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Activity Report 2011

Project-Team EVASION

Virtual environments for animation and image synthesis of natural objects

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Interaction and Visualization

Table of contents

Project-Team EVASION

Keywords: 3D Modeling, Computer Graphics, Geometry Modeling, Visualization

1. Members

Research Scientist

Rémi Ronfard [Research scientist, INRIA, CR1, HdR]

Faculty Members

Marie-Paule Cani [Team Leader, Professor, ENSIMAG/Grenoble INP, HdR]
François Faure [Professor, UJF, HdR]
Stefanie Hahmann [Professor, ENSIMAG/Grenoble INP, HdR]
Jean-Claude Léon [Professor, ENSE3/Grenoble INP, HdR]
Olivier Palombi [Professor in Anatomy and Neurosurgery, Anatomy Laboratory, UJF, HdR]

External Collaborator

Ahmad Shahwan [ANR ROMMA, Grenoble INP, October 2010 - September 2013]

Technical Staff

François Jourdes [Engineer, INRIA, September 2009 - November 2011]
Maxime Quiblier [Engineer, INRIA, December 2010 - December 2012]
Olivier Carré [Engineer, INRIA, October 2011 - December 2012]
Moreno Trlin [Engineer, INRIA, November 2011 - September 2012]

PhD Students

Adrien Bernhardt [MENRT, Grenoble INP, December 2008 - December 2011]
Guillaume Bousquet [PASSPORT, UJF, September 2008 - August 2011]
Flavien Boussuge [CIFRE EADS, UJF, June 2011 - May 2014]
Rémi Brouet [50% with IIHM/LIG, BQR Grenoble INP, October 2011 - September 2014]
Ali Hamadi Dicko [ANR Sohusim, UJF, September 2010 - September 2013]
Marie Durand [ANR RepDyn, April 2010 - April 2013]
Arnaud Emilien [MENRT, Grenoble University, October 2011 - September 2014]
Vineet Gandhi [ANR SCENOPTIQUE, Grenoble University, October 2011 - September 2014]
Bui Huu Phuoc [BQR Grenoble, October 2009 - September 2012]
Damien Rohmer [MENRT, Grenoble INP, October 2007 - September 2011]
Lucian Stanculescu [LIMA, Univ. Lyon 1, LIRIS-EVASION, October 2009 - September 2012]
Maxime Tournier [MENRT, Grenoble INP, October 2007 - October 2011]
Cédric Zanni [MENRT, Grenoble INP, September 2010 - August 2013]

Post-Doctoral Fellows

Dobrina Boltcheva [50% with MORPHEO, Grenoble INP, INRIA, November 2009 - September 2011]
Benjamin Gilles [Fatronik, Grenoble INP, January 2009 - September 2011]

Visiting Scientist

Alla Sheffer [Professor, UBC Canada, September 2010 - May 2011]

Administrative Assistant

Elodie Toihein [Administrative Assistant, INRIA, from October 2009]

2. Overall Objectives

2.1. Introduction

Since its creation in 2004, the EVASION project-team has focused on modeling, animation, visualization and rendering of natural scenes and phenomena. This was organized in three main scientific objectives: (1) creation of digital content; (2) animating nature; and (3) efficient visualization of very large scenes. In 2011, the team was re-organized to prepare the transition to a new research agenda on Intuitive Modeling and Animation for Interactive Graphics & Narrative Environments (IMAGINE). As a consequence, the first two scientific objectives of EVASION have been intensified and refocused, and the third scientific objective has been discontinued.

Our new research objectives are now best described with the three following items:

- **Shape design**: We aim to create intuitive tools for designing and editing 3D shapes, from arbitrary ones to shapes that obey application-dependent constraints (such as, for instance, being developable, to model virtual objects made of cloth or of paper). This is a continuation of our earlier work on the creation of digital content, with a much broader field of application that now includes both natural contents such as anatomic structures [10], landscapes and mountains [30], [17] and man-made contents such as garments, villages and mechanical assemblies [7], [23].
- **Motion synthesis**: Our goal is to design methods to convey and control real-time 3D motion and deformation, from motion of passive objects, materials or mechanisms to plausible animation of virtual creatures. This is a continuation of our earlier work on animating nature, again with a much broader field of application that now includes both natural physical motion [3], [4], [6], [16], [29], [27], mechanical motion [7] and high-level character motion [1], [13].
- **Narrative design**: Lastly, we are starting a new activity focusing on designing narrative content (stories) for virtual creatures and cameras on virtual stages. This new research direction includes work on semantic annotation of virtual worlds [9], [10], [23], [25] and automatic reasoning for virtual cinematography [31], [21], and is expected to evolve towards authoring tools for storyboarding and directing scenario-based dynamic scenes.

2.2. Highlights

- European Research Council (ERC) advance grant 2011, Marie-Paule Cani.
- Eurographics Outstanding Technical Contributions Award 2011, Marie-Paule Cani.
- Papers accepted at TOG [3], [4], and SPM [2].
- The Hand Navigator was presented at cité de la Vilette as part of Fête de la science.
- Aestem Studio and Hand Navigator were presented at Experimenta, Salon de la Biennale Arts et Sciences, organized by CEA-LETI and Theatre de l'Hexagone in Grenoble.

3. Scientific Foundations

3.1. Scientific Foundations

In 2011, the EVASION project team adopted a new research strategy which is described in full detail in the IMAGINE research proposal, and can be summarized as follows.

3.1.1. User-centered models for geometry and animation

The first axis of our research consists in developing the fundamental tools required to achieve expressive digital design, namely revisiting models for geometry and animation. By *models*, we mean both the representation of the object of interest, and the development of the associated algorithms for data generation and editing. Although unusual, thinking about shapes, motion and stories in a similar way enables cross fertilization and helps validating our design principles by applying them to different cases. Thinking about models in a user-centered way led us to the following principles, developed below:

1. Develop high-level models embedding a priori knowledge.
2. Allow these models to generate detailed shapes or motion from minimal, intuitive input.
3. Set up advanced editing and transfer tools.

Firstly, making models *user-centered* means that they should **behave the way a human would have predicted**. This is indeed the only way to advance towards the suggestive but predictable interaction we are seeking for. Users' expectations are typically based on the cognitive meaning they give to a model, combined with their experience on the way similar objects would behave in the real world. We must thus step away from standard low-level representations, but develop high-level models expressing a priori knowledge. For example, this includes knowledge about developable geometry to model folded paper or cloth; about constant volume deformation to edit virtual clay or to animate plausible organic shapes; about appropriate physical laws to control passive objects; or about film editing rules to model semi-autonomous camera with planning abilities, synthetic vision and cinematographic knowledge, that can receive higher-level instructions from the user.

