INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Project-Team EVASION

Virtual environments for animation and image synthesis of natural objects

Rhône-Alpes

THEME COG

Activity Report

2006

Table of contents

1. Team

The EVASION team, GRAVIR-IMAG laboratory (UMR 5527), is a joint project between CNRS, INRIA, Institut National Polytechnique de Grenoble (INPG) and University Joseph Fourier (UJF).

Head of the project

Marie-Paule Cani [Professor, INPG, HdR]

Staff member

Anne Pierson [Administrative Assistant, INPG]

Technical staff

Michael Adam [Engineer, RIAM Prodige, from 15/11/06 till 15/11/07]
Gregoire Aujay [Engineer, ANR Natsim and AXIATEC contract, from 01/09/06 till 01/09/07]
Florent Cohen [Engineer, RIAM Prodige, working at Bionatics]
Philippe Decaudin [Engineer, aimshape and Marie Curie OIF contract, from 23/05/06 till 19/01/08]
Christine Depraz [Engineer, RIAM Virtual Actors, RNTL Pari, ANR Kaméléon, 18/10/04 till 18/04/07]
Laure Heigeas [Engineer, 40%, from 01/11/06 till 30/09/06]
Sylvain Lefebvre [MENRT, RIAM Prodige, from 06/03/06 till 30/08/06]
Cedric Manzoni [Engineer, ANR Natsim, from 15/11/06 till 15/09/07]

Research scientist

Eric Bruneton [Research scientist, Detachement Corps Telecom, from 01/09/06 till 31/08/08]
Fabrice Neyret [Research scientist, CNRS CR1, HdR]
Lionel Reveret [Research Scientist, INRIA CR1]

Faculty member

Georges-Pierre Bonneau [Professor, UJF, HdR]
François Faure [Assistant Professor, UJF]
Franck Hétroy [Assistant Professor, INPG]

Post-doctoral fellow

Jeremie Allard [from 01/01/06 till 31/03/06]
Florence Bertails [L'Oréal contract, from 24/06/06 till 30/09/06]
Paul Kry [University of British Columbia, from 01/12/05 till 31/12/07]
Cesar Mendoza [University of Madrid, from 09/09/06 till 09/09/07]

PhD. student

Sebastien Barbier [MENRT, UJF, EVASION, from 01/10/06 till 01/10/09]
Florence Bertails [MENRT, INPG, EVASION, from 01/10/02 till 23/06/06]
Christian Boucheny [CIFRE EDF, UJF, EVASION, from 01/12/05 till 01/12/08]
Antoine Bouthors [MENRT, UJF, EVASION, from 01/10/04 till 30/09/07]
Mathieu Coquerelle [MENRT, INPG, EVASION, from 01/10/04 till 30/09/07]
Julien Diener [MENRT, INPG, EVASION, from 01/10/05 till 30/09/08]
Laurent Favreau [MENRT, INPG, EVASION, from 01/09/03 till 30/11/06]
Matthieu Nesme [MENRT, UJF, EVASION, from 01/10/04 till 30/09/07]
Laks Raghupathi [IRCAD, INPG, EVASION, from 01/09/03 till 15/11/06]
Jamie Wither [Visitor, INPG, EVASION, from 01/11/06 till 30/09/09]
Qizhi Yu [Visitor, INPG, EVASION, from 01/11/06 till 30/09/09]

External collaborators

Olivier Palombi [PhD, Anatomy Laboratory, Medicine Falculty of Grenoble, from 10/12/03 till 22/12/06]

2. Overall Objectives

2.1. Introduction

The EVASION project addresses the modeling, animation, visualization and rendering of natural scenes and phenomena. In addition to the high impact of this research on audiovisual applications (3D feature films, special effects, video games), the rising demand for efficient visual simulations in areas such as environment and medicine is also addressed. We thus study objects from the animal, mineral and vegetal realm, all being possibly integrated into a complex natural scene. We constantly seek a balance between efficiency and visual realism. This balance depends on the application (e.g., the design of immersive simulators requires real-time, while the synthesis of high quality images may be the primary goal in other applications).

From its creation, EVASION mostly tackled the modeling, animation, visualization and rendering of isolated natural objects or phenomena. A very challenging long term goal, that may be not reachable within the next few years but towards which we should tend, would be to simulate full, complex natural scenes combining many elements of different nature. This would enable us to test our algorithms on real-size data and to achieve new applications such as the interactive exploration of a complex, heterogeneous data set from simulation, or of a visually credible natural scene. Being able to animate this scene during exploration and to interact with the simulation taking place would be very interesting. The three objectives below set up several milestones towards this long term goal.

2.2. Creation of digital content

Natural scenes present a multitude of similar details, which are never identical and obey specific physical and space repartition laws. Modeling these scenes is thus particularly difficult: it would take years for a designer, and is not easy to do either with a computer. Moreover, interfaces enabling intuitive and fast user control should be provided. Lastly, explicitly storing the information for every detail in a landscape is obviously not possible: procedural models for generating data on the fly, controlled by mid or high-level parameters, thus have to be developed. Our first objective for the next few years is therefore to develop novel methods for specifying a natural scene. This includes modeling the geometry of individual elements, their local appearance, positioning them within a full scene and controlling motion parameters. More precisely, we will investigate:

- New representations and deformation techniques for intuitive shape modeling.
- The exploitation of sketching, annotation and analysis of real-data from video, 3D scanners and other devices for the synthesis and animation of natural scenes.
- The procedural synthesis of geometry, motion and local appearance (texture, shaders) using existing knowledge, user input and/or statistical data.

2.3. Animating nature

Most natural scenes are in motion. However, many of the animated phenomena that we can observe in nature have never been realistically, yet efficiently simulated in Computer Graphics. Our approach for tackling this problem is to increase and deepen our collaborations with scientist from other disciplines. From our past experiences, we believe that such interdisciplinary collaborations are very beneficial for both parties: they provide us with a better understanding of the phenomena to model and help us to get some input data and to experiment with the most recent models. On the other hand, our partners get interactive virtual prototypes that help them testing different hypothesis and enable a visual appreciation of their results. In particular, our aims are to:

- Improve interactive animation techniques for all kinds of physical models.
- Develop models for new individual phenomena.
- Work on the interaction between phenomena of different nature, such as forest and wind, sand and water, erosion (wind, water and landscape) or even eco-systems (soil, water, plants and animals).

2.4. Efficient visualization of very large scenes

Being able to handle massive data sets has been a strategic objective for French Computer Science for the last few years. In our research field, this leads us to investigate both the scientific visualization of very large data sets (which helps exploring and understanding the data provided, for instance, by our scientific partners from other research fields), and the real-time, realistic rendering of large size natural scenes, seeking for the interactive exploration and possible immersion in such scenes as a long term goal. More precisely, our objectives are to develop:

- Novel methods for the interactive visualization of complex, hybrid massive data sets, possibly embedding 1D and 2D structures within volumetric data which may represent scalar, vector or tensor fields.
- Perception based criteria for switching between level of details or between the representations of different nature we use in multi-models.
- Real-time techniques enabling us to achieve the rendering of full, natural scenes by exploring new, non-polygonal representations and relying on the programmable graphics hardware whereas possible.

3. Scientific Foundations

3.1. Scientific Foundations

The synthesis of natural scenes has been studied long after that of manufacturing environments in Computer Graphics, due to the difficulty in handling the high complexity of natural objects and phenomena. This complexity can express itself either in the number of elements (e.g., a prairie, hair), in the complexity of the shapes (e.g., some vegetal or animal organisms) and of their deformations (a cloud of smoke), from motions (e.g., a running animal, a stream), or from the local appearance of the objects (a lava flow). To tackle this challenge:

- we exploit *a priori* knowledge from other sciences as much as possible, in addition to inputs from the real world such as images and videos;
- we take a transversal approach with respect to the classical decomposition of Computer Graphics into Modeling, Rendering and Animation: we instead study the modeling, animation and visualization of a phenomenon in a combined manner;
- we reduce computation time by developing alternative representations to traditional geometric models and finite element simulations: hierarchies of simple coupled models instead of a single complex model; multi-resolution models and algorithms; adaptive levels of detail;
- we take care to keep the user in the loop (by developing interactive techniques whereas possible) and to provide him/her with intuitive control;
- we validate our results through the comparison with the real phenomena, based on perceptual criteria.

Our research strategies are twofold:

- **Development of fundamental tools**, i.e., of new models and algorithms satisfying the conditions above. Indeed, we believe that there are enough similarities between natural objects to factorize our efforts by the design of these generic tools. For instance, whatever their nature, natural objects are subject to physical laws that constrain their motion and deformation, and sometimes their shape (which results from the combined actions of growth and aging processes). This leads us to conduct research in adapted geometric representations, physically-based animation, collision detection and phenomenological algorithms to simulate growth or aging. Secondly, the high number of details, sometimes similar at different resolutions, which can be found in natural objects, leads us to the design of specific adaptive or multi-resolution models and algorithms. Lastly, being able to efficiently display very complex models and data-sets is required in most of our applications, which leads us to contribute to the visualization domain.

