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 3B

Activity Report

2003

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1. Team

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

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Olivier Palombi [Ph. D. student, Anatomy Laboratory, Medicine Falculty of Grenoble]
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John Hughes [Professor, Brown University (USA)]

2. Overall Objectives

The EVASION project addresses the synthesis of images of natural scenes and phenomena. This aim leads us to work jointly on the specification, representation, animation, visualisation and rendering of these scenes. In addition to the high impact of this research on audiovisual applications (3D feature films, special effects, video games), it helps address the rising demand for efficient visual simulations, in areas such as environmental and medical applications. We thus study objects from the animal, mineral and vegetable kingdom, 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).

3. Scientific Foundations

The synthesis of natural scenes has only been studied very recently compared to that of manufacturing environments, 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., many vegetable forms or animal organisms), of motions (e.g. a cloud of smoke, a stream), or of the local appearance of the objects (a lava flow).

To tackle this challenge:

- we exploit the *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 Modelling, Rendering and Animation: we instead study the modelling, animation and visualisation 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 an intuitive user control.
- we validate our results by comparing to images of the real phenomena, based on perceptual criteria.

Our research strategies are twofold:

1. **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 factorise 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 and aging phenomena. Secondly, the high number of details, sometimes similar at different resolutions, that 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 visualisation domain.
2. **Validation of these models by their application to specific natural scenes.** We are currently covering scenes from the mineral kingdom (lava-flows, mud-flows, avalanches, streams, smoke, cloud) to the animal kingdom (animals in motion, parts of the human body, from internal organs dedicated to medical applications to skin, faces and hair needed for character animation), without forgetting vegetal scenes (complex vegetable shapes, specific material such as tree barks, animated prairies, meadows and forests).

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 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 or/and 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 animation are particularly useful in medical application involving the modelling and simulation of virtual organs and their use in either surgery planning or interactive pedagogical surgery simulators. All 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 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 a realistic rendering is essential for enhancing simulation results.

4.5. Applications to industrial design and interactive modelling software

Some of the new geometrical representations and deformation techniques we develop lead us to design novel interactive modelling systems. This includes for instance applications of implicit surfaces, multi-resolution 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 (multi-resolution representations ; efficient display for huge data-sets) are exploited in several industrial collaborations, for instance with 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 though the development of general libraries. This section only describes the few softwares we are developing for the public domain.

5.2. AnimAL

Participants: Florence Bertails, François Faure, Olivier Galizzi, Laure Heïgéas, Caroline Larboulette, Laks Raghupathi.

AnimAL is a C++ library mostly dedicated to animation of 3D models. The kernel of AnimAL is intended to be highly flexible thanks to generic programming (templates). It includes classes representing basic variables (arrays, rotations, solid transforms, linear algebra, etc.) as well as standard algorithms (numerical integration, optimisation, interpolation, etc.). This kernel uses only standard libraries of C++. Thus it is totally independent of the other modules and is directly portable on another architecture or system.

Actually, except the basic tools and the standard algorithms, the existing code in AnimAL is mainly due to the result of our research code (physical mass-spring system, collision detection). We recently proposed its integration into a new modular architecture, supporting input-output of 3D files, internal 3D scene graphs, and graphic user interface which allows the control of the animation and the viewing of the animated 3D models. This architecture is partly based on free softwares developed by the ARTIS team (X3DToolKit and QGLViewer).

AnimAL, in its preliminary form, was already used within four collaborations:

1. with the LIGIM research laboratory at Lyon. The goal was to model and animate fractured materials.
2. with the LIFL research laboratory at Lille. Some parts of AnimAL were used in a chirurgical simulator.
3. with the University of Lecce (Italy).
4. with the University of Tuebingen (Germany) for cloth simulation.

The actual version of AnimAL will be used in the RNTL project PARI (see section 7.2), and in the RIAM project Virtual Actors (see section 7.3) with the video games company Galilea at Grenoble. In particular, AnimAL will be used to animate a character's clothes.

In future, AnimAL will integrate all the new animation technologies we develop at EVASION, and will become a free C++ library (see http://www-evasion.imag.fr/Ressources).

5.3. gluX

Participant: Sylvain Lefebvre.

The OpenGL graphics programming API is widely used by researchers to work with recent graphics hardware. To access hardware-specific functions, it relies on an extension loading mechanism. Due to the large variety of video card models, it is very important to be able to check if extensions are available at runtime. Moreover the same program often needs to include different versions of the same rendering code in order to adapt it to the set of available extensions. Unfortunately, the loading mechanism provided by OpenGL is different under Linux and Windows platforms, and requires a large amount of very repetitive loading code for each extension (more than 200 extensions are available). gluX is a cross-platform easy-to-use OpenGL extension loader (see http://www-evasion.imag.fr/Ressources). It offers a very simple mechanism for loading and using OpenGL extensions. It allows to detect at runtime if the required extensions are present or not and to select the appropriate rendering code. It is a very convenient tool as it allows to exchange programs without having to handle the painful task of writing the extension loading code for each platform and video card model.

5.4. MobiNet

Participants: Sylvain Lefebvre, Fabrice Neyret.

The MobiNet software allows to create simple applications such as video games or pedagogic illustrations relying on intuitive graphical interface and language allowing to program a set of mobile objects (possibly through a network). It is available in public domain for Linux and Windows at http://www-imagis.imag.fr/mobinet/ The main aim is pedagogical: MobiNet allows young students at high school level with no programming skills to experiment, with the notions they learn in math and physics by creating simple video games. This platform is massively used during the INPG "engineer weeks": 150 senior high school pupils per year, doing a 3h practice. This work is partly funded by INPG. Various contacts are currently developed in the educational world.

6. New Results

6.1. Multi-resolution representation of shapes

Participants: Alexis Angelidis, Georges-Pierre Bonneau, Marie-Paule Cani, Philippe Decaudin, Fabrice Neyret, Olivier Palombi, Basile Sauvage, Alex Yvart.