Secondly, the basic role of these high-level models is to generate detailed content from minimal user input, thus saving user's time on predictable or repetitive aspects. Achieving this goal requires the development of efficient procedural generation algorithms. For instance, designing with highlevel models for cloth or paper should free the user from having to manually design plausible geometric folds; setting a human settlement over a terrain should mean giving the strategy for land occupation, but leaving a procedural village model spread according to local resources and to terrain geometry; animating complex, composite objects should only require the specification of their material composition map, but leave physically-based animation – the most popular example of procedural method - generate plausible, detailed deformation under interaction.

Lastly, advanced transfer tools and editing techniques should be developed to enable quick, intuitive setting and fine tuning of the models. Transfer tools are aimed at allowing re-use of existing content, either in terms of global setting, details, or style. This is indeed a challenge when dynamic, composite models are concerned: for instance, how can a garment automatically be transferred to a creature of different morphology, while making it look *the same*? Similarly, to be intuitive, editing should maintain the main cognitive features of a model. For instance, deforming the bounding volume of crumpled paper should increase the amount of paper while maintaining its developable nature; and stretching a table with plates and glasses should ideally stretch the table geometry, but duplicate the objects on it.

3.1.2. Creating and experimenting with interactive virtual prototypes

Our second focus is the development of real-time environments where users can seamlessly create models, play with them and edit them, ideally without or with a very short learning stage. Developing this axis will provide the necessary test-bed for the high-level models and algorithms we just presented. It will also give us the opportunity to develop and validate general design principles for intuitive creation. Lastly, it will enable us to apply our work to a variety of practical cases, listed in the application section below.

The principles that will drive this part of our work, detailed below, are the following:

1. Allow to design animated prototypes and experiment with them within the same system.
2. Enable intuitive, gesture-based interaction.
3. Ensure real-time response from the system in both “editing” and “play” modes.

In current modeling pipelines, animated 3D content typically goes through several different digital or nondigital media, requiring user time and efforts. In contrast, we believe that these stages should ideally be performed within the same system, from early draft, through shape and motion refinement, processing, andpost-processing. This will enable users to iteratively refine their design thanks to immediate visual feedback and to the ability to interact with their prototypes at any stage, before further editing and refining them.

Our second principle is to design our new generation of interaction tools from a user-centred perspective: the idea is to conduct preliminary studies of spontaneous design and editing gestures, and to transparently drive the model and tool parameters from this interaction, in order to best suit users' expectations. We are already started to experiment with this paradigm for intuitive shape editing in 2D and 3D. There is indeed much to do to extend this approach to the intuitive design of motions and stories.

Lastly, one of the most important features towards effective creation tools is to provide real-time response at every stage. Creative design is indeed a matter of trial and error, and we even believe that creation more easily takes place when users can immediately see and play with a first version of what they have in mind, serving as support for refining their thoughts. For maybe the first time, the goal is to provide such interactive sculpting media not only for static, but also for dynamic shapes. In previous years, EVASION has developed a methodology that combines layered models, adaptive degrees of freddom and GPU processing for achieving that goal.

4. Application Domains

4.1. Application Domains

The applications of this research include any situation where users need to create new, imaginary, 3D content. Our goal is to promote interactive digital design as a tool to quickly express, test and refine the models they have in mind, as well as an efficient way for communicating them to other people. Applying our work to different domains enables us to work with different categories of users, from digital experts to professionals who never used digital modeling and to the general public. This diversity will be instrumental for the validation of our models, algorithms and interactive systems. The application domains we are currently interested into are listed below.

- Industrial Design *(Stefanie Hahmann, Jean-Claude Léon)*
- Mechanical & Civil Enineering *(Jean-Claude Léon, François Faure)*
- Natural Sciences *(François Faure, Olivier Palombi, Marie-Paule Cani)*
  - Virtual anatomy: ontology, 3D modeling & animation
  - Plants: high level representation for plats geometry
- Education, Communication & Art *(Olivier Palombi, Marie-Paule Cani, Rémi Ronfard)*
  - Interactive tools for education
  - Design tools for visual artists and for the public
  - Theater: virtual staging & rehearsals
- Films & Games *(Rémi Ronfard, Marie-Paule Cani, François Faure, Stefanie Hahmann)*
  - Real-time, plausible clothing
  - Virtual cinematography & film editing
  - Interactive story telling

5. Software

5.1. MyCorporisFabrica

Participants: Ali-Hamadi Dicko, François Faure, Olivier Palombi.

My Corporis Fabrica (MyCF) is an anatomical knowledge database (see fig. 1). During 2011, we have added new anatomical entities and improved some parts of FMA (Foundational Model of Anatomy). The FMA's license is now under Creative Commons licenses (CC-by : Licensees may copy, distribute, display and perform the work and make derivative works based on it only if they give the author or licensor the credits in the manner specified by these). The license of MyCF is not yet defined. Our new contribution this year, is the creation of a brand new ontology about human functions. Based on the International Classification of Functioning, Disability and Health, also known as ICF, we have organized human functions through a tree of 4330 items. A original journal paper must be submitted soon. MyCF browser is now available on line: http://www.mycorporisfabrica.org/. The MyCf's generic programming framework can be used for other domains. The link with semantic and 3D models matches research activities of IMAGINE towards interactive digital creation media. Anatomy can be seen as a study case.

Figure 1. My Corporis Fabrica is an anatomical knowledge database developed in our team.

5.2. SOFA

Participants: Guillaume Bousquet, Ali Hamadi Dicko, François Faure, François Jourdes.

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. The GPU capabilities of SOFA have been demonstrated at a SIGGRAPH talk [16] (see fig. 2) and presented in a book chapter [27].

SOFA is currently used by company Digital Trainers to develop basic skill endoscopic simulators. A start-up company based on SOFA, InSimo, is being created in the Strasbourg IHU, and is expected to start in first semester 2012.

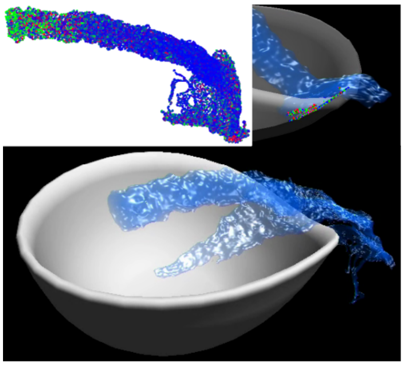

Figure 2. GPU methods in SOFA for detailed deformable objects at interactive rates.