- **Validation of these models by their application to specific natural scenes**. We cover scenes from the animal realm (animals in motion and parts of the human body, from internal organs dedicated to medical applications to skin, faces and hair needed for character animation), the vegetal realm (complex vegetal shapes, specific material such as tree barks, animated prairies, meadows and forests) and the mineral realm (mud-flows, avalanches, streams, smoke, cloud).

4. Application Domains

4.1. Introduction

The fundamental tools we develop and their applications to specific natural scenes are opportunities to enhance our work through collaborations with both industrial partners and scientists from other disciplines (the current collaborations are listed in Section 8.). This section briefly reviews our main application domains.

4.2. Audiovisual applications: Special effects and video games

The main industrial applications of the new representations, animation and rendering techniques we develop, in addition to many of the specific models we propose for natural objects, are in the audiovisual domain: a large part of our work is used in joint projects with the special effects industry and/or with video games companies.

4.3. Medical applications: Virtual organs and surgery simulators

Some of the geometric representations we develop, and their efficient physically-based animations, are particularly useful in medical applications involving the modeling and simulation of virtual organs and their use in either surgery planning or interactive pedagogical surgery simulators. All of our applications in this area are developed jointly with medical partners, which is essential both for the specification of the needs and for the validation of results.

4.4. Environmental applications and simulation of natural risks

Some of our work in the design and rendering of large natural scenes (mud flows, rock flows, glaciers, avalanches, streams, forests, all simulated on a controllable terrain data) lead us to very interesting collaborations with scientists of other disciplines. These disciplines range from biology and environment to geology and mechanics. In particular, we are involved in inter-disciplinary collaborations in the domains of impact studies and simulation of natural risks, where visual communication using realistic rendering is essential for enhancing simulation results.

4.5. Applications to industrial design and interactive modeling software

Some of the new geometrical representations and deformation techniques we develop lead us to design novel interactive modeling systems. This includes for instance applications of implicit surfaces, multiresolution subdivision surfaces, space deformations and physically-based clay models. Some of this work is exploited in contacts and collaborations with the industrial design industry.

4.6. Applications to scientific data visualisation

Lastly, the new tools we develop in the visualisation domain (multiresolution representations, efficient display for huge data-sets) are exploited in several industrial collaborations involving the energy and drug industries. These applications are dedicated either to the visualisation of simulation results or to the visualisation of huge geometric datasets (an entire power plant, for instance).

5. Software

5.1. Introduction

Although software development is not among our main objectives, the various projects we are conducting lead us to conduct regular activities in the area, either with specific projects or through the development of general libraries. This section only describes the few softwares we are developing for the public domain.

5.2. Sofa

Participants: François Faure, Matthieu Nesme, Michael Adam.

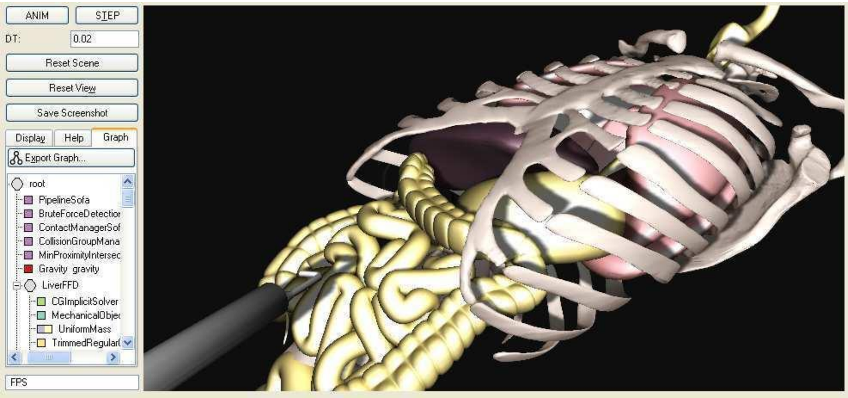

Figure 1. Simulation of laparoscopic surgery using SOFA at interactive rates (about 50Hz).

SOFA is a C++ library primarily targeted at medical simulation research. Based on an advanced software architecture, it allows to (1) create complex and evolving simulations by combining new algorithms with algorithms already included in SOFA; (2) modify most parameters of the simulation – deformable behavior, surface representation, solver, constraints, collision algorithm, etc. – by simply editing an XML file; (3) build complex models from simpler ones using a scene-graph description; (4) efficiently simulate the dynamics of interacting objects using abstract equation solvers; and (5) reuse and easily compare a variety of available methods (see figure 1).

SOFA is developed in collaboration with two other INRIA teams: Alcove and Asclepios, as well as The SIM-Group in the Massachussets General Hospital (MGH). The first offical release will occur in the first months of 2007. It will be presented to the medical community at conference Medicine Meets Virtual Reality (MMVR'07) in next February.

Dicussion currently take place between MGH and INRIA about the creation of a consortium, in order to maintain the development of SOFA in the mid- and long-term.

5.3. MobiNet

Participants: Fabrice Neyret, Franck Hétroy.

The MobiNet software allows for the creation of simple applications such as video games, virtual physics experiments or pedagogical math illustrations. It relies on an intuitive graphical interface and language which allows the user to program a set of mobile objects (possibly through a network). It is available in public domain for Linux and Windows at http://www-evasion.imag.fr/mobinet/index.en.html. It originated from 4 members of EVASION and ARTIS. The main aim of MobiNet is to allow young students at high school level with no programming skills to experiment, with the notions they learn in math and physics, by modeling and simulating simple practical problems, and even simple video games. This platform has been massively used during the INPG "engineer weeks" since 2002: 150 senior high school pupils per year, doing a 3 hour practice. This work is partly funded by INPG. Various contacts are currently developed in the educational world.

Besides "engineer weeks", every year a group of "monitors" PhD students conducts an experimentation based on MobiNet with a high scool class in the frame of the courses (see Section 9.5). Moreover, presentation in workshops and institutes are done, and a web site repository is maintained.

6. New Results

6.1. Creation of digital content and geometry processing

Participants: Grégoire Aujay, Georges-Pierre Bonneau, Marie-Paule Cani, Christine Depraz, François Faure, Laurent Favreau, Franck Hétroy, Paul Kry, Olivier Palombi, Lionel Reveret, Jamie Wither.

6.1.1. Multiresolution geometric modeling with constraints

Participant: Georges-Pierre Bonneau.

This work is done in collaboration with Stefanie Hahmann from LMC/IMAG. A collaboration is also taking place on this topic with Prof. Gershon Elber from Technion, in the framework of the Aim@Shape Network of Excellence (see Section 8.1.1). The purpose of this research is to allow complex nonlinear geometric constraints in a multiresolution geometric modeling environment. Two kinds of constraints have been firstly investigated: constraints of constant area and constant length, both for the modeling of curves.

Concerning the constraint of constant length, a multiresolution editing tool for planar curves which allows maintaining a constant length has been developed. One possible application is the modeling of folds and wrinkles. This work has been published in [31].

Lately, constraints of constant volume for the multiresolution deformation of BSpline tensor-product surfaces as well as subdivision surfaces have been investigated. Fig. 2 illustrates the deformation of a subdivision surface with constant volume.

A survey on integrating constraints into multiresolution models has been written in collaboration with Prof. Elber, and published in [11].

6.1.2. Virtual sculpture

Participants: Marie-Paule Cani, Paul Kry.

We compared two alternative approaches for interactively sculpting a 3D shape: a geometric approach based on space deformations and the use of a physically-based model for virtual clay.

The space deformation technique called “sweepers” [5], developed in collaboration with the University of Otago in New Zealand, is controlled by gesture: the user interactively sweeps tools that deform space along their path. The objects overlapping with the deformed part of space are locally re-meshed in real-time for accurate display. The resulting deformations are fold over-free: self-intersections are prevented, and the objects topological genius is preserved. This technique was extended to constant volume deformations, called “swirling sweepers” [4]: preserving volume makes the deformation even more intuitive, giving the user the impression of interacting with clay.

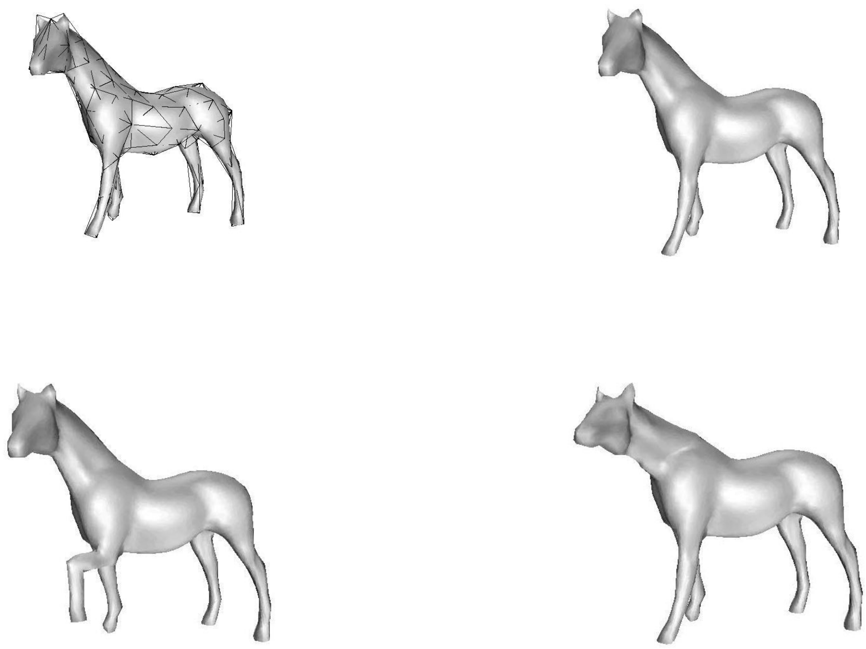

Figure 2. Several deformations of a multiresolution subdivision surface with constant volume

This approach was compared with different models for physically-based virtual clay within in a tutorial on "Interactive shape editing" we gave this summer at SIGGRAPH [6]. We concluded that the layered volumetric model we previously developed for clay achieves the desired plausibility in real-time, but opens the problem of providing intuitive interaction modes. We are currently working on this point with a master student, following the work Paul Kry presented at SIGGRAPH on interaction capture [25].

