimized method for unknown positioning in the matrix system, that is to say control points and lagrangian multipliers, to guarantee a banded structure. We also exploited all available symmetries to reduce computations. We finally proposed the quasi-dynamic simulation, that conciliates both dynamic simulation and quasi-static simulation. It consists of automatically switching between them during handling, thanks to some heuristics. They depend on the material parameters, applied constraints and allocated computation time. The time step computation is also very efficient, about one hundred of microseconds for a spline segment, while the algorithm complexity is fully linear. Most of the results concerning performance have been published in the proceedings of Solid and Physical Modeling Symposium [29].

6.2. Embedded Multigrid Approach For Real-Time Volumetric Deformation

Participants: Guillaume Saupin, Christian Duriez, Laurent Grisoni.

Finding efficient and physically based methods to interactively simulate deformable objects is a challenging issue. The most promising methods addressing this issue are based on finite elements and multigrid solvers. However, these multigrid methods still suffer, when used to simulate large deformations, from two pitfalls, depending on the kind of grids hierarchy used. If embedded grids are used, approximating complex geometries becomes difficult, whereas when unstructured grids hierarchy is used, solving speed-up is reduced by the necessity to update coarser levels stiffness matrices.



(a) (b) (c)

Figure 5. From left to right: original model, Coarse model, Hierarchically re-meshed model

We propose a framework that combines embedded grids solving with fast remeshing. We introduce a new hierarchical mesh generator which can build a hierarchy of topologically embedded grids approximating a complex geometry (see figure 5). We also show how to take advantage of the knowledge of the stiffness matrix sparsity pattern to efficiently update coarse matrices. These methods are tested on interactive simulation of deformable solids undergoing large deformations.

These results were published at ISVC 2007 [26].

6.3. Estimation of Mechanical Parameters of Deformable Solids from Videos

Keywords: *force capture device*, *identification*, *inverse mechanic*, *soft tissue simulation*, *video comparison metrics*.

Participants: Cédric Syllebranque, Samuel Boivin, Christian Duriez, Christophe Chaillou.

In this paper, we present a new method to estimate the mechanical parameters of soft bodies directly from videos of solids getting deformed under external user action. Our method requires one standard camera, a regular light source, a deformable solid and its 3D geometrical model. We make estimations using an inverse method based on a quasi-static FEM simulation and a visual error metric. The result is a set of two parameters, the Youngs modulus and the Poissons ratio, that can be used for more complex simulations, or force feedback applications like virtual surgery for example. We make estimations of those parameters from different materials like silicon or synthetic sponge. Then we validate our results by comparing them to a Zwick universal hardness tester measurments. We also present a new simple device for capturing the external forces applied on the deformable solids (see 6).

These results were published at Intuition Conference 2007 [28] and in Haptex workshop [27].

6.4. RubberEdge: Reducing Clutching by Combining Position and Rate Control with Elastic Feedback

Participants: Géry Casiez, Qing Pan, Christophe Chaillou.

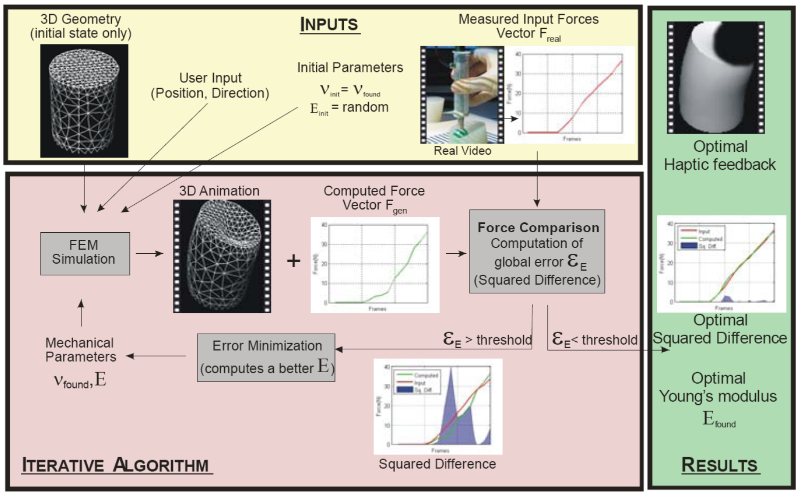


Figure 6.

Position control devices enable precise selection, but significant clutching degrades performance. Clutching can be reduced with high control-display gain or pointer acceleration, but there are human and device limits. Elastic rate control eliminates clutching completely, but can make precise selection difficult. We show that hybrid position-rate control can outperform position control by 20% when there is significant clutching, even when using pointer acceleration. Unlike previous work, our RubberEdge technique eliminates trajectory and velocity discontinuities. We derive predictive models for position control with clutching and hybrid control, and present a prototype RubberEdge position-rate control device including initial user feedback (Fig. 7).