5.3. AESTEM Studio

Participants: Adrien Bernhardt, Marie-Paule Cani, Maxime Quiblier.

AESTEM Studio is dedicated to free form shape Modeling through Interactive Sketching and Sculpting gestures. The goal is to provide a very intuitive way to create 3D shapes, as easy to use for the general public as roughly sketching a shape or modeling it with a piece of clay. This software is developed in the framework of a research contract with the company Axiatec. It enables to create a 3D shape by successively painting in 2D and smoothly blending different components: the painting step takes place at different scales and from different viewing angles. 3D is inferred from a 2D painted region by using an isotropic implicit surface along the skeleton of the region. Then, implicit blending, restricted to the intersection areas, is computed to connect the new component with the existing ones. This relies on our researches on free-form sketch-based modeling using geometric skeletons and on convolution surfaces. Our prototype is written in C++. It uses the Ogre open-source library and our new library Convol dedicated to convolution surfaces. Future extensions will include the combination of sketching with modeling gestures related to clay sculpting, such as deforming a shape through pulling, pushing, bending or twisting gestures.

5.4. Convol

Participants: Marie-Paule Cani, Maxime Quiblier, Cédric Zanni.

Convol is a new C++ library we develop for easing our work on implicit surfaces – and more particularly on the sub-calss of convolution surfaces. It enables us to make our latest research results soon available to the rest of the group and easily usable in our industrial partnerships. Convol incorporates all the necessary material for constructive implicit modeling: skeleton-based distance and convolution primitives, with closed form solution for the field values and gradient whenever possible; a variety of blending operators; and several methods for tessellating an implicit surface into a mesh, and for refining the later in highly curved regions. This development is funded by INRIA as support to our research group.

6. New Results

6.1. High level model for shapes

6.1.1. Constructive implicit modeling

Participants: Adrien Bernhardt, Marie-Paule Cani, Maxime Quiblier, Cédric Zanni.

Implicit surfaces are an appealing representation for free-form, volumetric shapes. In addition to being able to represent shapes of arbitrary topological genius, they have the ability to be constructed by successively blending different components, which eases interactive modeling.

Within Cédric Zanni's PhD, we are collaborating with a researcher in formal computation, Evelyne Hubert, to improve and extend the analytical methods for computing closed form solutions for convolution surfaces. We introduced a warping method for enabling the modeling of complex helical shapes from a single implicit primitive (fig. 3), which greatly enhances efficiency [14]. We also proposed a method based on anisotropic, surface Gabor noise, for generating procedural details on skeleton-based implicit surfaces. The surfaces enhanced with details can still be smoothly blended, with a natural transition between the details they carry. A paper has been submitted for publication. We are currently developing normalized convolution surfaces, invariant through homothetic transformations, and which will provide an intuitive blending sharpness parameter, usable with simple additive blending.

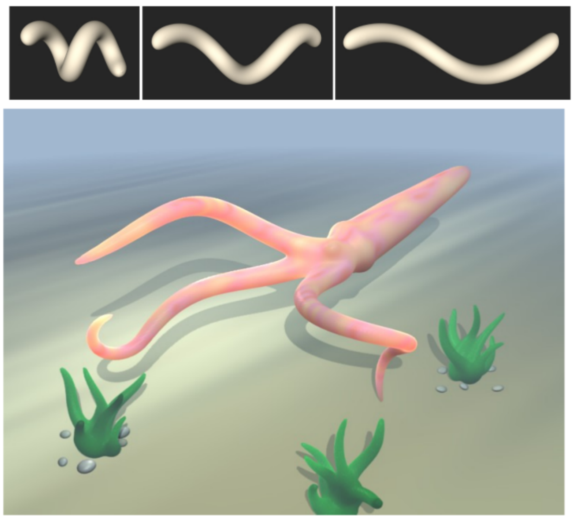

Figure 3. Top: Helical primitives. Bottom: Implicit modeling of a squid. Each tentacle is made of two helical primitives.

Lastly, we contributed to a new blending operator, gradient blending, which enables us to blend implicit shapes not only in function of the field values but also of their gradients. This solves a number long standing problems in implicit modeling: we can generate bulge-free blending, ensure that the topological genius of the blended shape remains the one of the union of the input one, and avoid the blur of small details. A paper is currently submitted for publication.

6.1.2. Ontology-based mesh segmentation

Participant: Olivier Palombi.

The smart use of data by automated systems is now a problem having implications as various as the optimization of the functioning of web search engine or medico-surgical simulation. The program MyCF is an attractive innovation in this field, gathering an organization of the biomedical knowledge in the form of ontologies, 3D acquisition of anatomical structures and also the possibility to export these 3D structures to biomechanics simulation programs, like SOFA. Our work consisted in creating , thanks to the program Protégé, an ontology of the functions of the human body (which didn't existed then) and to couple it with the anatomical ontology FMA (ontology we significantly reworked). The objective was to build connections introducing a link between anatomical structures and functions they bear. Once this goal reached, it became possible for a computer to link the elimination of an anatomical structure and the loss of a function, this real-time. Thus we established the foundations of an ontology which currently gather 84484 entities (4330 of which are functional entities) and 4159 relations. So, our contributions are threefold: first of all, the creation of an ontology of functions of the human body which is an original one; then the redrafting of the FMA ontology which allowed us to complete some lacks and above all to make of it a tool more oriented towards the practical applications we waited about it, and finally, the contribution which seems to us the more significant is, without any doubt, the institution of a link between these two ontologies. This work is at is moment unfinished and should be pursued in order to approach always more the reality in the field of medico-surgical simulation.

6.1.3. French translation of the Foundational Model of Anatomy (FMA) ontology

Participant: Olivier Palombi.

The goal of this study, performed in collaboration with the LITIS [1] was to facilitate the translation of FMA vocabulary into French. We compare two types of approaches to translate the FMA terms into French. The first one is UMLS-based on the conceptual information of the UMLS metathesaurus. The second method is lexically-based on several Natural Language Processing (NLP) tools.The two approaches permitted us to semi-automatically translate 3,776 FMA terms from English into French, this was to added to the existing 10,844 French FMA terms in the HMTP (4,436 FMA French terms and 6,408 FMA terms manually translated) [9].