6.1.3. Modeling by sketching

Participants: Grégoire Aujay, Marie-Paule Cani, Jamie Wither.

Sketch-based techniques are currently attracting more and more attention as a fast and intuitive way to create digital content. We are exploring these techniques with two different view-points:

A first class of sketching techniques directly infer free-form shapes in 3D from arbitrary progressive sketches, without any a priori knowledge on the objects being represented. Following a collaboration started last year with IRIT in Toulouse, we are studying the use of convolution surfaces for achieving this goal. This done within a direct industrial contract with the firm Axiatec (see Section 7.3), on which we hired an engineer: Grégoire Aujay.

A second class of sketching techniques create complex shapes from one or two sketches only (for instance a front and a back view), using some a priori knowledge on the object being sketched for inferring 3D. This is the topic of Jamie Wither's PhD. He first extended a previous work on sketching for fashion design by introducing the sketching of cloth folds [16] (see figure 3), and is now working towards the extension of this kind of technique for natural objects: we are developing a sketching interface for realistic hair in collaboration with UBC, Canada and will address sketch-based modeling of trees within the ANR project Natsim(see Sections 6.2.7 and 8.2.2).

6.1.4. Mesh repair with topology control

Participant: Franck Hétroy.

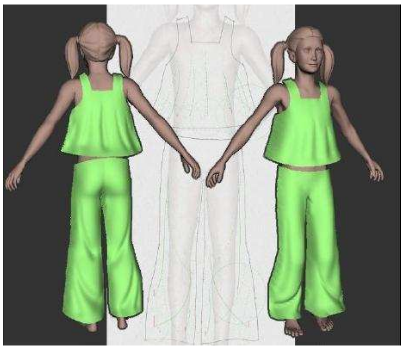

Figure 3. A sketch-based system for fashion design.

Meshes created from 3D laser scanned acquisition of real models often contain singularities (intersecting faces, holes, ...), due to defect during measures (for example, hidden parts of the model) or during the mesh creation process. The goal of this work is to transform a mesh with singularities into a "clean" mesh – mathematically speaking, a 2-manifold – with user control of the topology of the output (number of connected components and number of holes). It is a joint work between EVASION and the MOVING Group of the Technical University of Catalonia (UPC, Barcelona: Carlos Andújar, Pere Brunet, Jordi Esteve and Álvar Vinacua).

During her internship this summer, Stéphanie Rey has implemented an algorithm which computes and lets the user modify the topology of a voxel representation of the mesh, named "discrete membrane" [34]. Contrary to previous approaches, it allows the user to add or remove selected handles (of different sizes), in only a few seconds.

6.1.5. *Automatic computation of an animation skeleton*

Participant: Franck Hétroy.

Animation of a 3D model is usually made using a hierarchical representation of its articulations called the animation skeleton. Creation of this animation skeleton is a laborious task since it is made by hand. During his Master thesis, Grégoire Aujay has developed an algorithm which uses geometrical information on the model to automatically compute a hierarchical geometric skeleton, which can be converted into an animation skeleton [36], [19]. User intervention is restricted to the selection of one or a few points at the very beginning of the process, but the algorithm is customizable and users can adjust the skeleton to their needs. This work has done in collaboration with Francis Lazarus, from the Laboratoire des Images et des Signaux (LIS) in Grenoble. A result is shown on figure 4.

6.1.6. *Morphable model of quadruped skeletons for animating 3D animals*

Participants: Lionel Reveret, Laurent Favreau, Christine Depraz, Marie-Paule Cani.

Skeletons are at the core of 3D character animation. The goal of this work is to design a morphable model of 3D skeleton for four footed animals, controlled by a few intuitive parameters. This model enables the automatic generation of an animation skeleton, ready for character rigging, from a few simple measurements performed on the mesh of the quadruped to animate (see fig. 4). Quadruped animals - usually mammals - share similar anatomical structures, but only a skilled animator can easily translate them into a simple skeleton convenient for animation. Our approach for constructing the morphable model thus builds on the statistical learning of reference skeletons designed by an expert animator. This raises the problems of coping with data that includes both translations and rotations, and of avoiding the accumulation of errors due to its hierarchical structure. Our solution relies on a quaternion representation for rotations and the use of a global frame for expressing the skeleton data. We then explore the dimensionality of the space of quadruped skeletons, which yields the extraction of three intuitive parameters for the morphable model, easily measurable on any 3D mesh of a quadruped. We evaluate our method by comparing the predicted skeletons with user-defined ones on one animal example that was not included into the learning database. We finally demonstrate the usability of the morphable skeleton model for animation. Laurent Favreau has defended his PhD [2] on this topic in November 2006.

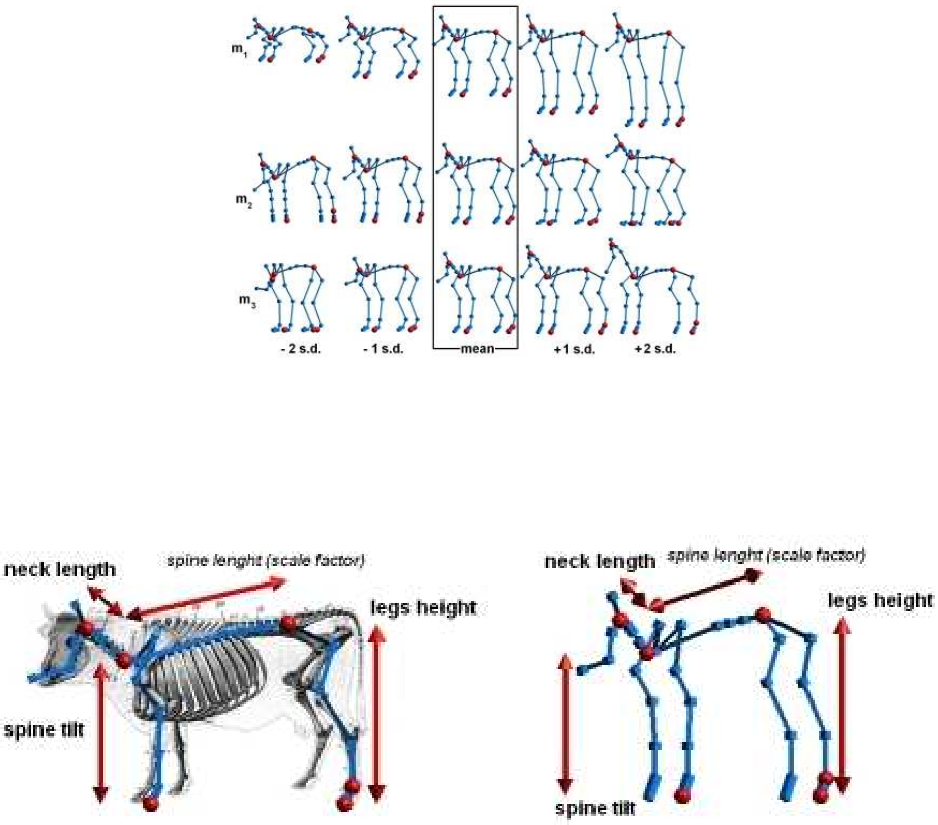

Figure 4. Morphable model of skeletons

6.1.7. Detection and quantification of brain aneurysms

Participants: François Faure, Franck Hétroy, Olivier Palombi.

Aneurysms are excrescences on blood vessels. They can break, letting the blood propagate outside the vessel, which often leads to death. In some cases, the blood clots sufficiently fast so that people survive. However, a neurosurgeon or a neuroradiologist should intervene very quickly in order to repare the vessel before the aneurysm breaks once more.

The purpose of this research is to help neurosurgeons and neuroradiologists to plan surgery, by giving them quantitative information about the size, shape and geometry position of aneurysms. The first part of this work has been done this summer during the internship of Sahar Hassan [39] : we have developed a simple algorithm for the automatic detection of aneurysms on CTA images.

This work will continue in 2007 with the Master thesis of Sahar Hassan.

6.2. Animating nature

Participants: Alexis Angelidis, Florence Bertails, Marie-Paule Cani, Christine Depraz, Julien Diener, François Faure, Laurent Favreau, Matthieu Nesme, Fabrice Neyret, Laks Raghupathi, Lionel Reveret, Qizhi Yu.