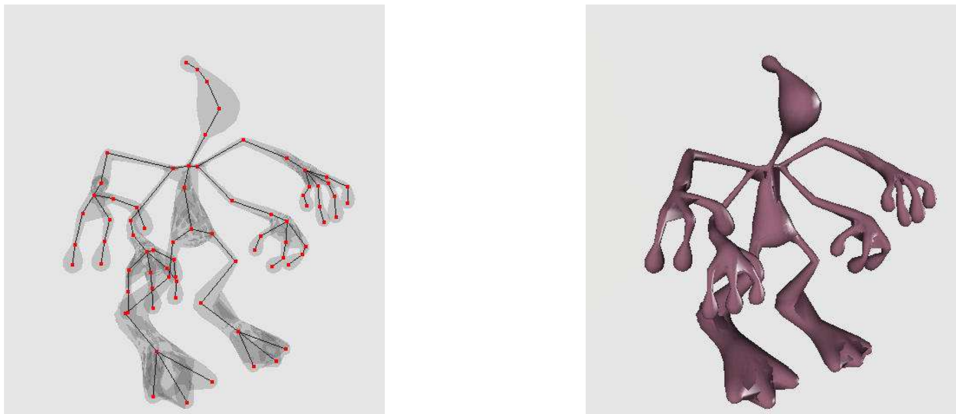

Figure 1. An example of skeleton-based implicit-surface.

6.1.1. Subdivision Surfaces: Hierarchical surface modelling

Participants: Georges-Pierre Bonneau, Alex Yvart.

The purpose of this research is to define a surface model that has all the advantages of subdivision surfaces, while still having a low degree polynomial parameterization (See figure 2). This research is the result of a collaboration with Stefanie Hahmann from the LMC/IMAG.

In previous works a polynomial interpolation method for triangular meshes has been introduced. This interpolant can be used to design smooth surfaces of arbitrary topological type. In a design process, it is very useful to be able to locate the deformation made on a geometric model. The previously introduced interpolant has the so-called strict locality property: when a mesh vertex is moved, only the surface patches containing this vertex are changed. This enables to locate the deformation at the size of the input triangles. Unfortunately this is not sufficient if the designer wants to add some detail at a smaller level than that of the input triangles. In this research work, we propose a modification of our interpolant, that enables to arbitrarily refine the input triangulation, without changing the resulting surface. We call this property the subdivision invariance. After the refinement of the input triangulation, the modification of one of the vertices will change the shape of the interpolant at the scale of the refined triangulation. In this way, it is possible to add details at an arbitrary fine scale.

6.1.2. Multiresolution geometric modelling with constraints

Participants: Georges-Pierre Bonneau, Basile Sauvage.

The purpose of this research is to allow complex non-linear geometric constraints in a multiresolution geometric modelling environment. Two kinds of constraints have been investigated: constraint of constant area inside a planar curve, and constraint of constant length of a curve.

Constant Area: A method for multiresolution deformation of closed planar curves that keeps the enclosed area constant has been developed (see figure 3). We use a wavelet based multiresolution representation of the

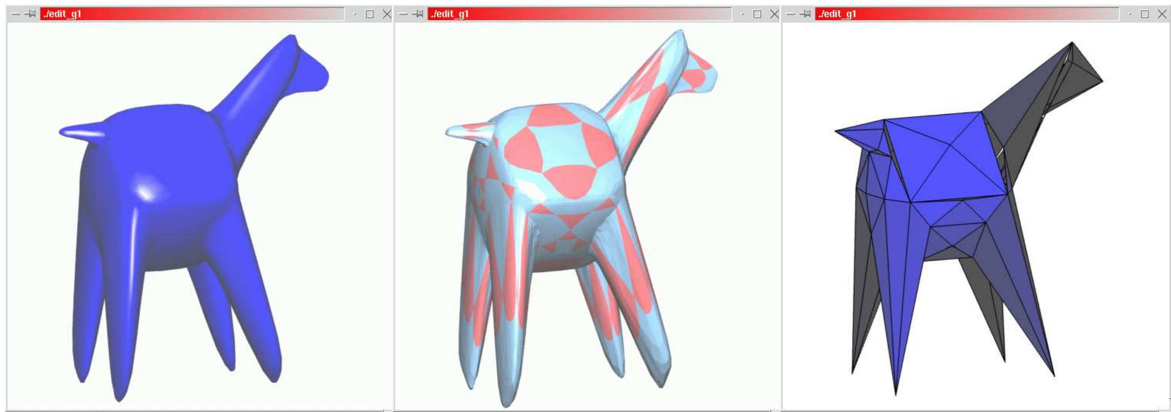

Figure 2. A hierarchical surface with 3 levels of subdivision. Left: input mesh. Middle: control polyhedron. Right: smooth surface.

curves. The key contribution of this work is the efficient computation of the area in the wavelet decomposition form: the area is expressed through all levels of resolution as a bilinear form of the coarse and detail coefficients.

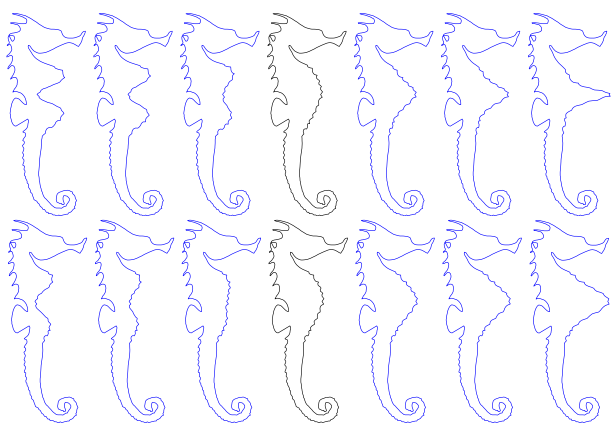

Figure 3. A sea horse shape is deformed with (top)/without (bottom) constant area constraint.