6.1.4. Homology computation

Participants: Dobrina Boltcheva, Jean-Claude Léon.

This work is a part of the BQR project IDEAL (see Section 8.1.2) which is performed in collaboration with Leila de Floriani from the University of Genova in Italy. The main goal of this project is to study non-manifold geometrical models and to find out features allowing to classify these models and criteria for determining their shape. We are interested in non-manifold models such as idealized industrial CAD models, since they are still ill-understood even if they are frequently used in computer graphics and many engineering applications. This year, we have worked on the computation of topological invariants on non-manifold simplicial complexes, such as the homology groups, since they play a crucial role in the field of shape description and analysis. The goal was also to acquire a better understanding of the behaviour of the homological groups on non-manifold models. A first step towards this goal has been achieved this year and we have developed an efficient method for computing the homology of a large simplicial complex from the homologies of its sub-complexes. This work has been already published in a research report in 2010 and a journal paper in the context of the international conference on Solid and Physical Modeling [[2]].

[1] Laboratoire d'Informatique, de Traitement de l'Information et des Systèmes (LITIS) Institut National des Sciences Appliquées de Rouen – Université du Havre – Université de Rouen

6.1.5. Creased paper modeling

Participants: Marie-Paule Cani, Stefanie Hahmann, Damien Rohmer.

Although very common in real life, 3D creased paper models are rarely seen in virtual scene due to the lack of available modeling tools.

Figure 4. Example of static creased paper generated by our method.

We developed a new approach to efficiently generate a 3D model of creased paper from a boundary curve (see fig. 4). The generated surface lie on the given boundary curve while preserving the lengths with respect to the original pattern. Contrary to other approaches, this method can seamlessly handles sharp creases while automatically generating the optimal mesh to this shape. The generation is fast enough to be used interactively, and the physical properties such as developability are approximatively preserved. This generation of static surface generation has been published in EG short paper [22].

6.1.6. Spline surface models for arbitrary topologies

Participant: Stefanie Hahmann.

In geometric modeling quad meshes have always been popular, in the sense that NURBS surfaces which are composed of a tensor product network of quadrilateral patches, are the inevitble standard for describing free-form shapes. They are defined on a chess board like assembly of quadrilateral parameter domains. But when modeling shapes of arbitrary topological type with tensor product NURBS, it is necessary to overcome the restriction of the tensor product configuration where always 4 patches meet at a common corner by using singular parameterizations.

We are developing new smooth parametric surface models defined on irregular quad meshes are in fact a powerful alternative to singularly parameterized tensor product surfaces since they combine the advantages of both, the arbitrary topology of quad meshes and the smoothness of the tensor product patches. Herein, tensor product polynomial patches are assembled with tangent plane continuity, in one-to-one correspondence to the mesh faces. They are thus capable to represent manifold shapes of arbitrary topological type since no restriction on the number of patches assembled around a mesh vertex exists.

While subdivision surfaces can also produce a smooth shape with only a few subdivision steps from a coarse mesh, our parametric surfaces have the advantage to provide an explicit parameterization. Moreover, all classical modeling operations such as trimming, intersection, blending and boolean operations can be preformed with parametric patches. Tensor product patches can furthermore make profit from the powerful tools of existing modeling systems for purposes of evaluation, display, interrogation and all operations cited above.

In collaboration with G.-P. Bonneau (Artis team) several parametric triangular surface models for arbitrary topologies have been published in the past (CAGD, IEEE TVCG and ACM ToG). A new tensor product spline surface model has been developed this year. It solves the problem of defining a G^1-continuous surface **interpolating** the vertices of an irregular quad mesh with low degree polynomial tensor product patches. It further aims to produce shapes of very high visual quality while reducing the number of control points. A comparison with existing methods and a journal paper are on-going work.

6.1.7. Point sampled surfaces

Participant: Stefanie Hahmann.

Point sampled geometry from scanned data exhibits very characteristic shapes, due to the presence of sharp features in most manufactured and designed objects. Therefore, reconstruction of surfaces from unorganized point sets using MLS fitting requires additional attention. In fact, it is an inherent property of MLS fitting to produce smooth surfaces, thus all sharp features in the point cloud may also be smoothed out. Instead of searching for appropriate new fitting functions our approach was to introduce a new method for selecting an appropriate local point neighborhood for the projection operator so that a standard MLS fitting automatically reproduces sharp features.
This work was part of Christopher Weber's Ph.D. thesis, which has been co-advised by S. Hahmann and H. Hagen from TU Kaiserslautern, Germany. First part of the work on Gauss map clustering for feature point detection has been published in the SMI 2010 proceedings. The second part has been submited to a Computer Graphics journal. The thesis has been defended in August 2011.

6.1.8. Volume preserving Free-Form Deformations

Participant: Stefanie Hahmann.

Figure 5. Comparison between standard FFD deformation (top) and our method preserving the volume (bottom).

Free Form Deformation (FFD) is a well established technique for deforming arbitrary object shapes in space. Although more recent deformation techniques have been introduced, amongst them skeleton-based deformation and cage based deformation, the simple and versatile nature of FFD is a strong advantage, and justifies its presence in nowadays leading commercial geometric modeling and animation software systems. Several authors have addressed the problem of volume preserving FFD. These previous approaches however make either use of expensive non-linear optimization techniques, or resort to first order approximation suitable only for small-scale deformations. Our approach was to take advantage from the multi-linear nature of the volume constraint in order to derive a simple, exact and explicit solution to the problem of volume preserving FFD. Two variants of the algorithm have been developed, without and with direct shape manipulation. Moreover, we showed that the linearity of our solution enables to implement it efficiently on GPU.
This work has been done in collaboration with G. Elber from TECHNION, H. Hagen from TU Kaiserslautern, G.-P. Bonneau and S. Barbier from Artis INRIA. It has been accepted for publication in the journal The Visual Computer [6].

6.2. High level models for animation

6.2.1. Geometrical methods for skinning character animations

Participants: Marie-Paule Cani, Stefanie Hahmann, Damien Rohmer.

Figure 6. Exemple of constant volume deformation generated using the active geometry framework from [1].

Skeletal animation is an efficient and widely used technique in video games or movie industry due to its flexibility and simplicity. Still, the skinning method do not take into account informations about the physical properties of the underlying material. Therefore effects such as muscle bulging or fat tissue compression cannot be modeled without the addition of a teadious manual correction. Within Damien Rohmers PhD [1], an *active geometry* framework was proposed in order to enhance geometry information with a priori knowledge about how the unerdlying material can deform. For instance, bending the belly of an animal will be constraint to generate bulges that will preserve locally the volume (see fig. 6). The process can be either purely automatically generated, or it can be artistically controled.