6.2.1. Highly colliding deformable bodies

Participants: Marie-Paule Cani, François Faure, Laks Raghupathi.

We address the question of simulating highly deformable objects in real-time, such as human tissues or cloth. The main problem is to detect and handle multiple (self-)collisions within the bodies. This year, we have focused on the robust response to multiple collisions using two different approaches, one based on Lagrange multipliers and the other based on stiff penalties.

Laks Raghupathi presented his work in a national workshop [30], and he defended his Ph.D. on this topic on November, 15, 2006.

6.2.2. Robust finite elements for deformable solids

Participants: François Faure, Matthieu Nesme.

We continue a collaboration on surgical simulation with laboratory TIMC through a co-advised Ph.D. thesis. Its purpose is to develop new models of finite elements for the interactive physically-based animation of human tissue.

Two new models of hexahedron-based finite elements have been proposed. The first [27], [15] is based on octree-based wavelets (see figure 5). Given the geometrical model of an object to simulate, we first compute a bounding box and then recursively subdivide it where needed. The cells of this octree structure are labeled with mechanical properties based on material parameters and fill rate. An efficient physical simulation is then performed using hierarchical hexaedral finite elements. The object surface is used for rendering and to apply boundary conditions. Compared with traditional finite element approaches, our method dramatically simplifies the task of volume meshing and increases the propagation of the deformations. This allows us to dynamically concentrate the computational force where it is most needed.

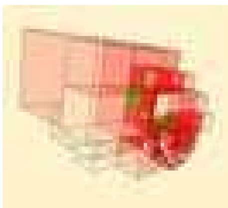

Figure 5. A liver animated using octree-based finite elements.

However, the mix of elements at different resolution in the same equation system creates numerical problems. The second model [28] is composed of elements at the same resolution. Starting from voxels at high resolution, we build voxels bottom-up and set the masses and stiffnesses in order to model the physical properties as accurately as possible at any given resolution. Additionally, we extend a fast and robust tetrahedron-FEM approach to the case of hexahedral elements. This permits simulation of arbitrarily complex shapes at interactive rates in a manner that takes into account the distribution of material within the elements. Figure 6 illustrates our results.

In the next future, we plan to extend our second approach with multigrid solution methods, allowing us to consider the bodies at different resolutions while avoiding the problems of the wavelets.

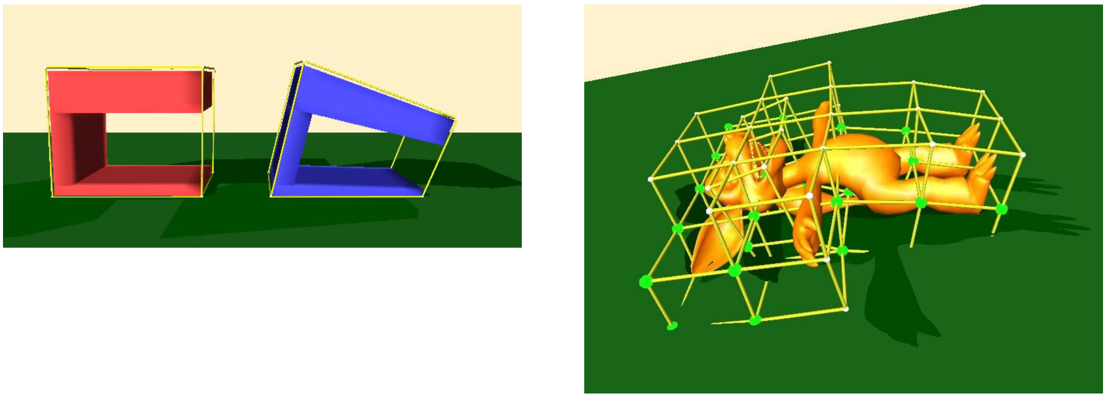

Figure 6. Non-unifrom voxels. Left, a single voxel with non-uniform stiffness and mass, compared with a traditional uniform voxel. Right, a more complex object animated with our technique.

6.2.3. Simulation of 1D models and application to hair

Participants: Florence Bertails, Marie-Paule Cani.

Realistically predicting the shape of hair requires an accurate 1D mechanical model, which takes into account the mechanical properties of inextensible, naturally curled hair strands. In the framework of our collaboration with the industrial partner L'Oréal (see Section 7.1), we developped a new physically-based method for strand called "Super-Helices", which was presented this summer at SIGGRAPH [20]. Super-Helices are a novel deformable model for solving the dynamics of elastic, Kirschoff rods: each strand is represented by a piecewise helical rod which is animated using the principles of Lagrangian mechanics. This results in a realistic and stable simulation, allowing large time steps. We validated this strand model through a series of comparisons between real and simulated hair wisps. We incorporated efficient methods for processing the self-collisions inside hair and with obstacles [7], enabling us to extend the model to the animation of a full head of hair (see Figure 7).

Figure 7. Hair animation using super-helices.

6.2.4. Control of smoke simulation based on vortex filaments

Participants: Alexis Angelidis, Fabrice Neyret.

Based on our last year model of efficient high resolution smoke simulation based on vortex filaments, we developed a new representation adapted to the control of the simulation feature by the user. The idea is to decompose a vortex ring filament into a frame plus harmonic components. The frame is obtained using a PCA analysis (i.e., the average orientation), and is used to represent and control the global trajectory and target of smoke. In this frame, the ring is decomposed into wavelets which represent the animated details of the puff of smoke. This allows us to control the apparence, the simplification with size or distance, and the complexity in a stability/efficiency purpose. This work led to a publication at SCA'06 [18].

Figure 8.

6.2.5. Real-time animation of liquids and river surfaces

Participants: Marie-Paule Cani, Mathieu Coquerelle, Fabrice Neyret, Qizhi Yu.

This year, a PhD student (Qizhi Yu) obtained a European Marie-Curie funding (Visitor programm) to work on this topic. The purpose is to obtain a realistical detailled appareance of landscape-long animated rivers in real-time, with user-editible features. The idea is to separate the river simulation into 3 scales, corresponding to different specification and simulation tools: macroscale for the topographic shape and global flow characteristics (relying on simple CFD at coarse resolution), mesoscopic scale for the local waves patterns (relying on dedicated phenomenological models), microscopic scale for the details (relying on textural procedural schemes). Note that this topic is included in the scope of the NATSIM collaboration (see Section 8.2.2).

The PhD of Mathieu Coquerelle, co-advised by Georges-Henri Cottet, explores the use of vortex particules for animating liquids and gases and to simulate their interactions with rigid solids.

6.2.6. Motion capture of animal motion

Participants: Lionel Reveret, Laurent Favreau, Christine Depraz, Marie-Paule Cani.

The motion of animals is still a challenging problem in 3D animation, both for articulated motion and deformation of the skin and fur (see Figure 9). The goal of this project is to acquire information from the numerous video footage of wild animals. These animals are impossible to capture into a standard framework of motion capture with markers. There are several challenges in the usage of such video footage for 3D motion capture : only one 2D view is available, important changes occur in lighting, contrast is low between the animal and foreground, etc. Currently, a method has been developed to first extract a binary silhouette of the animals and then, to map this silhouette to pre-existing 3D models of animals and motion thanks to a statistical prediction. This work has been selected as one of the best papers of the Symposium on Computer Animation 2004 (SCA'04) and an extended version has been published to the Graphical Models Journal [13].

In several domains of character animation, footsteps are one of the most important constraints. It guarantees one of the main aspects of a realistic animation of locomotion. This task, when done manually, is even more complex for quadrupeds. Being able to automatically predict the footsteps information from a video footage is thus an important contribution. The method developed is based on the design of a dedicated image filter to detect the pattern of animal legs. Along the time range of the video, the positive filter responses are clustered so that a single trajectory point is given per leg. As 2D images are considered (profile view), there exist ambiguities in the prediction of each individual foot position when side views of legs are crossing each other (typically left and right side of the animal, and front and back legs for higher velocities). A motion model has been developed to take into account this problem. This work has been done in collaboration with the University of Washington, in Seatle, USA.

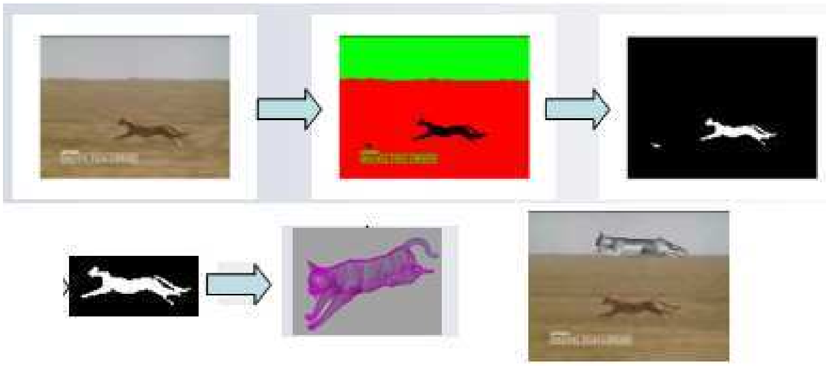

Figure 9. Motion capture of animal motion

The activity on this topic for this year has been dedicated to the ANR project Kameleon. Database of Xray video of a rat has been collected and is currently under processing. In addition, 3D surface reconstruction has been investigated. The approach is based on structured light scanner technique. This work has been done by a PhD student of the University of Montreal, Jamil Drareni. This work has been sponsored by an INRIA Internship grant for a 5 months stay at INRIA Rhône-Alpes. First results are available on the website of the project http://www-evasion.inrialpes.fr/people/Lionel.Reveret/kameleon.