Constant Length: A multiresolution editing tool for planar curves which allows satisfying the non-linear constraint of length preserving has been developed (See figure 4). The focus is on the generation of folds when the curve is compressed. Since the deformation is based solely on a geometric model, the computing time is improved compared to physical models. Also the multiresolution framework allows to easily and precisely control the scales of the folds.

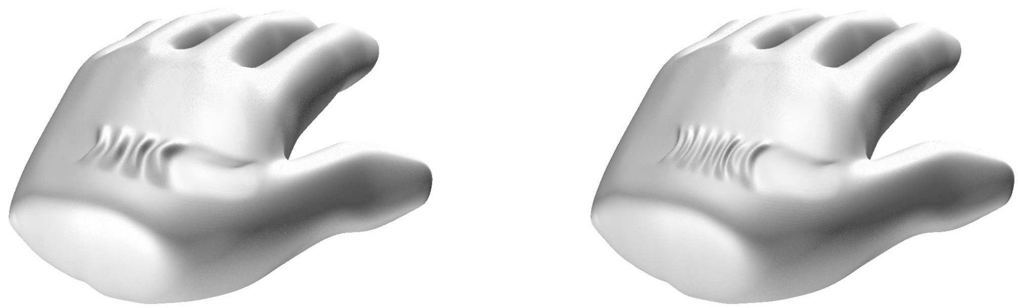

Figure 4. Left: Large wrinkles. Right: Fine wrinkles.

6.1.3. Implicit Surfaces

Participants: Alexis Angelidis, Marie-Paule Cani, Olivier Palombi.

Our work on multi-resolution implicit modelling introduces multi-resolution representations to skeleton-based implicit surfaces. This is done through the use of subdivision curves and surfaces as skeleton (see figure 1). Convolution kernels admitting a closed form solution for the integral are used for generating a smooth surface around them. Our first contributions in the area are now available in a journal paper [5]. This work will be further pursued in Olivier Palombi's PhD thesis which just started this fall and will examine the use of this representation for a specific anatomical study (see section 6.6.1).

6.1.4. Volumetric Textures

Participants: Philippe Decaudin, Fabrice Neyret.

In the scope of the Vertigo collaboration (RIAM funding, cf 7.1), we are extending our past work on realistic, real-time volumetric textures, the target being the management of forest covered scenery in virtual reality applications (see figure 5).

Figure 5. Real-time and realistic forests using Volumetric textures.

6.2. Procedural methods for geometry and motion

Participants: Marie-Paule Cani, Caroline Larboulette, Sylvain Lefebvre, Fabrice Neyret, Frank Perbet.

6.2.1. A generic tool for multi-resolution procedural modelling

Participants: Marie-Paule Cani, Frank Perbet.

Procedural modelling is probably the only approach enabling the modelling of a virtually infinite world with an unlimited number of details of different scales, that may be auto-similar or not. The last part of Frank Perbet's thesis, which will be defended in February 2004, proposes a generic tool, based on dynamic graphs, for exploring this kind of model very efficiently. Only the parts of the scene which are currently visible are generated, at the adequate level of details, enabling real-time display even during interactive zooming operations [24].

6.2.2. Procedural Textures based on Patterns

Participants: Sylvain Lefebvre, Fabrice Neyret.

We developed a representation for virtually very large textures, which are especially useful is the case of natural scenes since the field of view is very large and at the same time the first stage requires a very high resolution. The principle consists in starting with a set of samples, then to describe how to spread and combine them in texture space: non-periodic tiling, Poisson-disk distribution, probability distribution, control of the spatial spreading, etc... (see figure 6). This model draws on the new means offered by the current graphics board revolution. A *fragment program* (or *shader*) running on the graphics board determines for each pixel with given texture coordinates (u, v) which colour (or transparency, or normal...) to apply depending of the specifications. This work has been published at the ACM Symposium on Interactive 3D Graphics'03 [15].

This allows to encode a large part of an object's aspect in texture space, without modifying the geometry (refinement can then be controlled exclusively by independent criteria). We started to apply this approach to the *volumetric textures* representation previously developed in the team. Moreover, our model also deals with animation.

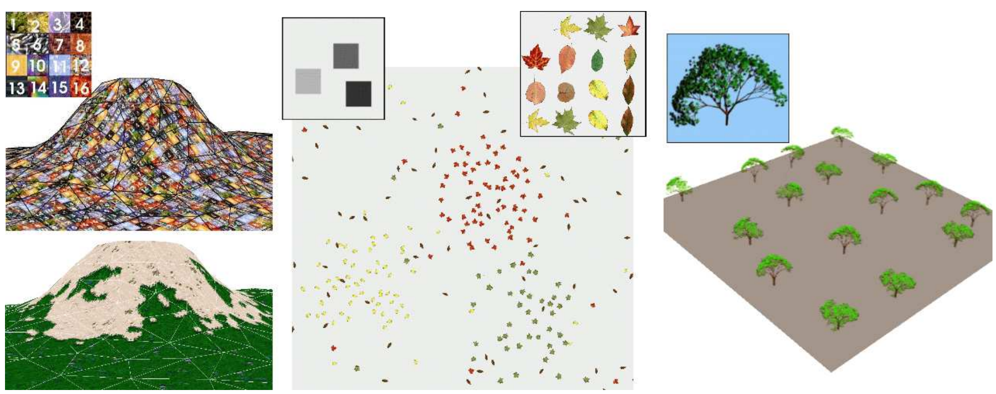

Figure 6. From left to right: non-periodic tiling (top) and boundary management (bottom). Poisson distribution with control of the probabilities and heterogeneity. Application to volumetric textures.

6.2.3. Procedural geometric skinning

Participants: Marie-Paule Cani, Caroline Larboulette.

Adding details to an animation while avoiding the heavy coast of a physically-based simulation can be done through a procedural approach. We just proposed a method of that kind for generating skin and cloth wrinkles on top of a standard character animation [23] : the dynamic wrinkles layer uses the deformations of the underlying mesh together with constraints such as length preservation for generating local deformations mimicking wrinkles. Results are generated in real-time.