6.2.2. Action representation, segmentation and recognition

Participant: Remi Ronfard.

Following Daniel Weinland's PhD thesis, we published a survey of modern methods for representing, segmenting and recognizing full-body actions in video [12]. A taxonomy of methods is elaborated in that paper, where actions can be represented with local, structured or global features both in time and in space. The potential for future work in grammar-based action recognition is emphasized, with possible applications in corpus-based procedural modeling of actions.

6.2.3. Frame-based simulation of deformable solids

Participants: Guillaume Bousquet, Françcois Faure.

We present a new type of deformable model which combines the realism of physically based continuum mechanics models and the usability of frame-based skinning methods [4]. The degrees of freedom are coordinate frames (see Figure 15). In contrast with traditional skinning, frame positions are not scripted but move in reaction to internal body forces. The displacement field is smoothly interpolated using blending techniques such as dual quaternions . The deformation gradient and its derivatives are computed at each sample point of a deformed object and used in the equations of Lagrangian mechanics to achieve physical realism. This allows easy and very intuitive definition of the degrees of freedom of the deformable object. The meshless discretization allows on-the-fly insertion of frames to create local deformations where needed.

We formulate the dynamics of these models in detail and describe some pre-computations that can be used for speed. We show that our method is effective for behaviors ranging from simple unimodal deformations to complex realistic deformations comparable with Finite Element simulations.

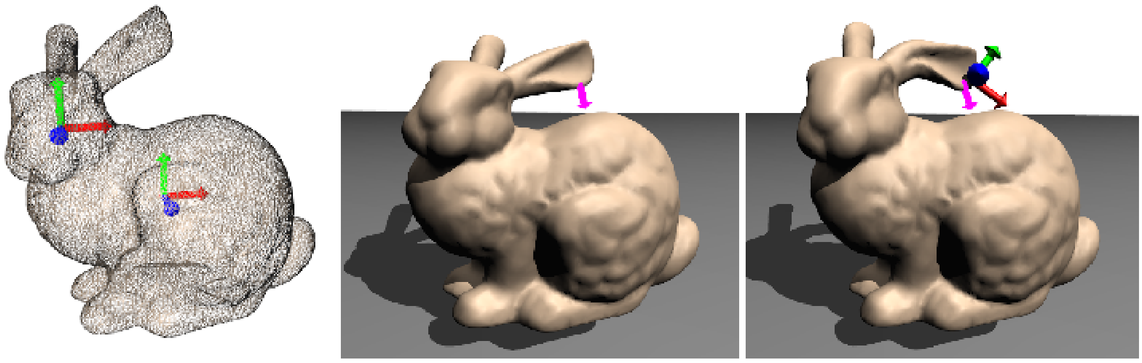

Figure 7. Physical realism is obtained with very sparse sampling: two frames are sufficient to model a dynamically deformable bunny [3].

We extend the approach (see fig. 7) to the simulation of complex, intricated material distributions using material-aware shape functions [3]. Given a volumetric map of the material properties of an object and a number of control nodes, a distribution of the nodes is computed automatically, as well as the associated shape functions. Reference frames are attached to the nodes, and deformations are applied to the object using lin- ear blend skinning. A continuum mechanics formulation is de- rived from the displacements and the material properties. We in- troduce novel material-aware shape functions in place of the tradi- tional radial basis functions used in meshless frameworks. These allow coarse deformation functions to very ef?ciently resolve non- uniform stiffnesses. Complex models can thus be simulated at high frame rates using a small number of control nodes.

To encourage its use, the software is freely available in the simulation platform SOFA.

6.3. Towards interactive digital creation media

6.3.1. Sketch-based modeling and shape editing

Participants: Adrien Bernhardt, Rémi Brouet, Marie-Paule Cani, Jean-Claude Léon, Olivier Palombi.

3D modeling from a sketch is a fast and intuitive way of creating digital content.

We developed a method based on convolution surfaces for inferring free-form shapes in 3D from arbitrary progressive sketches, without any a priori knowledge on the objects being represented (see the section describing the Aestem Studio software. We recently investigated whether 2D deformation could be a better approach than sketching for defining the 2D sketch given as input [18]. Results are very promising; We are planning both to allow such intuitive deformations, combined with sketching, within the Astem software, and to extend them to the editing of the 3d deformed shape. This will be done in the context of Rémi Brouet's PhD thesis, co-advised by Renaud Blanch from the IIHM/LIG team.

We also develop methods for interpreting complex sketches (contours with T-junctions) based on some a priori knowledge. Our first work on this topic used the conventions of anatomical drawing to infer the 3D geometry of vascular systems, with branching and occlusions, from a single sketch [10]. We are also investigating the design of realistic terrains from a single sketch, within the PhD thesis of Adrien Bernhardt (see fig. 8). Our first advances include a new representation and new methods for generating a high-field from user-sketched constraint curves [30], [17].

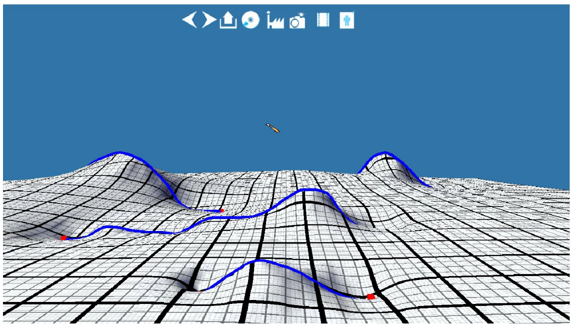

Figure 8. User-sketched high-field modeling a terrain.

6.3.2. Free-form sculpture

Participants: Marie-Paule Cani, Lucian Stanculescu.

In the context of Lucian Stanculescu's PhD thesis, co-advides by Raphaelle Chaine from LIRIS (Lyon), we developed an interactive sculpting system enabling both arbitrary deformation and topological changes of a free-form shape [11]. Our method is based on a semi-regular mesh which adaptively refines and changes its topology according to the need. See Figure 9. We are currently extending the method for handing the sculpting of composite objects made of many different components.