This work has been carried out with Daniel Vogel from University of Toronto and the results were published at UIST 2007 [18].

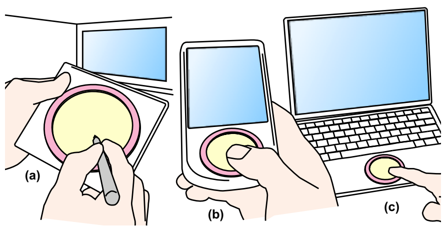


Figure 7. Design Concepts for RubberEdge Devices: (a) handheld pen tablet for a large display; (b) PDA with touch pad; (c) laptop touch pad

6.5. 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.

This work has been carried out with Daniel Vogel and Ravin Balakrishnan from University of Toronto and Andy Cockburn from the University of Canterbury and the results will be published in HCI Journal [12].

6.6. Depth-of-Field Blur Effects for First-Person Navigation in Virtual Environments

Participant: Géry Casiez.

This work studies the use of visual blur effects, i.e., blurring of parts of the image fed back to the user, for First-Person-Navigations in Virtual Environments (VE). First, we introduce a model of dynamic visual blur for VE which is based on two types of blur effect: (1) a Depth-of-Field blur (DoF blur) which simulates the blurring of objects located in front or back of the focus point of the eyes, and (2) a peripheral blur which simulates the blurring of objects located at the periphery of the field of vision (Fig. 8). We introduce two new techniques to improve real-time DoF: (1) a paradigm to compute automatically the focal distance, and (2) a temporal filtering that simulates the accommodation phenomenon. Second, we describe the results of a pilot experiment conducted to study the influence of blur effects on the performance and preference of video gamers during multiplayer sessions. Interestingly, it seems that visual blur effects did not degrade performance of gamers and they were preferred and selected by nearly half of the participants to improve fun and game-play. Taken together, our results suggest that the use of visual blur effects could thus be suitable in videogames and in other virtual environments.

This work has been carried out with Sébastien Hillaire, Anatole Lécuyer and Rémi Cozot from the INRIA Bunraku project at the University of Rennes I and the results were published at VRST 2007 [22] and AFIG 2007 [23].

6.7. Simulating fine textured surfaces

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

A specific tactile stimulator has been designed according to guidelines of the phD thesis of François Martinot.It is made of a copper plate on which a layer of piezo-electric elements are bonded 9. They create a vibration, inducing a "squeeze film effect" which decreases friction between the fingertip and the device. Illusion of touching finely textured surfaces is created by turning on and off the vibrations, in synchronization with fingertip's position. The technology used and our know-how allows us to build one of the largest device using friction reduction.

Figure 8. Image with DoF blur and peripheral blur

Figure 9. The tactile stimulator and the experimental test bench

Because quality of the textures rendered with such devices and their matching to real textures have never been thoroughly investigated, we investigated the differential thresholds for square gratings simulated with a friction based tactile device by dynamic touch. We then compare them to the differential thresholds of real square wave gratings. We found that the Weber fraction remains constant across the different spatial period at 9% which is close to the Weber fraction found for corresponding real square gratings. This study enclines us to conclude that friction based tactile displays can be used for co-located tactile displays and offer a realistic alternative to pin based arrays.

6.8. Desk based on instruments and graphs

Participant: Johann Vandromme.

Current graphical interfaces offer more and more functionalities. These functionalities are symbolized by tools which are grouped and ordered in menus or toolboxes without any convention. In order to simplify these interfaces, we propose to use a generic toolbox. This box will be made of tool that can be used on any kind of document. To make it possible, we will use a generic structure for documents, by using graphs. This research has been published at IHM07 [30].

6.9. Designing Viewpoint Awareness for 3D Collaborative Virtual Environment Focused on Real-Time Manipulation of Multiple Shared Objects

Participants: Luciana Provenzano, Julie Delzons, Patricia Plénacoste, Johann Vandromme.

In some collaborative manipulation activities for example, medical experts making a diagnosis based on a 3D reconstruction of a human organ remote participants may tailor their views on the shared object to their particular needs and task. This implies that each user has her viewpoint on the object. Awareness of viewpoint is then necessary both to coordinate each other and to understand remote users activities. This work investigates how to provide the remote viewpoint awareness in a 3D collaborative desktop in which multiple shared objects can be independently positioned and manipulated to accomplish a common single activity. Preliminary results of ergonomic evaluations of the proposed metaphors are also provided. This work has been published in the Lecture notes in computer science [24].

6.10. Gesture Recognition Based On Elastic Deformation Energies

Participants: Radu-Daniel Vatavu, Laurent Grisoni, Stefan-Gheorghe Pentiuc.