6.2.4. Interactive procedural animation

Participants: Marie-Paule Cani, François Faure, Frank Perbet.

We address the issue of interactively animating large complex vegetal scenes such as a meadow with trees and characters acting on the vegetation (see figure 7). We build on our previous model which consists of three levels of detail (LODs): 3D vegetation in the foreground, semi-transparent textures on deformable polygons in the middle, and ground texture for the background. We improve on our previous approaches by reducing several artefacts due to LODs and allowing the characters to tread the grass. The terrain is seen as a continuous noised function sampled at mesh nodes. Walking characters generate a potential stored in terrain nodes. This potential is combined with other parameters (shape, height, density, etc.) to render the grass. The potential eventually vanishes to simulate a progressive shape recovery [13].

Figure 7. An animated large complex vegetal scenes: a prairie with trees and characters acting in the vegetation.

6.3. Physically-based simulation

Participants: Marie-Paule Cani, Jean Combaz, Guillaume Dewaele, François Faure, Fabrice Neyret, Laks Raghupathi, Florence Zara.

6.3.1. Morphogenesis, expansion textures

Participants: Jean Combaz, Fabrice Neyret.

The purpose is to offer a modelling tool for complex surfaces which shape results from a growing phenomena (e.g. biological or geological surfaces), by allowing the user to control the growing rather than the shape itself. Controlling is done through a texture encoding the intensity and orientation of the deformations, either explicitly (e.g. map of rifts and subductions) or generatively (e.g. reticulation, hot spots...). Moreover, the control can also be interactive by ‘painting’ the effects directly on the surface. In particular, we simulated wrinkles and folds, which adds a complexity that is important for realism, but that the artist wants to control without having to explicitly describe the local shape (voir figure 8).

Jean Combaz is finishing his PhD on Expansion Textures. He is expected to defend his PhD in early 2004.

6.3.2. Virtual clay

Participants: Marie-Paule Cani, Guillaume Dewaele.

Efficiently animating virtual clay is a challenge, since neither optimisations proposed for solids (and based on a constant topology) nor for fluids (since there is a moving limit surface) are directly applicable. We, thus, proposed the first real-time model for this material [12], based on a layered approach. Three sub-models

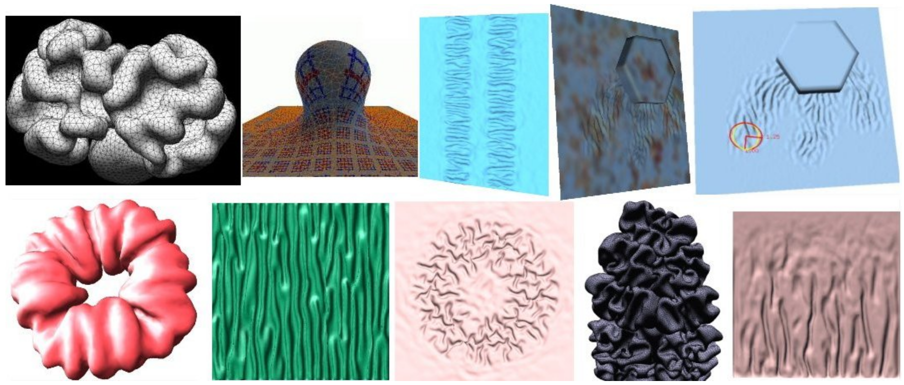

Figure 8. Complexe surfaces obtained using pre-drawn or interactively controlled expansion textures.

respectively handling large-scale deformations, local matter displacements, and surface tension, cooperate overtime for providing the desired behaviour.

6.3.3. Physically-based interactive rigid bodies

Participants: François Faure, Olivier Galizzi.

We addressed the issue of simulating large cliff collapses, in collaboration with the laboratory 3S (Sols, Solids, Structures) whose specialisation is mechanics. We have currently worked on two main topics:

- extend a popular mechanical model based on individual spheres, namely the Discrete Element Model, to assemblies of spheres in order to obtain a better rotational behaviour;
- apply levels of detail to collision detection and modelling.

6.3.4. Highly colliding deformable bodies

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

We addressed the issue 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. We developed a new approach for collision detection, based on a pool of "active pairs" of geometric primitives [17][25]. These pairs are randomly chosen, and they iteratively converge to a local distance minimum or to a pair of colliding elements. Managing the size of the pool allows us to tune the computation time devoted to collision detection. Temporal coherence is obtained by reusing the interesting pairs from one step to another. While not guaranteeing that we detect every collision at each time step, this approach has shown its efficiency when applied to the simulation of an intestinal surgery simulator as one can see in figure 9 (see also sections 6.6.3 and 8.2.2 for the resulting medical application).

6.3.5. Parallel simulation of cloth

Participants: François Faure, Florence Zara.

We addressed the issue of simulating cloth on a PC cluster, in collaboration with the laboratory ID and the company Yxendis. Cloth is modelled as a physically-based deformable mesh. There are two important difficulties:

- to reduce the amount of communication between the cluster nodes;
- to transfer the data from the cluster to the rendering machine.

We split the cloth in compact pieces, thus reducing communication to data related to the borders of the patches. We use socket communications to transfer the data scattered in the cluster to the rendering machine [20][10][19].

Figure 9. An example of highly deformable objects simulated in real-time.

6.4. Multi-Resolution Animation

Participants: Florence Bertails, Marie-Paule Cani, Fabrice Neyret.

6.4.1. Advected textures

Participant: Fabrice Neyret.

In order to add animated high-resolution details to a coarse fluid simulation, we developed a method which consist of advecting a flow noise texture (a previous technique proposed by Perlin and Neyret) in such a way to avoid the classical flaws such as stretching and ghosting artefact (see figure 10). The vorticity of the flow noise procedural texture is controlled by relying on a Kolmogorov cascade model conveying the energy from the highest spatial frequencies of the coarse simulation. Various parameters let the users control the behaviour of the animated texture. This work has been published at the Symposium on Computer Animation'03 [16].