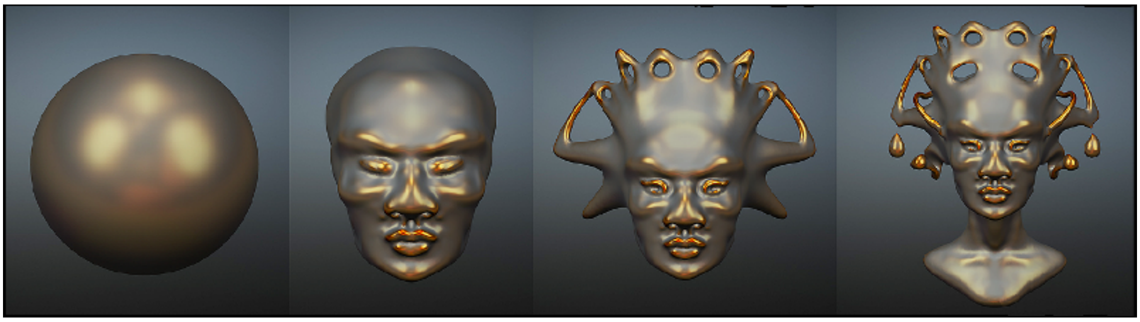

Figure 9. Sculpting with topological changes made within the framework from [11].

6.3.3. Hand Navigator

Participants: Jean-Rémy Chardonnet, Jean-Claude Léon.

The different deformation models we developed in the past few years open the problem of providing intuitive interaction tools for specifying the desired deformations in real-time. Therefore, our recent work focused on developing new devices for interacting with the model to deform. For the past two years, we focused on developing a peripheral device similar to a mouse, called the HandNavigator, enabling to control simultaneously ten or more degrees of freedom of a virtual hand. This device consists in a 3D mouse for the position and orientation of the hand in 3D space, enhanced with many sensors for moving and monitoring the virtual fingers. Thanks to a pre-industrialization project funded by the incubator GRAVIT, the first prototype, patented by INRIA, has been extended with the incorporation of new sensors and new shapes to improve the device efficiency. An ongoing extension of the patent and a partnership with HAPTION company are new step toward the industrialization of this device. Dissemination to general public has been performed at the "Fête de la Science" and another exhibition. Publications will take place after setting up the patent extension. The ongoing BQR INTUACTIVE funded by Grenoble-INP will lead to further scientific topics regarding interactions during grasping as well as with deformable bodies and a partnership has been set up with GIPSA-Lab to study the muscular activity during interactions.

6.3.4. Procedural modeling

Participants: Marie-Paule Cani, Arnaud Emilien.

We developed a method for procedurally generating villages with the appropriate roads and streets on arbitrary terrains, in collaboration with Eric Galin from LIRIS, Lyon. This work will be continued within Arnaud Emilien's PhD thesis towards more general models for populating terrains with houses, vegetation, and animals. We will focus on the development of intuitive ways to edit procedural models, to overcome the main drawback of these approaches.

6.3.5. Computational model of film editing

Participant: Remi Ronfard.

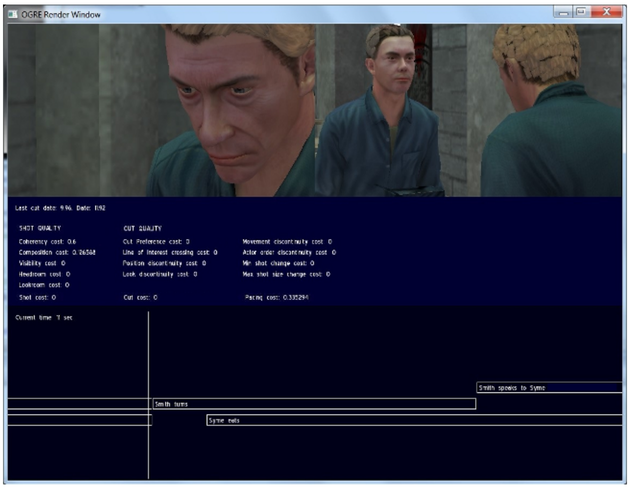

Figure 10. Interface developed for automatic editing of animated movies [31], [21].

Building on Remi Ronfard's experience leading the virtual cinematography research team at Xtranormal Technology, Montreal, we designed a novel computational model for automatic editing of animated movies (see fig. 10). A prototype has been implemented in a collaboration with the Bunraku/mimetic team, and demonstrated in poster sessions at the Symposium on Computer Animation (SCA) [31] and International Conference on Interactive Digital Storytelling (ICIDS) [21]. This early work opens new directions that will be further explored by the IMAGINE team, including corpus-based learning of cinematography and editing styles.

7. Contracts and Grants with Industry

7.1. Contracts and Grants with Industry

7.1.1. Axiatex 11/2009-04/2011

Participants: Adrien Bernhardt, Marie-Paule Cani, Jean-Claude Léon.

We extended the Aestem Studio software to cover the needs of the company Axiatec, which sells 3D printers in France. The goal is to provide 3D modeling system based on a very intuitive sketch-based technique, in order to enable the general public to model 3D shapes. Our extensions included the introduction of texturing methods and of interactive editing mechanisms, in addition to an eraser tool enabling to carve the surface through sketching.

7.1.2. EADS - Idealization of components for structural mechanics (05/2011 - 04/2014)

Participants: Jean-Claude Léon, Stefanie Hahmann.

Cifre PhD in partnership with EADS IW to generate the shape of mechanical components through dimensional reduction operations as needed for mechanical simulations, e.g. transformations from volume bodies to shells or plates forming surface models, usually non-manifold ones. The topic addressed covers also the shape detail removal process that takes place during the successive phases where subsets of the initial shape are idealized. Mechanical criteria are taken into account that interact with the dimensional reductions and the detail removal processes. The goal is to define the transformation operators such that a large range of mechanical components can be processed as automatically and robustly as possible. Some results from the homology computation topic may be used in the present context. An ongoing publication should address the description of the various stages of a component shape transformation in the context of assemblies.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. BQR Intuactive (2011-2014)

Participants: Rémi Brouet, Marie-Paule Cani, Jean-Claude Léon.

The Intuactive project is a collaboration between our research group, the conception group of G-scop lab, and the HCI group of LIG lab. The goial is to develop and compare 2D vs 3D interaction for selecting, placing and editing 3D shapes. The project is funded by Grenoble-INP and provides the grant for Rémi Brouet's PhD.

8.1.2. BQR INP IDEAL (04/2009 - 03/2012)

Participants: Dobrina Boltcheva, Jean-Claude Léon.