We defined a gesture recognition method based on deformable shapes and curvature templates [31]. Gestures are modeled using a spline representation that is enhanced with elastic properties: a gesture trajectory as a whole or any of its parts may stretch or bend. We regard such an approach as well-suited for dealing with the inherent variability of human gesture execution. The results of our gesture classifier are demonstrated with a video-based acquisition approach.

7. Contracts and Grants with Industry

7.1. France Télécom R&D

We work in collaboration with France Télécom since 1994. From 1994 to 2005, several contracts were established (3 PhD thesis, 3 co-development contracts). A pre-industrial software platform for collaborative virtual environments, called Spin|3D, has been developed in collaboration with France Télécom R&D (Lannion center).
We did participate with France Telecom to several projects (european, and national), and we are currently collaborating on the Part@ge ANR 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 fully funded by CEA.
- M. Hafez is copromoter of the PhD thesis of R. Demersseman who works on magneto-rheological fluids in order to design a tactile display. This study has begun in November 2005.

7.3. Hopale

We are starting a Ph.D. thesis with Jean-Philippe Deblonde on the study and development of adaptive interaction techniques with an application to the rehabilitation of brain injured patients using virtual reality. This thesis, co-funded by the Hopale foundation and the Nord Pas-De-Calais region, comes in addition to the ANR TecSan Reactive project that will start in January 2008.

7.4. Idées3com

Idées3com is a new start-up specialized in Web 3D content creation for e-shopping and advertising. Several collaborations are currently in preparation, around natural 3D interactions, and enhanced 3D metaphors. Idées3com is one of the industrial partner of the Hopale project, an ANR founded TechSan project.

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-06-MDCA-015) Partners : LSIIT(strasbourg), IRCAD(strasbourg), IRCOM/SIC (poitiers). 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.

- REACTIVE Partners : Hopale (Berck), CEA-LIST, Idees3COM

  We started this year some research on patient rehabilitation. This activity is supported by the ANR TecSan Reactive project, that will start in january 2008.

- ARC simple Partners : CHU University Hospital of Nancy, INRIA Magrit project

  Many vascular pathologies can now be operated on in a non invasive way thanks to interventional radiology. Using such technique, therapeutic tools are inserted within the arteries, up to the lesion through a catheter. As a particular case, intracranial aneurisms present like herniae onto the arterial wall. The endovascular treatment consists in filling the aneurismal cavity by placing coils. These are sorts of long platinum springs that, once deployed, wind into a compact ball. Considering the location of the lesion, close to the brain, and its small size, a few millimeters, the interventional gesture requires a good planning and cannot but be performed by a very experienced surgeon.

  A simulation tool of the interventional act, available in the operating room, reliable, adapted to the patient's anatomy and physiology, would help to plan the coil placement, train the surgeon, and improve the medical training to the technique. The SIMPLE project, an INRIA cooperative research action (ARC), aims at developing methods to simulate coil deployment in an intracranial aneurism, running in real time and adaptable to any patient data.

  For further information, see the web site of the project : http://simple.loria.fr/

- AEN SOFA Partners : INRIA Asclepios and Evasion projects

  The main objective of this national initiative is to accelerate / foster research activities in the field of Medical Simulation, with the long term goal of developing patient-specific simulations. This ambitious objective will initially translate into improved realism - and therefore higher credibility - of training systems. These research activities are essential to the development of patient-specific simulation systems dedicated to the planning of medical procedures. Most of these research activities rely on competencies shared across the different teams involved in this program. The second set of research activities relates to peripheral themes, for which the main effort consists in adapting existing algorithms of methods to a new set of problems.

  One of the main difficulties of Medical Simulation research is its multidisciplinary aspect. The diagram below (10) illustrates the three main themes we plan to study during this program.

  It clearly shows the interdependency between research themes, which reinforces the idea that only a coordinated program, where teams work together, can advance the state-of-the art significantly.

  – Biomechanical behavior modeling
  – Interactions
  – Real-time optimization,
  – Patient-specific models,
  – Validation

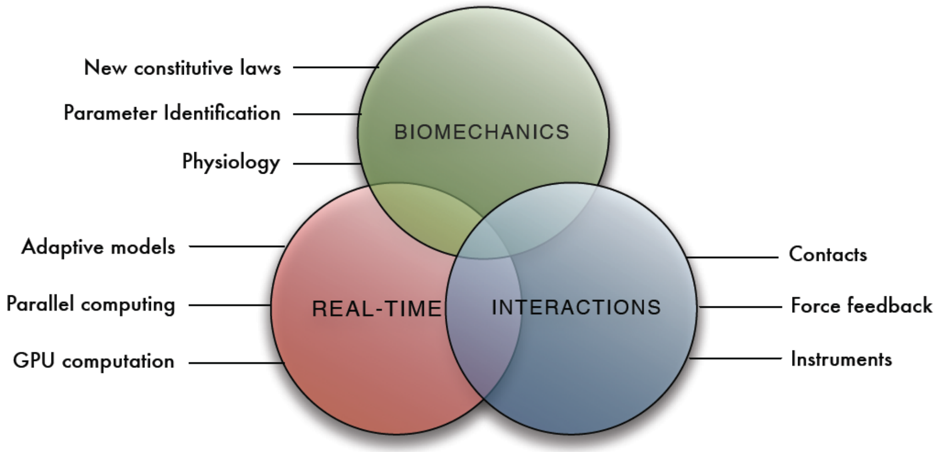


Figure 10.