Figure 10. Coarse simulation and its dressed counter-part. Three 2D and one 3D examples (note that the corresponding 3D grid is only $8 \times 8 \times 8$*).*

6.4.2. Multi-Resolution Particle Systems

Participant: Fabrice Neyret.

We have worked on the phenomenological simulation of avalanches, in the scope of the "slides and avalanche" local-ARC collaboration (see section 8.2). The model consists of hierarchical particles implementing the various passive and active elements such as the front vortex, point and tube vortices existing at various scales, and fluid markers. Main particles are only affected by the coarse fluid simulation (or by an autonomous dynamics model) while lower particles are affected by the velocity field generated by the higher level vortex particles (see figure 11). We are currently working on coupling the Advected Texture method to this by associating texture coordinates to the marker particles (at the lowest level).

6.4.3. Adaptive hair animation

Participants: Florence Bertails, Marie-Paule Cani.

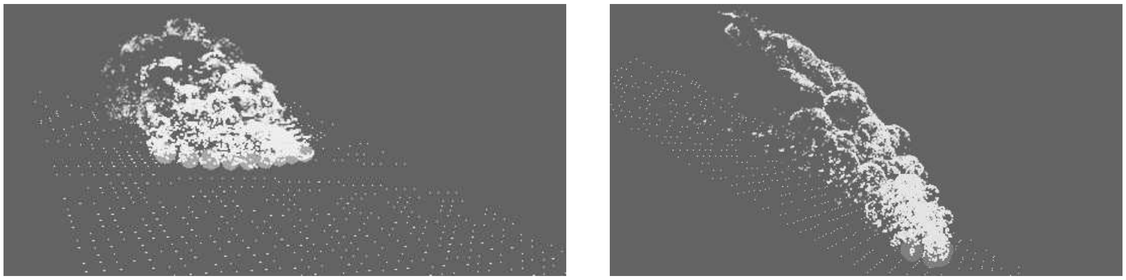

Figure 11. The visualisation of passive marker particles reveals the action of vortex particles of various scales acting on them.

The layered models we had experimented in the past for hair animation were far from real-time, due to the number of interacting hair wisps needed to capture the complexity of hair motion (see figure 12). To gain in efficiency, we recently proposed an adaptive animation technique, according to the methodological principles listed in section 3: hair wisps subdivision (where complex motion is observed) and fusion (where wisps have the same motion than their neighbours) enable the hair to automatically refine when and where needed [11]. This method results in interactive rates, and has been selected for an industrial transfer of technology (see sections 7.3 and 7.4).

Figure 12. Comparison between real hair and our adaptive hair simulation.

6.5. Motion capture from video

Participants: Laurent Favreau, Alexandre Perrin, Lionel Reveret.

This research project aims at capturing motion from the automatic processing of video to provide information for 3D animation of characters, such as humans or animals. Unlike several approaches in computer vision research, the goal is not to recognize activities, but rather to acquire robust geometric hints to control animation. Three main projects are currently under investigation: facial animation, deformation of skin surface and motion of animals.

6.5.1. Motion capture of facial expression

Participants: Alexandre Perrin, Lionel Reveret.

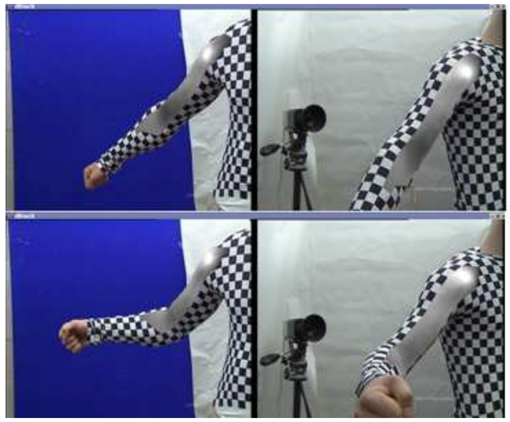

Figure 13. Motion capture of skin deformation

Previous results showed that 3D animation of facial expression can be described with a compact set of linear modes. This parametric reduction guarantees robustness when applied to the tracking of facial motion from video. However, it does not take into account the motion due to expressions such as smiling. The goal of this project is to combine several methods of facial animation into a coherent framework (see figure 14). As preliminary results, a method has been implemented to allow integration between linear models for speech production and pseudo-muscles models for expressions (see sections 7.3 and 7.4).

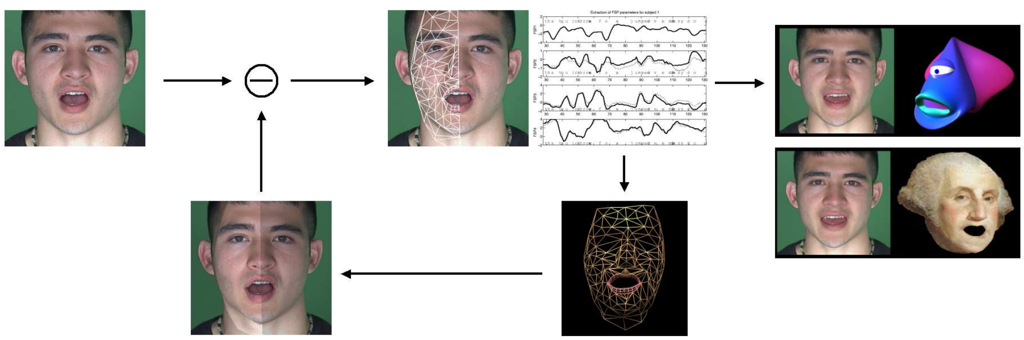

Figure 14. Animation of facial expression from video

6.5.2. Motion capture of skin deformation

Participant: Lionel Reveret.