6.2.7. Motion capture of tree motion

Participants: Lionel Reveret, Julien Diener, Fabrice Neyret.

This work investigates how the complex motion of plants and trees under wind effect can be analyzed from video and retarget to complex 3D model to create realistic animation. A first method has been proposed and published at the SCA conference in 2006. The particularity of the method is to be based on statistical clustering only, without the need of any physical model of the tree. The key idea is to retarget hierarchical clustering of moving features as the automatic building of an animated 3D geometrical strcuture of the branches. This work has been done in cooperation with Pr. Eugene Fiume from the University of Toronto, thanks to the "Equipe associée" grant I-MAGE between EVASION and the DGP laboratory of the U. of Toronto. This work will be continued in cooperation with the laboraties from INRA dedicated to the physiology of trees and the fluid mechanics laboratory of "Ecole Polytechnique", within the ANR project Chene-Roseau to be started in 2007.

6.2.8. Evaluation of 3D facial animation

Participant: Lionel Reveret.

Techniques for rendering of the skin surface have now achieved a highly realistic level. However, human subject are highly trained to perceive other faces and require 3D animation of faces to be accurate in terms of amplitude and timing of motion of facial features to be believable. We are conducting experiments with experimental psychologists to evaluate the naturalness of the synthetic control of facial features motion, using an exhaustive search over the tunings of the control parameters. Two rendering techniques are considered: a 3D geometrical modeling of the face including texture map (in collaboration with David Sander, from Experimental Department of the University of Geneva), and a 2D image-based approach using re-synthesis of video of real faces (in collaboration with Edouard Gentaz, from UFR de psychologie expérimentale, Université Pierre Mendès-France, Grenoble).

6.3. Efficient visualization of very large scenes

Participants: Sebastien Barbier, Georges-Pierre Bonneau, Antoine Bouthors, Eric Bruneton, Christian Boucheny, Philippe Decaudin, Fabrice Neyret.

6.3.1. Visualisation of large numerical simulation data sets

Participants: Georges-Pierre Bonneau, Sebastien Barbier.

The energy industry sector has to perform numerical simulation on very large data sets, in thermodynamics, mechanics, aerodynamics, neutronics, etc. Visualization of the results of these simulations is crucial in order to gain understanding of the phenomena that are simulated. The visualization techniques need to be interactive - if not real time - to be helpful for engineers. Therefore multiresolution techniques are required to accelerate the visual exploration of the data sets. In the PhD of Fabien Vivodtzev (who is now working at CEA on Visualization systems) we have developed multiresolution algorithms devoted to volumetric data sets based on tetrahedral grids in which inner structures of dimension 2, 1 or 0 are preserved. Typically these algorithms are used to compute a sequence of simplified volumetric meshes with good properties. Sebastien Barbier is now starting a PhD on the interactive rendering of these simplified meshes. The aim is to integrate today's standard visualization algorithms - including slicing, iso-surfacing, volume rendering - with the multiresolution models developed previously.

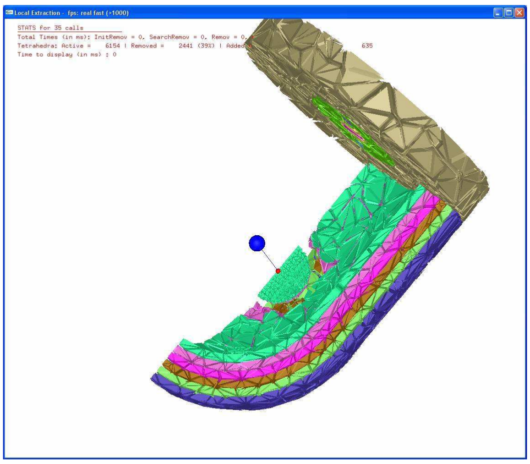

Figure 10. Region of interest (ROI) extracted in a multiresolution volumetric mesh

6.3.2. Perceptive Visualization

Participants: Georges-Pierre Bonneau, Christian Boucheny.

This project is part of a collaboration with the research and development department of EDF, and with LPPA (Laboratoire de Physiologie de la Perception et de l'Action, Collège de France). The general context is similar to the collaboration with CEA (Section 6.3.1), i.e., the visualisation of large numerical data sets. The focus in this project in on the following problem: How should human perception be taken into account in Visualization algorithms, and more specifically in algorithms based on multiresolution techniques. Previous works in this area are mostly based on image analysis techniques, that are used to measure important features in a static image resulting from some visualization algorithm. These results do not take into account information on the specific person using the visualization system. We are especially interested in taking into account such information, like the point where the user is looking at. We also want to insert dynamic parameters in the perceptive measure, like the movement of the user's head, since such parameters greatly influence the actual perception of the rendered scene. In the framework of this collaboration, EDF is funding a PhD grant on these topics, started by Christian Boucheny in December 2005.

6.3.3. Efficient representation of landscapes

Participants: Eric Bruneton, Fabrice Neyret.

In September, Eric Bruneton joined the team as a researcher, on the topic or lanscape representation and rendering. The goal of this work is the real time rendering of large landscapes with forests, rivers, fields, roads, etc. with high rendering quality, especially in term of details and continuity. A first step toward this goal is the modeling, representation and rendering of the terrain itself (i.e., without taking into account the vegetation - see Section 6.3.4 - the rendering of rivers - see Section 6.2.5 - etc.). Since an explicit representation of the whole terrain elevation and texture at the maximum level of detail would be impossible, we generate them procedurally on the fly (completely from scratch or based on low resolution digital elevation models). Our main contribution, in this context, is to use vector based data to efficiently and precisely model linear features of the landscape (such as rivers, hedges or roads), from which we can compute in real time the terrain texture and the terrain elevation (in order to correctly insert roads and rivers in the terrain - see figure 11).

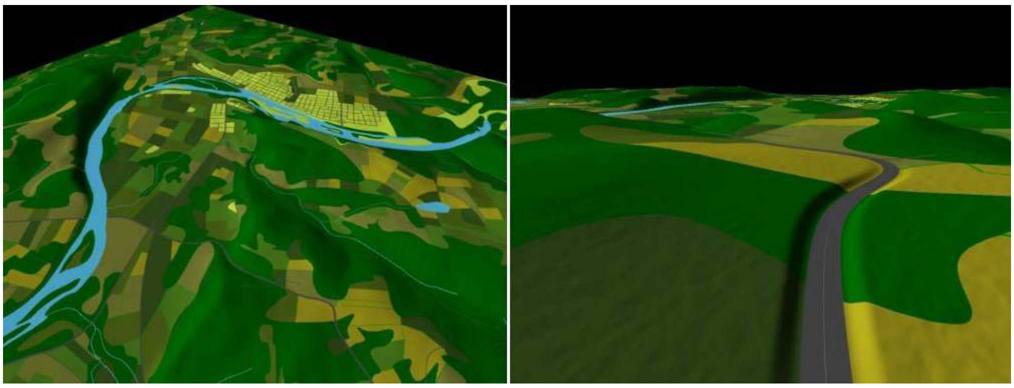

Figure 11.

6.3.4. Efficient representation of forest

Participants: Philippe Decaudin, Fabrice Neyret.

This year, we obtained a European Marie-Curie OIF "mobility" funding (see Section 8.4) allowing Philippe Decaudin to start (in October) a long stay in Beijin (CN) to collaborate with LIAMA on the topic of the real time realistical exploration of forestry landscape. The idea is to extend our volumetric models of forest combined with GPU-based rendering algorithms to visualize the huge data sets obtained by the LIAMA and CIRAD ecosystem simulations.

6.3.5. Real-time quality rendering of clouds layers

Participants: Antoine Bouthors, Fabrice Neyret.

Antoine Bouthors continues his PhD on Cumulus clouds. This year, we developped an illumination model embedding the main local and global lighting effects in reflectance and transmitance (halo, glory, pseudo-specular, diffusion, etc.) in the form of a local *shader* such that a cloud layers (represented as a height-field) can be rendered on the fly on the GPU without precomputations or global simulation. We also accounted for inter-reflections between the clouds base and the floor through a real-time GPU-adapted radiosity algorithm. This work has been published at Eurographics Workshop on Natural Phenomena'2006 [21].

Figure 12.

This year, Antoine also did a long stay at UC Davis (California, USA) to work with Nelson Max, thanks to a EURODOC Regional funding plus a France-Berkeley funding (see Section 8.4). In this collaboration, we intend to generalize the approach to non layer kinds of clouds.

6.4. Applications covered by this year's results

The above sections presented our research in terms of fundamental tools, models and algorithms. A complementary point of view is to describe it in terms of application domains. The following sections describe our contribution to each of these domains, with reference to the tools we relied on if they were already presented above.

6.4.1. Interactive modeling systems

Participants: Grégoire Aujay, Georges-Pierre Bonneau, Marie-Paule Cani, Paul Kry, Jamie Wither.