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 was in sabbatical leave in LIAMA for 2006-2007 year. Pan Chunhong and C Chaillou organised two seminars:

- Virtual Reality: 3D Interactions and Collaborations during the Liama Anniversary.

  http://liama.ia.ac.cn/wiki/projects:10_anniversary:program:evente
- China-EU Virtual Reality Initiative: Foundational Meeting.

  http://liama.ia.ac.cn/wiki/projects:showroom:vr:meeting1

With Pan Chunhong Associate Professor CASIA, we start a collaboration "A New Human Representation Mixing Avatar and Video". We hope to integrate the advantages from both virtual reality and videoconference. From video, we are interested in obtaining motion information of body and head, which will be transferred to the virtual model and to express the communication and collaboration in the virtual world. By virtual reality techniques we are able to realistically represent avatars from the natural environment. Currently 4 students (two PhDs, two Masters) are involved in this project.

In September, Stéphane Cotin start a new collaborative project on "Virtual reality based planning technology for hand-eye coordinated surgical operation" with Pan Chunhong and Wang Dangxiao associate professor School of Mechanical Engineering & Automation,Beihang University The objective of the research project is to develop a high performance virtual reality surgical assistant system, which supports realistic simulation of surgical process with hard or deformable tissue manipulation, haptic display, hand-eye coordination, and skill evaluation. The system can not only be used for surgical planning and rehearsal, but also can be used for surgical training. Dental surgical operation is adopted as en example to validate our idea and typical operation include drilling-burring-probing will be studied.Three students (one PhD, two Masters) are involved in this project.

Betty Semail and Zhang Yuru initialize a new topic on "Coupling of kinesthetic and tactile feedback devices for touch simulation"

8.4. Visiting scientists

8.4.1. Dr. Eléna Lomonova

She is from university of technology of Eindhoven and has spent two months (October-November) in Lille, invited by L2EP and USTL. She is specialist in electrical engineering and focuses her attention on high precision position control. Scientific collaboration are foreseen on the design and control of piezo-actuators for special applications, such as haptics.

9. Dissemination

9.1. Leadership within scientific community

- Jérémie Allard was reviewer for VR 2008
- Géry Casiez was reviewer for CHI 2008, IHM 2007, Eurographics 2008, EGVE 2007 and The Visual Computer. He was also session chair at UIST 2007.
- Christophe Chaillou was reviewer for the ANR (8 projects). He also reviews 3 PhD Thesis. He is a member of the program committee of Vriphys 07 (workshop on virtual reality interaction and physical simulation) and was reviewer for TSI and REFIG. He was invited for a talk to the Chinese conference "Digital Média and Virtual Museum" at Hangzhou.
- Christian Duriez was reviewer for VR 2008, ICRA 2008.
- Betty Lemaire-Semail participate to external PhD committees: 9 since 2003 (7 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), EPE-Dresde (2005). She took part in the organisation and was chairman of an invited session about the "modelling and control formalisms of electro-mechnaical systems" at IECON Paris , November 2006.
- Frédéric Giraud is Journal reviewer for Transactions on Ultrasonics, Ferroelectrics and Frequency Control since 2005.

9.2. Teaching

- Master students (University of Lille I) :
  - Samuel Boivin : computer graphics (rendering and inverse rendering)
  - Laurent Grisoni : computer graphics (Animation, geometric modeling)

  - Frédéric Giraud : Fundamentals of Piezo-electricity.
  - Christian Duriez: digital image processing.

- Engineer students (Polytech'Lille)
  - Jérémie Allard : multi-core and GPU-based processing
  - Géry Casiez : HCI, Haptics
  - Laurent Grisoni : Animation, Advanced Computer Graphics, data compression and security (DCT, wavelets, watermarking, cryptology)
  - Christophe Chaillou : Hardware and Computer architecture
  - Sylvain Karpf : Computer architecture, Computer Graphics
  - Patricia Plénacoste : HCI - Ergonomics
  - Betty Lemaire-Semail : electromagnetism, piezo-electric control

- Engineer students (ENIC - Lille)
  - Géry Casiez : Haptics, graphics cards

- 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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