A character animation pipeline consists of 3 main phases: firstly, the character appearance is modelled as a 3D surface. Secondly, a simplified skeleton is built to animate several parts of the model. Finally, a skinning phase asserts how the geometry of a 3D model is precisely deformed by the underlying skeleton animation. For this phase, several semi-manual techniques exist. They take into account effects such as smoothness and bulge of muscles. These techniques are still tedious and time-consuming. As a goal to simplify this step, this project investigates if the motion of skin surface can be learned from video analysis. To ensure time coherence of tracked motion, we have designed and used a special cloth of elastic fabric, printed with black and white squares. Tracking from several cameras allow to rebuild the 3D surface. Later, the 3D surface will need to be related to rigid motion to be applicable to character animation.

6.5.3. Motion capture of animal motion

Participants: Laurent Favreau, Lionel Reveret.

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 15). 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.

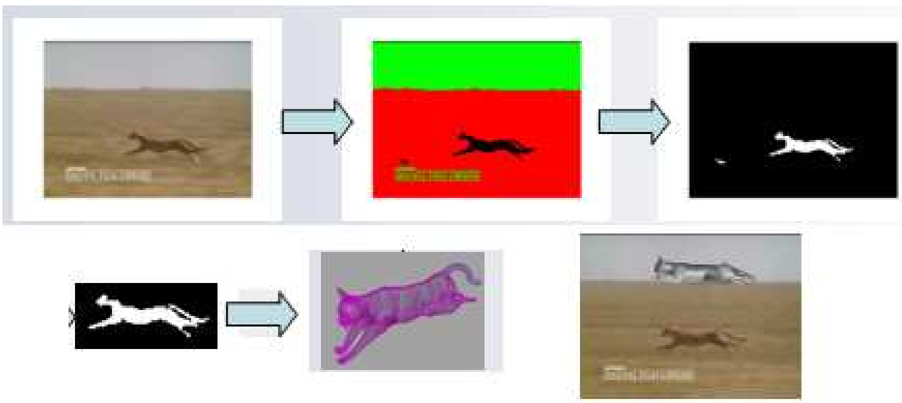

Figure 15. Motion capture of animal motion

6.6. 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.

6.6.1. Interactive modelling systems

Participants: Alexis Angelidis, Marie-Paule Cani, Guillaume Dewaele, Georges-Pierre Bonneau, Alex Yvart.

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

- The multi-resolution subdivision surfaces presented in section 6.1.1 have been used for interactive multi-resolution modelling;
- The real-time physically-based model for virtual clay presented in section 6.3.2 is dedicated to a sculpting system as close as possible to interaction with real-clay: in the context of Guillaume Dewaele's thesis, co-advised by Radu Horaud from the MOVI group, the virtual clay model is currently being combined with a vision interface for capturing the motion of the user's hands. So our clay model will be directly sculpted by fingers, making it usable for any artist, or even as an educational tool for small children.
- The *expansion textures* developed by Jean Combaz (see section 6.3.1) aim at offering high or middle-level tools to graphics users to design complex shapes such as wrinkles and folds.
- Lastly, the work of our external collaborator, Alexis Angelidis, at the University of Otago, is dedicated to interactive sculpting using space deformations: an initial shape is progressively edited using reversible fold-over free deformations, specified by swept user-defined tools [21].

6.6.2. Synthesis of natural sceneries

Participants: Philippe Decaudin, François Faure, Sylvain Lefebvre, Alexandre Meyer, Fabrice Neyret, Frank Perbet.

The diverse fundamental tools we are developing can be combined to allow the large scale specification (see section 6.2.2), efficient rendering (see sections 6.1.4, 6.2.1) and animation (see section 6.2.4) of vegetation (prairies, trees, forest, etc). These elements are currently used in the Vertigo project, enabling industrial transfer of our research results (see section 7.1).

Our work on fluid animation also applies to the synthesis of natural sceneries, as in the case of avalanche simulations we described in section 6.4.2, that were used in a local project with scientists from other disciplines (see section 8.2.1 and [6]). The advected textures (see section 6.4.1), aimed at adding animated details to any kind of fluid simulation, could be used to improve the rendering of our avalanches.

Lastly, the specification of complete natural sceneries is one of the aims of the Dereve II project (see section 8.1.1).

6.6.3. Medical applications

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

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

Firstly, the multi-resolution implicit representation (see section 6.1.3) we have developed provides an intuitive understanding of shapes, which is useful in anatomical applications. In addition to our use of this representation in a surgical simulator [22], we are planning to rely on this model for a new collaboration with the Anatomy lab at the Medicine Faculty of Grenoble, set up at the occasion of Olivier Palombi's PhD.

Secondly, our tools for efficient physically-based simulation, and in particular our new contributions to collision detection and response (see section 6.3.4), have been used for real-time simulation of intestinal surgery (see section [17][25]), in the context of a project funded by INRIA (see section 8.2.2).

6.6.4. Animation of virtual creatures

Participants: Florence Bertails, Marie-Paule Cani, Christine Depraz, François Faure, Laurent Favreau, Caroline Larboulette, Alexandre Perrin, 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 (general body motion, faces, and body deformations, see section 6.5); the procedural method we developed for adding skin details (see section 6.2.3); the physically-based animation tools (sections 6.3.4 and 6.3.5) that we are currently applying to the simulation of virtual garments; and our adaptive animation algorithm for efficiently computing hair motion (see 6.4.3).

Except for the extraction of an animal's global motion from video, all these contributions are developed within projects with industrial partners (see Virtual Actors RIAM project section 7.3, 7.4 and RNTL PARI project section 7.2).

7. Contracts and Grants with Industry

7.1. RIAM Vertigo

Participants: Philippe Decaudin, Fabrice Neyret.

The partners of this collaboration are Bionatics (developer of softwares dedicated to the creation of 3D models of plants for image production and video games), Thales Training & Simulation (flight simulators) and EVSION. The project is funded (115000euros for Evasion) by the CNC (Centre National de la Cinématographie) and RIAM (Réseau pour la Recherche et l'Innovation en Audiovisuel et Multimédia) for 18 months and started in February 2003. The purpose is to extend and transfer our representations and techniques of realistic real-time rendering of a forest. An engineer and a student (to date) are specifically working on this.