3D models, coming for instance from engineering fields, are often 'idealized', or 'simplified' (topologically speaking), in order to be used for simulation. The goal of this project IDEAL, funded by Grenoble-INP, is to study these models, in particular the most general ones which are called 'non-manifolds' and which are not handled by current software. We collaborate in this project with the University of Genova in Italy (Leila De Floriani).

8.1.3. BQR INP "Modèles multirésolutions de fissures" (04/2009 - 09/2012)

Participants: Marie Durand, François Faure.

A project on the simulation of fracture propagation in concrete structures has started, funded by INP Grenoble. The puropose is to develop a mixed, dynamic model of structures, using finite elements everywhere excepted near crak fronts, where a discrete model is applied. This goes beyond the ANR Vulcain project (section 8.2.1) because we want to dynamically switch between finite element and discrete models. Bui Huu Phoc has started a Ph.D. in October, co-tutored by Frederic Dufour and Vincent Richefeu, from the L3S-R CNRS laboratory, and François Faure from EVASION.

8.1.4. LIMA "Loisirs et Images" (2007 - 2011)

Participants: Marie-Paule Cani, François Faure, Damien Rohmer.

LIMA (Loisirs et Images) was a Rhône-Alpes project in the ISLE cluster (Informatique, Signal, Logiciel Embarqué) focussed on classification and computer graphics. This project founded the PhD for Lucian Stanculescu with Raphaelle Chaine (LIRIS) and Marie-Paule Cani. It leaded to the generation of a new free form sculpture tool [11]. A research seminar in July had been organised to end the project in July. It gathers scientist from computer graphics and computer vision, and Bob Sumner presented the recent work from Disney Research Zurich to the community. An other project from the ISLE cluster will start in the futur on a similar topic in order to pursue gathering scientists from Rhône-Alpes region and continue on the promising results of LIMA.

8.1.5. Scenoptique

Participant: Rémi Ronfard.

In October 2011, we started a collaboration with Theatre des Celestins in Lyon on the topic of interactive editing of rehearsals. This research program is funded by the Region Rhone Alpes as part of their CIBLE project, with a budget for a doctoral thesis (Vineet Gandhi) and three large sensor video cameras. Theatre des Celestins is interested in novel tools for capturing, editing and browsing video recordings of their rehearsals, with applications in reviewing and simulating staging decisions. We are interested in building such tools as a direct application and test of our computational model of film editing, and also for building the world's first publicly available video resource on the creative process of theatre rehearsal. Using state-of-the-art video analysis methods, this corpus is expected to be useful in our future work on procedural animation of virtual actors and narrative design. The corpus is also expected to be shared with the LEAR team as a test bed for video-based action recognition.

8.2. National Initiatives

8.2.1. ANR Vulcain (06/2008-06/2011)

Participants: Marie Durand, François Faure.

We participate to the ANR Vulcain project (http://vulcain.ujf-grenoble.fr/), which purpose is to evaluate the vulnerability of buildings such as industrial facilities undergoing explosions of projectile impacts. Marie Durand has implemented discrete element models in GPU in order to speed up concrete fracturing simulations, and an article has been submitted to the European Journal of Environmental and Civil Engineering.

8.2.2. ANR RepDyn (01/2010-12/2012)

Participants: Marie Durand, François Faure.

We participate to the ANR RepDyn project, startied at the beginning of 2010, in collaboration with CEA, EDF, Laboratoire de Mécanique des Structures Industrielles Durables (LaMSID), and ONERA. The purpose of this project is to enhance the performance of discrete elements and fluid computations, for the simulation of cracks in nuclear reactors or planes. Our task is to propose GPU implementations of particle models, as well as load balancing strategies in the context of multi-core, multi-GPU hardware. Marie Durand is doing a PhD thesis on this task.

8.2.3. ANR ROMMA (01/2010-12/2013)

Participants: François Faure, Stefanie Hahmann.

The ANR project ROMMA has been accepted in 2009 and started in January 2010. The partners of this project are academic and industry experts in mechanical engineering, numerical simulation, geometric modeling and computer graphics. There are three academic members in the consortium: the LMT in Cachan, G-SCOP and LJK (EVASION and MGMI teams) in Grenoble. There are four industrial members: EADS, which coordinates the project, SAMTECH, DISTENE and ANTECIM. The aim of the project is to efficiently and robustly model very complex mechanical assemblies. We are working on the interactive computation of contacts between mechanical parts using GPU techniques. We will also investigate the Visualization of data with uncertainty, applied in the context of the project.

8.2.4. ANR SOHUSIM (01/2010-12/2013)

Participants: Ali Hamadi Dicko, François Faure.

Sohusim (Soft Human Simulation) is done in collaboration between: EVASION (INRIA), Fatronik France (TECNALIA), DEMAR (INRIA), HPC PROJECT and the CHU de Montpellier.

This project deals with the problem of modeling and simulation of soft interactions between humans and objects. At the moment, there is no software capable of modeling the physical behavior of human soft tissues (muscles, fat, skin) in mechanical interaction with the environment. The existing software such as LifeMod or OpenSim, models muscles as links of variable length and applying a force to an articulated stiff skeleton. The management of soft tissues is not taken into account and does not constitute the main objective of this software.

A first axis of this project aims at the simple modeling and simulation of a passive human manipulated by a mecatronics device with for objective the study and the systems design of patient's manipulation with very low mobility (clinic bed). The second axis concentrates on the detailed modeling and the simulation of the interaction of an active lower limb with objects like orthesis, exoskeleton, clothes or shoes. The objective being there also to obtain a tool for design of devices in permanent contact with the human who allows determining the adequate ergonomics in terms of forms, location, materials, according to the aimed use.

Dicko Ali Hamadi is a Ph.D. student within EVASION team. His works turns around the problems in SOHUSIM project. He is co-tutored by Olivier Palombi in EVASION, in collaboration with Benjamin Gilles in DEMAR.

8.2.5. PlantScan3D (ARC INRIA 09/2009-09/2011)

Participants: Dobrina Boltcheva, Marie-Paule Cani, Cédric Zanni.

This project is in collaboration with Vitual Plants and Galaad teams. Its objective is to develop the use of laser scanner for plant geometry reconstruction, in partnership with biologists-agronomists from several teams in France and Europe. Our last contributions include the development of new representation for the plant enabling to use the skeleton and thickness information computed by the other teams from scanner data.