Several of the tools we are developing are devoted to a new generation of interactive modeling systems:

- The multiresolution geometric modeling with constraints tool presented in Section 6.1.1 has been used for interactive modeling.
- The real-time physically-based model for virtual clay presented in Section 6.1.2 is dedicated to a sculpting system as close as possible to interaction with real clay.
- The sketching tools presented in Section 6.1.3 have been used to model garments and hair, and are being extended to model more general free form shapes. They are used in the industrial contract with Axiatec (see Section 7.3).

6.4.2. Synthesis of natural scenes

Participants: Antoine Bouthors, Eric Bruneton, Marie-Paule Cani, Mathieu Coquerelle, Philippe Decaudin, Fabrice Neyret, Qizhi Yu.

Many of the diverse fundamental tools we are developing (see Sections 6.2.4, 6.2.5, 6.3.3, 6.3.4 and 6.3.5) are contributing to the long term, general goal of modeling and animating natural scenes. They can be combined to allow the large scale specification, efficient rendering and animation of landscapes (rivers and cloudy sky, etc). The synthesis of complete natural sceneries is one of the aims of the Natsim project (see Section 8.2.2).

6.4.3. Medical applications

Participants: Marie-Paule Cani, François Faure, Frank Hetroy, Matthieu Nesme, Olivier Palombi, Laks Raghupathi.

Some of our work on geometric modeling and physically-based animation has been successfully applied to the medical domain:

Our tools for efficient physically-based simulation, and in particular our new contributions to collision detection and response (see Section 6.2.1), is being used in a new European medical project called *Odysseus* (see Section 8.1.2).

Furthermore, Mathieu Nesme's PhD research (see Section 6.2.2), which is co-advised by Yohan Payam of laboratory TIMC, concentrates on the development of improved models for human tissue simulation for surgical simulations.

6.4.4. Animation of virtual creatures

Participants: Florence Bertails, Marie-Paule Cani, Christine Depraz, François Faure, Laurent Favreau, Lionel Reveret.

Several of our new models and algorithms contribute to the animation of virtual creatures. This includes our work on motion capture from video (Section 6.2.6); the physically-based animation tools (Sections 6.2.1 and 6.2.2) that we are currently applying to the simulation of virtual garments; and our adaptive animation algorithm for efficiently computing hair motion (see 6.2.3).

A first work towards the perceptive evaluation of animation has been achieved in collaboration with the dept. of Psychology of the U. of Geneva for facial animation. A study has been made to evaluate what different parts of the brain are activated when a picture of an expressive face is showed to a subject, with gaze pointing towards the subject or not. It has been necessary to adapt a 3D model to standard photographs of expressive faces, so that the eye orientation on the photographs could be accurately controlled in a realistic manner.

7. Contracts and Grants with Industry

7.1. Hair simulation with l'Oreal

Participants: Florence Bertails, Marie-Paule Cani.

We have been working for three year on an industrial contract with l'Oréal, which ended in august 2006. The goal was to develop methods able to predict the shape and motion of hair as a function of the strand's physical parameters. After the first results on static hairstyles, we ended this project with a validated method for hair dynamics (see Section 6.2.3). L'Oréal will now use the resulting software for hair prototyping applications, with the final goal of first testing the new cosmetic products in virtual.

7.2. RIAM Prodige

Participants: Fabrice Neyret, Florent Cohen, Sylvain Lefebvre, Julien Diener.

This RIAM contrat started in 2006 for 18 monthes with Bionatics aims at developping tools for the creation of landscape-related digital contents and real-time models, including procedural generation of shape, aspect and motion.

7.3. Intuitive free-form modeling for Axiatec

Participants: Gregoire Aujay, Marie-Paule Cani.

We just started at the fall 2006 an industrial contract with a new partner, Axiatec. The aim is to design a very intuitive modeling system for the public, in order that people can model shapes and then receive a 3D print of them, produced by Axiatec. Our product will be based on our research work on sculpting and sketching (see Sections 6.1.2 and 6.1.3).

7.4. Collaboration with ATI and Nvidia Graphics board constructors

Participants: Philippe Decaudin, François Faure, Sylvain Lefebvre, Fabrice Neyret, Lionel Reveret.

We are still in close contact with the ATI and Nvidia development teams providing suggestions and bug reports, and testing prototype boards.

8. Other Grants and Activities

8.1. European projects

8.1.1. Network of excellence Aim@Shape

Participants: Georges-Pierre Bonneau, Marie-Paule Cani, Franck Hétroy.

The mission of AIM@SHAPE is to advance research in the direction of semantic-based shape representations and semantic-oriented tools to acquire, build, transmit, and process shapes with their associated knowledge. We foresee a new generation of shapes in which knowledge is explicitly represented and, therefore, can be retrieved, processed, shared, and exploited to construct new knowledge. This Network of Excellence started in December 2003. This year Georges-Pierre Bonneau and Marie-Paule Cani have actively collaborated in the publication of STAR reports on the topics covered by the Network. Marie-Paule Cani has co-organized with Marc Alexa a summer school on Interactive Shape Modeling, held in Darmstadt in july 2005: http://www.interactiveshapemodeling.net/.

8.1.2. Odysseus

Participants: Marie-Paule Cani, François Faure, Laks Raghupathi.

Odysseus is a European EUREKA project on the simulation of laparoscopic surgery, running from 2004 to 2007. Driven by IRCAD, it involves two industrial partners (Karl Storz, SimSurgery) and three research projects of INRIA: EVASION, EPIDAURE, ALCOVE. The overall project is to develop commercial products for collaborative diagnosis and patient-specific planning. Our participation is related to the planning and real-time simulation of surgery using patient-specific data. Our contribution is based on the SOFA library described in Section 5.2.

8.2. National projects

8.2.1. ANR Masse de données et simulation KAMELEON

Participants: Lionel Reveret, Laurent Favreau, Franck Hetroy, Marie-Paule Cani.

Current techniques for animating the skin surface of a virtual creature from the motion of its skeleton do not take into account complex phenomena such as the rolling of the internal tissue over the bones. In order to tackle this problem, a research project has been initiated between EVASION and the National Museum of Natural History in Paris. For the study of locomotion, the Museum has access to Xray video of live animals, making possible to visualize the motion of the internal skeleton during locomotion. Using standard stereovision techniques, the 3D surface of the animal will be extracted in order to be correlated into an innovative machine learning framework with the internal Xray data of the skeleton. As a result of this learning phase, more realistic 3D motion of the skin will be achieved, controlled by standard 3D skeleton motion. This project is sponsored by an ANR grant for the next three years. It gathers 4 participants: EVASION project, National Museum of Natural History, Université de Rennes et Université Paris 5.

8.2.2. ANR Masse de données et simulation NATSIM

Participants: Fabrice Neyret, Antoine Bouthors, Qizhi Yu, Marie-Paule Cani, Eric Bruneton, Jamie Wither, Cedric Manzoni.

This project aims at developping new techniques and hybrid representations to model, visualize, animate and transmit natural scenes. It involves EVASION, IRIT and LABRI. Evasion took action in two workpackages: edition tools in order to "sketch" high level user specification concerning the landscape, and animation of complex realtime scenes (such as rivers, clouds, trees).

8.2.3. ANR Chênes et roseaux

Participant: Lionel Reveret.

The aim of the project CHENE-ROSEAU is to develop and test experimental and theoretical methodologies for the analysis and simulation of the motion of plants induced by wind. The knowledge of motion of plants under wind is important for several reasons. First, in terms of plant damage, excessive motion can lead to lodging in crops, where the deformation becomes permanent or to wind throw in isolated or grouped trees. Second, motion of lesser amplitude is known to influence plant growth (thigmomorphogenesis), particle spreading, liquid retention on leaves or light spreading inside a canopy. More recently applications in computer graphics for video games or movies have appeared, where the simulation of realistic plant motion is still a major difficulty. Partners for this project are the Laboratoire d'Hydrodynamique-LadHyX (Ecole polytechnique), UMR 547 PIAF (Physiologie Intégrée de l'Arbre Fruitier et Forestier) (INRA), UR Ephyse (Ecologie fonctionnelle et Physique de l'Environnement) (INRA) and Projet EVASION (INRIA Rhône-Alpes).

8.3. Regional projects

8.3.1. Rhône-Alpes Project: Dereve II

Participants: Florence Bertails, Antoine Bouthors, Marie-Paule Cani, Laurent Favreau, Fabrice Neyret, Lionel Reveret, Jamie Wither.

This regional project in the domain of Computer Graphics took place between July 2003 and July 2006. In the last year, the contributions of EVASION were:

- Workpackage 1 *Realistic modeling and animation of characters and natural scenes*: systems for modeling clothing and animating human hair; a method for animating wild animals from images and videos.
- Workpackage 3 *Modeling and real-time rendering of natural scenaries*: a method for rendering realistic clouds.

8.3.2. IMAG Project: MIDAS

Participants: François Faure, Matthieu Nesme, Laks Raghupathi.

We drive the MIDAS (Modèles Interactifs Déformables pour l'Aide à la Surgétique) project, which also involves laboratories TIMC and ICP, from 2005 to 2007. The goal of this project is to provide the biomechanics community with physically-based deformable models fast enough for use in per-operative planning, or in the context of trial-and-error parameter tuning where a large number of simulation are performed.