7.2. RNTL PARI

Participants: Marie-Paule Cani, François Faure, Laure Heigeas, Caroline Larboulette, Laks Raghupathi.

The goal of this collaboration (started in June 2003 for 2 years) with the video games company Galilea, the software development company Virtools, and LEIBNIZ/INPG Laboratory is to develop tools for easily including physically-based animation in video games, especially for more realistic humanoids. We will develop and transfer new tools for interactive physically-based animation, and specific modules dedicated to skin and cloth simulation.

7.3. RIAM Virtual Actors

Participants: Florence Bertails, Marie-Paule Cani, Alexandre Perrin, Lionel Reveret.

In the context of a RIAM contract started in June 2003 for 18 months with Galilea and LEIBNIZ/INPG, new technologicals tools are developed to create believable 3D characters for video games. EVASION is involved in two main projects : facial animation for talking characters and real-time animation of hairs. A lipsync product is developed from previous results on facial animation (see section 6.5.1). "Lipsync" consists of synchronising the animation of facial movement of a 3D character with a corresponding soundtrack. Previous research results allow to perform an analysis of live video of a person speaking without the need of markers. Animation of hair (see section 6.4.3) will be based on our recent works on hierarchical simulation of the dynamics of hairs motion [11]. The adaptive simulation will be improved to allow the real-time animation of hair wisps.

7.4. Start-up Virtual Actors

Participants: Florence Bertails, Marie-Paule Cani, François Faure, Laure Heigeas, Caroline Larboulette, Alexandre Perrin, Laks Raghupathi, Lionel Reveret.

To ease industrial transfer in the contracts with the company GALILEA listed above, people from Galilea, LEIBNIZ/INPG lab and EVASION/GRAVIR just created a start-up company (October 2003), Virtual Actors, which develops and sells software tools to game developers. Some of our exiting software, plus some of the new technologies we develop in the project listed above, will be transfered to this startup.

7.5. Collaboration with ATI and Nvidia Graphics board constructors

Participants: Philippe Decaudin, François Faure, Sylvain Lefebvre, Alexandre Meyer, Fabrice Neyret, Frank Perbet, Lionel Reveret.

We are in close contact with the ATI and Nvidia developpement teams (see also section 8.2.4), providing suggestions and bug reports, and getting prototype boards.

7.6. Collaboration with Alias|Wavefront

Participants: Christine Depraz, Alexandre Perrin, Lionel Reveret.

For the year 2003, Alias|Wavefront has granted EVASION licences of their 3D modeling and animation software Maya in the context of a research agreement. Maya is currently used to edit and visualize animation of animals motion and facial animation. Another project explores the use of Maya as a graphical front end for a 3D modeling tool from hand gestures.

8. Other Grants and Activities

8.1. Regional projects

8.1.1. Rhône-Alpes Project: Dereve II

Participants: Marie-Paule Cani, Alexandre Meyer.

This is a regional project in the domain of Computer Graphics started in July 2003 for one year, where EVASION is involved on two points. First, on the morphing of textured models: collaboration between Marie-Paule Cani and Eric Galin (LIRIS). Second, on the modelling and rendering of the Alpine landscapes: collaboration between Alexandre Meyer, Eric Tosan (LIRIS) and Xavier Marsault (Ecole d'Architecture de Lyon).

8.1.2. Rhône-Alpes Project: Physically-based cloth simulation on PC clusters

Participants: François Faure, Florence Zara.

This work is described in section 6.3.5. The project is now completed and Florence Zara has just defended her Ph.D. thesis (December 1th, 2003). The current results are not mature enough to be transferred directly to Yxendis, our industrial partner. We are investigating on how to pursuit this collaboration.

8.2. National projects

8.2.1. local ARC Slides and Avalanches

Participants: Marie-Paule Cani, Florence Bertails, Fabrice Neyret.

A local cooperation with LEGI, CEMAGREF and Idopt/LMC project was held between April 2001 and April 2003. Its purpose was to obtain tools for visually realistic avalanches for communication about risks (for government authorities, citizens, etc.). Evasion successively studied dense and volatil avalanches, adding visually realistic rendering and small scale animated features to the numerical simulations (See our last results in section 6.4.2).

8.2.2. ARC Intestinal surgery simulation

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

This project, funded by INRIA as a national research action (ARC), was held between January 1999 and July 2003. The partners were EVASION, ALCOVE (FUTURS Research Unit of INRIA), the company SIMEDGE and IRCAD, a surgical training centre in Strasbourg. Several solutions for animating a virtual intestine were experimented (see section 6.3.4 and 6.6.3). The final prototype was tested by surgeons on July 2003.

8.2.3. ARC Docking

Participant: Georges-Pierre Bonneau.

The partners of this collaboration are EVASION, ISA (INRIA-Nancy Research Unit), and Geometrica (Sophia-Antipolis Research Unit). The main goal of this project (from January 2003 to December 2004) is to develop an immersive, interactive and easy-to-use modelling environment to enhance molecular docking. Website: `http://www.loria.fr/projets/docking/pages/`

8.2.4. CNRS AS Real-Time

Participants: Philippe Decaudin, Sylvain Lefebvre, Alexandre Meyer, Fabrice Neyret.

CNRS AS "real-time" from October 2002 to December 2003: EVASION members participated actively to this AS, which allowed in particular to transmit our remarks and wishes to graphics board developers ATI and Nvidia, with whom we keep in contact.

8.2.5. CNRS AS Collisions

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

We have been one of the managers of the AS Collisions, a one-year working group sponsored by CNRS (October 2002 to October 2003). Several meetings and one session of the annual "Groupe de travail Animation et Simulation" have been devoted to identify and classify the major current practical and theoretical difficulties related to the domain of collision detection.

8.2.6. CNRS AS Virtual Human

Participants: Florence Bertails, Marie-Paule Cani, Caroline Larboulette, Alexandre Perrin, Lionel Reveret.