8.3. European & International Initiatives

8.3.1. PASSPORT (06/2008-05/2011)

Participants: Guillaume Bousquet, François Faure.

The PASSPORT for Liver Surgery project (http://www.passport-liver.eu/Homepage.html) deals with the objectives of the Virtual Physiological Human ICT-2007.5.3 objective. PASSPORT's aim is to develop patient-specific models of the liver which integrates anatomical, functional, mechanical, appearance, and biological modelling. To these static models, PASSPORT will add dynamics liver deformation modelling and deformation due to breathing, and regeneration modelling providing a patient specific minimal safety standardized FLR. These models, integrated in the Open Source framework SOFA, will culminate in generating the first multi-level and dynamic *Virtual patient-specific liver* allowing not only to accurately predict feasibility, results and the success rate of a surgical intervention, but also to improve surgeons? training via a fully realistic simulator, thus directly impacting upon definitive patient recovery suffering from liver diseases.

The final review was held in December in Strasbourg. Our deliverables were delivered in time.

8.3.2. IRIS Network of Excellence (2009-2011)

Participant: Rémi Ronfard.

The IRIS (Integrating Research in Interactive Storytelling) Network of Excellence (NoE) started its work in January 2009, as a new EC-funded initiative (under FP7's Intelligent Content and Semantics).

The IRIS network include work packages on Narrative Formalisms; Artificial Intelligence Tools and Techniques; Authoring Tools and Creation Methods; Hybrid Intelligent Virtual Actors; Cinematography; Interaction and Dialogue. As part of the work package on cinematography, we proposed a computational framework for film editing suitable for interactive storytelling applications. The model has been implemented in a collaboration with the Bunraku/Mimetic team and demonstrated to IRIS project members.

8.3.3. SHARE INRIA Associate Teams (2009-2011)

Participants: Adrien Bernardt, Marie-Paule Cani, François Faure, Damien Rohmer.

SHARE is a joint associate with the INRIA project BIPOP, which funds collaborations with the University of Vancouver. It brings together researchers with complementary expertise in geometric modeling, computer graphics, mechanics, robotics, control, neuroscience and perception, and who aim to jointly tackle key elements of modeling and animation of humans and animals interacting with their environment. The project had three foci: 1) designing enriched geometric and mechanical models for the shape and motion of soft tissues, skin, cloth and hair; 2) improving existing models of human and animal motion; and 3) modeling interaction between moving creatures and complex, realistic environments.

8.3.4. Visits of International Scientists

- Alla Scheffer visited EVASION team for 6 months.

9. Dissemination

9.1. Animation of the scientific community

9.1.1. Organization of conferences and editorial boards

- Editorial board member of Computer Graphics Forum, Marie-Paule Cani.
- SGP 2011, Paper Chair, Stefanie Hahmann.
- SBIM 2011, Symposium Chair, Jean-Claude Léon.
- MIG 2011, Program Committee, Rémi Ronfard.
- EG 2011, Program Committee, Marie-Paule Cani.
- SBIM 2011, Program Committee, Marie-Paule Cani.
- Dagstuhl Seminar on Geometric Modeling 2011, Co-organizer Stefanie Hahmann.
- SIAM Geometric Design / SPM 2011, Paper co-chair, Stefanie Hahmann.
- SPM 2012, Paper co-chair, Stefanie Hahmann.
- SIAM Mathematics for Industry 2012, organization committee, Stefanie Hahmann.
- Eurographics 2011, IPC, Stefanie Hahamann.
- SMI 2012, Program Commitee, Stefanie Hahmann.
- Journal CAD (Elsevier), special Issue of SPM 2011, co-editor Stefanie Hahmann [[29]].
- Journal Graphical Models (Elsevier), special Issue on Geometric Modeling, co-editor Stefanie Hahmann.

9.1.2. Management and administration of scientific organisations

- Director at Large within the ACM SIGGRAPH executive committee, Marie-Paule Cani, 2008-2011.
- Marie-Paule Cani has joined the *ACM Publication board* in september 2011, where she represents the Computer Graphics domain.

- Vice president of AFIG (Association Française d'Informatique Graphique) in charge of international issues, Marie-Paule Cani, 2008-2011.
- President of GTMG (*Groupe de Travail en Modelisation Géometrique*) part of GDR IM and GDR IG, Stefanie Hahmann.
- Member of the *Conseil du Laboratoire* at LJK, Francois Faure, Stefanie Hahmann, Rémi Ronfard.
- Director of the *Géométrie et Image* department at LJK, Rémi Ronfard.
- Vice chair of SIAM activity group Geometric Design, Stefanie Hahmann.
- Responsible of Maths-Info Department of the Grenoble doctoral school MSTII, Stefanie Hahmann.

9.1.3. Public dissemination

- We presented Aestem Studio and Hand Navigator to Experimenta, Salon de la Biennale Arts et Sciences, organized by CEA-LETI and Theatre de l'Hexagone in Grenoble (10/2011). Adrien Bernhardt, Marie-Paule Cani, Jean-Claude Léon, Maxime Quiblier, Rémi Ronfard. http://www.rencontres-i.eu/2011/salon-experimenta/
- Exposing Hand Navigator at "Fête de la Science", cité la Vilette, Jean-Claude Léon, Maxime Quiblier.
- Publication in "Le journal du CNRS", and radio annoucement (France Inter) of cloth animation results [1].

9.2. Teaching

9.2.1. Responsabilities of academic programs

- Responsible of the French Campus numérique of anatomy, Olivier Palombi.
- Member of CNU 42-01 (anatomy), Olivier Palombi.
- Member of the *commission n.6* for the renewing of the ECN (*Examen Classant National*) in medical studies for the French *ministère de l'éducation*, Olivier Palombi.
- Promoting medical studies at *Salon de l'Etudiant*, Alpes Expo, Olivier Palombi.

9.2.2. Educational activities

- Marie-Paule Cani, 200 hours a year, Professor ENSIMAG/Grenoble INP.
- Stefanie Hahmann, 200 hours a year, Professor ENSIMAG/Grenoble INP, M2R MIA.
- Jean Claude Léon, 300 hours a year, Professor ENSE3/Grenoble INP.
- Olivier Palombi, 200 hours a year, Professor UJF, medicine.
- Rémi Ronfard, 18 hours, M2 Pro, UJF.

Note that MOSIG is joint master program between University Joseph Fourier (UJF) and Institut Polytechnique de Grenoble (INPG) taught in English since it hosts a number of internal students. If belongs to the doctoral school MSTII.

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