8.3.3. IMAG project: MEGA

Participants: Marie-Paule Cani, Laurent Favreau, Franck Hétroy, Lionel Revéret.

We also drive the MEGA (MEthodes Géométriques de décomposition et déformation de surfaces pour l'Animation 3D") project, involving the LIS laboratory (image processing) and the MGA team from the LMC laboratory (applied maths). This projects aims at developping a new approach to surface deformation for character animation, using new geometrical models and tools with strong mathematical basis.

8.4. Mobility grants

Participants: Antoine Bouthors, Mathieu Coquerelle, Matthieu Nesme.

Each year several students get a regional EURODOC grant to spend several months in another laboratory in another country. This year Antoine Bouthours did a long stay at UC Davis (USA, California) with Nelson Max (he also got a France Berkeley funding), Mathieu Coquerelle went to the University of Berkeley with Nelson O'Bien, and Matthieu Nesme went to Montreal with Pierre Poulin.

Philippe Decaudin got a European Marie-Curie OIF mobility funding to go to Beijin (CN) to collaborate with LIAMA.

9. Dissemination

9.1. Leadership within the international scientific community

Marie-Paule Cani served in the SIGGRAPH'2007 steering committee, in the ACM-EG Symposium on Computer Animation steering committee, and in the steering committee of the IEEE Shape modeling & Applications conference. She is also a member of the Eurographics Workshop Board, responsible for the EUROGRAPHICS working group on Computer Animation.

9.2. Editorial boards and program committees

Editorial boards:

Marie-Paule Cani and Georges-Pierre Bonneau are members of the editorial board of IEEE Transactions on Visualization and Computer Graphics.

Conference organization:

Marie-Paule Cani serves in the executive committee of Eurographics 2006, and is also a member of the executive committee of the French chapter of Eurographics.

Program Committees:

- Marie-Paule Cani was paper co-chair of ACM-EG SCA'2006. She was a program committee member of the EUROGRAPHICS workshop on Natural Phenomena, of the EUROGRAPHICS workshop on Sketch-Based Interfaces and Modeling, of the 4th Non Photorealistic Animation and Rendering symposium (NPAR'2006), of the Computer Animation and Social Agents conference (CASA'2006), of the Interactive Graphics and Games symposium (I3D'2007), and of the Solid and Physical Modeling symposium (SPM'2007).
- Georges-Pierre Bonneau was a program committee member of ACM SPM 2007, June 4-6, 2007, at Tsinghua University, Beijing, China and of IEEE SMI 2006, Hotel Taikanso, Matsushima, Japan 14-16th June, 2006.
- François Faure was a program committee member for for VRIPHYS'06 (Madrid, Spain, November 6-7, 2006). He has also made reviews for IEEE TVCG, Computer Aided Design, Siggraph sketches, Siggraph/Eurographics Symposium on Computer Animation (SCA'06), Computer Animation and Social Agents'06, Eurographics Workshop on Natural Phenomena'06.
- Lionel Reveret was a program commitee member of the Siggraph/Eurographics Symposium on Computer Animation (SCA'06).
- Fabrice Neyret was a program commitee member of the Siggraph/Eurographics Symposium on Computer Animation (SCA'06), of the Eurographics Workshop on Natural Phenomena 2006, of the Brazilian Symposium on Computer Graphics and Image Processing (SIBGRAPI'06) and of the Second International Symposium on Plant Growth Modeling, Simulation, Visualization and Applications (PMA'06).

9.3. Invited conferences

The EVASION team members have also given several invited talks in addition to their involvement in the many aforementioned conferences and workshops during the year. Marie-Paule Cani was a Key-note speaker at the "Curves and Surfaces" international conference, Avignon, France, June 2006. She was an invited speaker at the "Iberico-American Symposium on Computer Graphics", Santiago de Compostella, Spain, July 2006. François Faure gave an invited talk at the University Rey Juan Carlos, Madrid, in November 2006. Fabrice Neyret was an invited speaker at "Journées de l'AFIG", Bordeaux, France, in November 2006.

9.4. Book chapters

- Marie-Paule Cani wrote with Eric Galin a chapter on implicit surfaces in "Informatique graphique et géométrique, animation" [8];
- Marie-Paule Cani and Fabrice Neyret are co-writers of a chapter on computer models and tools for natural environments in "Le traité de la réalité virtuelle" [9].
- François Faure is co-author of a chapter on physically-based animation in the "Traité de la réalité virtuelle", to be published in 2006 [12];

9.5. Large public conferences and meetings

- The 'MobiNet' team (Joelle Thollot (at Artis), Fabrice Neyret and Franck Hétroy (at Evasion) plus a dozen of temporary assistants) organizes 8 practices per year on a half-day basis for about 150 senior high school students in the scope of INPG "engineer weeks". The purpose is to give a more intuitive practice of math and physics, and to give insights on programming and engineering. See Section 5.3 and http://www-evasion.imag.fr/mobinet/index.en.html.

  In addition to "engineer weeks", every year a group of "monitors" PhD students conducts an experimentation based on MobiNet with a high school class in the frame of the lectures. This year, 4 students advised by Fabrice Neyret and Frank Hetroy prepared class exercices for math and physics class in collaboration with the teachers on the topic of statistical physics (reports and booklets available on MobiNet web site: http://www-evasion.imag.fr/mobinet/index.en.html).

  Moreover, Fabrice NEYRET presents the tool and the experiment in various workshop and institutes ("journées Greco", IREM, IUFM, etc.). He also maintains a web site repository.

- Fabrice Neyret takes part of various publics operations:
  - He co-animates some operations:
    * He is in the leading staff of "Observatoire Zetetique" (http://www.observatoire-zetetique.org/), an organisation which aims at promoting intelligent and scientific approach especially facing paranormal or pseudo-scientist thesis, by organising test protocols, enquiries, publications and broadcasts, public conferences, formations.
    * He is in the leading staff of the “Cafés Sciences et Citoyen” team (Grenoble), funded by the communication department of CNRS, and he maintains the web site `http://www-evasion.imag.fr/cafesSC/`. Conferences are organised on a monthly basis.
  - He maintains web sites for various operations, plus some more related on research topics.
  - He participates as an expert to various public debates and press interviews.

9.6. Teaching

In addition to the regular teaching activities (UJF, INPG) of the faculty members, several researchers at EVASION taught some courses to the "Image, Vision, Robotics" Master Research, the "Mathematic Engineering" Master and to the 3rd year "Image and Virtual Reality" of ENSIMAG. François Faure gave a course on animation at the Vienna University (Austria) during 2 weeks (22 hours).

Georges-Pierre Bonneau is Director of the Doctorate School of Computer Science, Applied and Pure Mathematics, Grenoble, and head of department "Geometry & Image" in the research laboratory LJK `http://www-ljk.imag.fr`

10. Bibliography

Year Publications

Doctoral dissertations and Habilitation theses

[1] F. Bertails. *Simulation de Chevelures Virtuelles*, Ph. D. Thesis, Institut National Polytechnique de Grenoble, 2006, http://www-evasion.imag.fr/Publications/2006/Ber06.

[2] L. Favreau. *Modélisation du mouvement des quadrupèdes à partir de la vidéo*, Ph. D. Thesis, INPG, nov 2006, http://www-evasion.imag.fr/Publications/2006/Fav06.

[3] L. Raghupathi. *Vers Une Animation Robuste d' Objets Complexes en Interaction*, Ph. D. Thesis, Institut National Polytechniqe de Grenoble, 46 Avenue Felix Viallet, 38031 Grenoble Cedex, France, November 2006, http://www-evasion.imag.fr/Publications/2006/Rag06.

Articles in refereed journals and book chapters

[4] A. Angelidis, M.-P. Cani, G. Wyvill, S. King. *Swirling-sweepers: constant volume modeling*, in "Graphical Models (GMOD)", Special issue on PG'04, vol. 68, n^{o} 4, jul 2006, http://www-evasion.imag.fr/Publications/2006/ACWK06.

[5] A. Angelidis, G. Wyvill, M.-P. Cani. *Sweepers: Swept Deformation Defined by Gesture*, in "Graphical Models (GMOD)", Special issue on SMI 2004, vol. 68, n^{o} 1, January 2006, p. 2-14, http://www-evasion.imag.fr/Publications/2006/AWC06.

[6] M.-P. CANI, A. ANGELIDIS. *Towards Virtual Clay, in course 'Interactive Shape Editing'*, Course proceedings., chap. chapter 7, ACM SIGGRAPH, Boston, USA, august 2006, http://www-evasion.imag.fr/Publications/2006/CA06.

[7] M.-P. CANI, F. BERTAILS. *Hair Interactions, in tutorial 'Collision Handling and its applications'*, EG Tutorial Series, chap. Chapter 4., The Eurographics association, Vienna, Austria, Sept 2006, http://www-evasion.imag.fr/Publications/2006/CB06.

[8] M.-P. CANI, E. GALIN. *Informatique graphique et géométrique, animation: chapitre Surfaces Implicites*, chap. 5, Hermès, 2006, http://www-evasion.imag.fr/Publications/2006/CG06.