This project (from October 2003 to October 2004) is an initiative from C. Pelachaud (U. Paris VIII), S. Donikian (SIAMES project, IRISA) and J.P. Jessel (IRIT) to gather state-of-the-art and perspective on the modelling and animation of 3D character animation among the French research community. A initial meeting was held in Paris on the 9th of October 2003. It resulted in the creation of working groups. In particular, the members of EVASION will participate in two groups : Modelling of the human body, lead by S. Akkouche (LIRIS), and Conversation Agents, lead by C. Pelachaud (U. Paris VIII).

8.2.7. Robea "Modèles Bayésiens pour la Génération de Mouvement"

Participants: Marie-Paule Cani, François Faure, Olivier Galizzi, Frank Perbet.

The goal of this project, with SHARP and IRISA (from October 2002 to October 2005), is to model the behaviour of autonomous characters in complex environments. Our contribution is to model a vegetal scene and to simulate uneven ground with local collapses under the feet of the characters. This year we have ported our virtual meadow to OpenMask, the software platform chosen for the project (see section 6.2.4).

8.3. European projects

8.3.1. Network of excellence AimShape

Participants: Alexis Angelidis, Georges-Pierre Bonneau, Marie-Paule Cani, Basile Sauvage, Alex Yvart.

Our group is involved in the newly accepted network of excellence AimGShape leaded by Bianca Falcitiendo (CNR IMA, Italy). We will be wondering on the design of novel geometry representations. The project starts in December 2003.

8.3.2. European project SHARING

Participant: Georges-Pierre Bonneau.

Participation to the writing of an European Union project proposal. If the project is accepted it will be the second part of the European project MINGLE ending in January 2004.

9. Dissemination

9.1. Leadership within the international scientific community

Marie-Paule Cani contributed to the creation of a French chapter for the Eurographics association in July 2003. She has been the president of this chapter since then. The first event of the French chapter was the conference "Rencontres Francophones d'Informatique Graphique" held in Paris in December 2003, jointly with AFIG (Association Française d'Informatique Graphique).

9.2. Editorial boards and program comittee

Program Committees:

- Marie-Paule Cani served as "Topic chair" for the "animation" domain in the program committee of Eurographics'03. She was a program committee member for "Computer Animation and Social Agents" (CASA'03, Rutgers, USA) and the "ACM Symposium on Computer Animation" (SCA'03, San Diego, USA), "Surgery Simulation and Soft Tissue Modelling" (IS4TM'03, Juan les Pins).
- Georges-Pierre Bonneau was a program committee member for "Shape Modelling International" (Genova, 7-9 june 2004, `http://smi2004.ge.imati.cnr.it`), "Eurographics Symposium on Parallel Graphics and Visualisation" (Grenoble, 10-11 june 2004, `http://www-id.imag.fr/EGPGV04`). He was a senior reviewer for Eurographics 2004 (Grenoble, 30 August-3 September 2004, `http://eg04.inrialpes.fr`). He organised (with G. Nielson, ASU, T. Ertl, Uni. Stuttgart) the Dagstuhl Seminar on Scientific Visualisation (Dagstuhl, Allemagne, 01-06 Juin 2003, `http://www.dagstuhl.de/03231`). He was co-Chair for the conference Visualisation Symposium 2003 (Eurographics and IEEE Technical Committee on Visualisation and Graphics, Grenoble, 26-28 Mai 2003, `http://www.inrialpes.fr/VisSym03`).

- Lionel Reveret was a program committee member for "ACM Symposium on Computer Animation" (SCA'2003, San Diego, USA).
- Fabrice Neyret served in the Program Committee of SIGGRAPH'03

Editorial boards:
Marie-Paule Cani serves in the editorial board of the journal Graphical Models (academic press); Georges-Pierre Bonneau serves in the editorial board of the IEEE TVCG journal.

9.3. Invited conferences

In addition to the communications in the conferences listed in the bibliography section, Marie-Paule Cani gave an invited talk at the multi-disciplinary conference of the "Institut Universitaire de France" on "Complexity" (Lyon, March 2003) and an invited talk at the Computer Science Lab of the Ecole Polytechnique (LIX) in March 2003.

Fabrice Neyret gave a talk at Universite Libre de Bruxelle.

Alexandre Meyer gave a talk at LIRIS (Lyon) in November 2003.

9.4. Large public conferences and meetings

- Active participation to the national day of science "Science en Fête" with 12 people involved to present an overview of our work to a large audience with a demonstration video.
- Fabrice Neyret is member of the "Cafés Sciences et Citoyen" animation team (Grenoble), funded by the communication department of CNRS, and is the creator of the web site `http://www-evasion.imag.fr/cafesSC/`. Conferences are organized on a monthly basis.
- Fabrice Neyret has been collaborating with the junior high school "collège Jules Flandrin" (Corenc) to present the various aspects of a researcher's work. The project "passion recherche" is in collaboration with Martine Désigaux, teacher. Fabrice Neyret is also member of the "Soirées Sciences et Citoyen Junior" animation team at the junior high school "collège Jules Flandrin" funded by Rhône-Alpes region. Conferences are organized on a quarter basis. He is also the creator of the website `http://www-evasion.imag.fr/soireesSCJ/`
- Fabrice Neyret gave a talk "sciences in movies special effects and video games" at the "Midisciences" conference in Grenoble.
- Fabrice Neyret served as invited speaker in the "rencontres de l'imaginaire" meeting gathering scientists and artists.
- Fabrice Neyret is part of the scientific committee of the exhibition "les fils d'Ariane" on cartography organized by CCSTI-Drome.
- The 'MobiNet' team (4 members of Artis and Evasion including a "monitorat" project plus a dozen of temporary assistants) organises 8 practices per year on a half-day basis for about 150 senior high school pupils in the scope of INPG "ingeneer weeks". The purpose is to give a more intuitive practice of maths and physics, and to give insights on programming and engineering. See 5.4 and `http://www-imagis.imag.fr/mobinet/`.

9.5. 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).

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