[9] M.-P. CANI, F. NEYRET, M. PARENTHOEN, J. TISSEAU. *Le traité de la réalité virtuelle. Volume 3: outils et modeles informatiques des environnements naturels*, collection sciences mathematiques et informatiques, vol. 3, chap. Modeles pour les env. naturels, Mines Paris, 2006, p. 315–331, http://www-evasion.imag.fr/Publications/2006/CNPT06.

[10] P. DECAUDIN, D. JULIUS, J. WITHER, L. BOISSIEUX, A. SHEFFER, M.-P. CANI. *Virtual Garments: A Fully Geometric Approach for Clothing Design*, in "Computer Graphics Forum (Eurographics'06 proc.)", vol. 25, n^{o} 3, sep 2006, http://www-evasion.imag.fr/Publications/2006/DJWBSC06.

[11] G. ELBER, G.-P. BONNEAU, S. HAHMANN, B. SAUVAGE. *Multiresolution Analysis*, Shape analysis and Structuring, L. De Floriani and M. Spagnuolo (eds.),, chap. to appear, Springer Verlag, 2006, to appear, http://www-evasion.imag.fr/Publications/2006/EBHS06.

[12] F. FAURE, B. STANCIULESCU. *Le traité de la réalité virtuelle. Volume 3: outils et modeles informatiques des environnements naturels*, chap. 3, Mines Paris, 2006, p. 185–216, http://www-evasion.imag.fr/Publications/2006/FS06.

[13] L. FAVREAU, L. REVERET, C. DEPRAZ, M.-P. CANI. *Animal gaits from video: comparative studies*, in "Graphical Models (GMOD)", vol. 68, n^{o} 2, mar 2006, p. 212-234, http://www-evasion.imag.fr/Publications/2006/FRDC06.

[14] C. LARBOULETTE, M.-P. CANI, B. ARNALDI. *Ajout de détails dynamiques à une animation temps-réel de personnage*, in "Technique et Science Informatiques (TSI)", Hermes Science, vol. 6, 2006, http://www-evasion.imag.fr/Publications/2006/LCA06.

[15] M. NESME, F. FAURE, Y. PAYAN. *Hierarchical Multi-Resolution Finite Element Model for Soft Body Simulation*, in "Lecture Notes in Computer Science", vol. 4072, july 2006, p. 40–47, http://www-evasion.imag.fr/Publications/2006/NFP06b.

[16] E. TURQUIN, J. WITHER, L. BOISSIEUX, M.-P. CANI, J. HUGHES. *A sketch-based interface for clothing virtual characters*, in "IEEE Computer Graphics & Applications", Special issue on sketch based modeling. To appear., 2006, http://www-evasion.imag.fr/Publications/2006/TWBCH06.

[17] K. WARD, F. BERTAILS, T.-Y. KIM, S. R. MARSCHNER, M.-P. CANI, M. LIN. *A Survey on Hair Modeling: Styling, Simulation, and Rendering*, in "IEEE Transactions on Visualization and Computer Graphics (TVCG)", To appear, 2006, http://www-evasion.imag.fr/Publications/2006/WBKMCL06.

Publications in Conferences and Workshops

[18] A. ANGELIDIS, F. NEYRET, K. SINGH, D. NOWROUZEZAHRAI. *A Controllable, Fast and Stable Basis for Vortex Based Smoke Simulation*, in "ACM-SIGGRAPH/EG Symposium on Computer Animation (SCA)", sep 2006, http://www-evasion.imag.fr/Publications/2006/ANSN06.

[19] G. AUJAY, F. HETROY, F. LAZARUS. *Construction automatique d'un squelette pour l'animation de personnages*, in "AFIG", 2006.

[20] F. BERTAILS, B. AUDOLY, M.-P. CANI, B. QUERLEUX, F. LEROY, J.-L. LÉVÊQUE. *Super-Helices for Predicting the Dynamics of Natural Hair*, in "ACM Transactions on Graphics (Proceedings of the SIGGRAPH conference)", accepted to Siggraph'06, August 2006, http://www-evasion.imag.fr/Publications/2006/BACQLL06.

[21] A. BOUTHORS, F. NEYRET, S. LEFEBVRE. *Real-time realistic illumination and shading of stratiform clouds*, in "Eurographics Workshop on Natural Phenomena", sep 2006, http://www-evasion.imag.fr/Publications/2006/BNL06.

[22] J. COMBAZ, F. NEYRET. *Semi-interactive morphogenesis*, in "Shape Modeling International", 2006, http://www-evasion.imag.fr/Publications/2006/CN06.

[23] J. DIENER, L. REVERET, E. FIUME. *Hierarchical retargetting of 2D motion fields to the animation of 3D plant models*, in "ACM-SIGGRAPH/EG Symposium on Computer Animation (SCA)", ACM-Siggraph/Eurographics, 2006, http://www-evasion.imag.fr/Publications/2006/DRF06.

[24] P. KRY, D. PAI. *Grasp Recognition and Manipulation with the Tango*, in "International Symposium on Experimental Robotics", July 2006, http://www-evasion.imag.fr/Publications/2006/KP06a.

[25] P. KRY, D. PAI. *Interaction Capture and Synthesis*, in "ACM Transactions on Graphics (Proceedings of the SIGGRAPH conference)", vol. 25, 2006, p. 872–880, http://www-evasion.imag.fr/Publications/2006/KP06.

[26] M. MARCHAL, P. PROVENT, F. RUYER, P. DJOHARIAN, F. NEYRET. *Computer-assisted Teaching in Class Situation: a High-school Math Lab on Vectors*, in "Edutainment", published as a volume in Lecture Notes in Computer Science, Springer, 2006, http://www-evasion.imag.fr/Publications/2006/MPRDN06.

[27] M. NESME, F. FAURE, Y. PAYAN. *Hierarchical Multi-Resolution Finite Element Model for Soft Body Simulation*, in "Workshop on Computer Assisted Diagnosis and Surgery, Santiago de Chile", march 2006, http://www-evasion.imag.fr/Publications/2006/NFP06a.

[28] M. NESME, Y. PAYAN, F. FAURE. *Animating Shapes at Arbitrary Resolution with Non-Uniform Stiffness*, in "Eurographics Workshop in Virtual Reality Interaction and Physical Simulation (VRIPHYS), Madrid", Eurographics, nov 2006, http://www-evasion.imag.fr/Publications/2006/NPF06.

[29] F. NEYRET. *Créer, Simuler, Explorer des Univers Naturels sur Ordinateur*, in "AFIG", invited paper, 2006, http://www-evasion.imag.fr/Publications/2006/Ney06.

[30] L. RAGHUPATHI, F. FAURE. *QP-Collide: A New Approach to Collision Treatment*, in "journées du groupe de travail Animation et Simulation (GTAS)", Annual French Working group on Animation and

Simulation, Institut de Recherche en Informatique de Toulouse, June 2006, p. 91-101, http://www-evasion.imag.fr/Publications/2006/RF06.

[31] B. SAUVAGE, S. HAHMANN, G.-P. BONNEAU. *Length Constrained Multiresolution Deformation for Surface Wrinkling*, in "Shape Modeling International", IEEE CS, 2006, http://www-evasion.imag.fr/Publications/2006/SHB06.

Internal Reports

[32] A. AUGUSTIN, F. NEYRET. *Flow-noise en temps réel*, Rapport de stage d'option, Ãcole polytechnique - Evasion, laboratoire GRAVIR, juin 2006, http://www-evasion.imag.fr/Publications/2006/AN06.

[33] G. CLAUZEL. *Real-Time Animation of Quadrupeds based on Physics*, Technical report, DEA IVR, jun 2006, http://www-evasion.imag.fr/Publications/2006/Cla06.

[34] S. REY, F. HETROY. *Morphological operators for the topology control of volumetric models*, Rapport de stage 2ème année, ENSIMAG-INPG, August 2006, http://www-evasion.imag.fr/Publications/2006/RH06.

[35] T. STEIN. *Animation de plis de tissus pour le rendu non-photoréaliste*, Technical report, INPG, 2006, http://www-evasion.imag.fr/Publications/2006/Ste06.

Miscellaneous

[36] G. AUJAY. *D'un squelette géométrique à un squelette d'animation*, Technical report, M2R IVR, 2006, http://www-evasion.imag.fr/Publications/2006/Auj06.

[37] S. BARBIER, G.-P. BONNEAU. *Exploration interactive de gros maillages surfaciques et volumiques*, Technical report, M2R IVR, 2006, http://www-evasion.imag.fr/Publications/2006/BB06.

[38] N. CHAVEROU, L. REVERET. *Extension aux quadrupèdes d'un moteur d'animation 3D de personnages*, Technical report, M2R IVR, Juin 2006, http://www-evasion.imag.fr/Publications/2006/CR06.

[39] S. HASSAN, F. FAURE, F. HETROY. *Caractérisation et quantification d'anévrismes sur des modèles volumiques*, pré-rapport de M2R IVR, September 2006, http://www-evasion.imag.fr/Publications/2006/HFH06.

[40] T. PHILIPPE, M.-P. CANI. *Une approche géométrique pour la modélisation de vêtements virtuels*, Technical report, M2R IVR, 2006, http://www-evasion.imag.fr/Publications/2006/PC06.