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Université de Grenoble Alpes

Activity Report 2017

Project-Team IMAGINE

Intuitive Modeling and Animation for Interactive Graphics & Narrative Environments

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

RESEARCH CENTER
Grenoble - Rhône-Alpes

THEME
Interaction and visualization

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Creation of the Team: 2012 January 01, updated into Project-Team: 2013 January 01

Keywords:

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A5.5.3. - Computational photography
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Other Research Topics and Application Domains:

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1. Personnel

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Melina Skouras [Inria, Researcher, from Dec 2017]

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Marie-Paule Cani [Institut polytechnique de Grenoble, Professor, until Feb 2017]
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Alexandre Gauthier-Foichat [Inria]
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Maud Lastic [Inria, from Apr 2017 until Jul 2017]
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Estelle Noé [Institut polytechnique de Grenoble, until Mar 2017]
Pauline Olivier [Inria, until Apr 2017]
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Sanie Claraz [Institut polytechnique de Grenoble, until Aug 2017]
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2. Overall Objectives

2.1. Context

With the fast increase of computational power and of memory space, increasingly complex and detailed 3D content is expected for virtual environments. Unfortunately, 3D modeling methodologies did not evolve as fast: most users still use standard CAD or 3D modeling software (such as Maya, 3DS or Blender) to design each 3D shape, to animate them and to manually control cameras for movie production. This is highly time consuming when large amounts of detailed content need to be produced. Moreover the quality of results is fully left in the user's hand, which restricts applicability to skilled professional artists. More intuitive software such as Z-Brush are restricted to shape design and still require a few months for being mastered by sculpture practitioners. Reducing user load can be done by capturing and re-using real objects or motions, at the price of restricting the range of possible content. Lastly, procedural generation methods can be used in specific cases to automatically get some detailed, plausible content. Although they save user's time, these procedural methods typically come at the price of control: indirect parameters need to be tuned during a series of trial and errors until the desired result is reached. Stressing that even skilled digital artists tend to prefer pen and paper than 3D computerized tools during the design stages of shapes, motion, and stories, Rob Cook, vice president of technology at Pixar animation studios recently stated (key-note talk, Siggraph Asia 2009): *new grand challenge in Computer Graphics is to make tools as transparent to the artists as special effects were made transparent to the general public*.

Could digital modeling be turned into a tool, even more expressive and simpler to use than a pen, to quickly convey and refine shapes, motions and stories? This is the long term vision towards which we would like to advance.

2.2. Scientific goals

The goal of the IMAGINE project is to develop **a new generation of models, algorithms and interactive environments for the interactive creation of animated 3D content and its communication through virtual cinematography**.

Our insight is to revisit models for shapes, motion, and narration from a user-centred perspective, i.e. to give models an intuitive, predictable behaviour from the user's view-point. This will ease both semi-automatic generation of animated 3D content and fine tuning of the results. The three main fields will be addressed:

1. **Shape design**: We aim to develop intuitive tools for designing and editing 3D shapes and their assemblies, from arbitrary ones to shapes that obey application-dependent constraints - such as, for instance, developable surfaces representing cloth or paper, or shape assemblies used for CAD of mechanical prototypes.
2. **Motion synthesis**: Our goal is to ease the interactive generation and control of 3D motion and deformations, in particular by enabling intuitive, coarse to fine design of animations. The applications range from the simulation of passive objects to the control of virtual creatures.
3. **Narrative design**: The aim is to help users to express, refine and convey temporal narrations, from stories to educational or industrial scenarios. We develop both virtual direction tools such as interactive storyboarding frameworks, and high-level models for virtual cinematography, such as rule-based cameras able to automatically follow the ongoing action and automatic film editing techniques.

In addition to addressing specific needs of digital artists, this research contributes to the development of new expressive media for 3D content. The long term goal would be to enable any professional or scientist to model and interact with their object of study, to provide educators with ways to quickly express and convey their ideas, and to give the general public the ability to directly create animated 3D content.

3. Research Program

3.1. Methodology

As already stressed, thinking of future digital modeling technologies as an Expressive Virtual Pen enabling to seamlessly design, refine and convey animated 3D content, leads to revisit models for shapes, motions and stories from a user-centered perspective. More specifically, inspiring from the user-centered interfaces developed in the Human Computer Interaction domain, we introduced the new concept of user-centered graphical models. Ideally, such models should be designed to behave, under any user action, the way a human user would have predicted. In our case, user's actions may include creation gestures such as sketching to draft a shape or direct a motion, deformation gestures such as stretching a shape in space or a motion in time, or copy-paste gestures to transfer some of the features from existing models to other ones. User-centered graphical models need to incorporate knowledge in order to seamlessly generate the appropriate content from such actions. We are using the following methodology to advance towards these goals:

- Develop high-level models for shapes, motion and stories that embed the necessary knowledge to respond as expected to user actions. These models should provide the appropriate handles for conveying the user's intent while embedding procedural methods that seamlessly take care of the appropriate details and constraints.
- Combine these models with expressive design and control tools such as gesture-based control through sketching, sculpting, or acting, towards interactive environments where users can create a new virtual scene, play with it, edit or refine it, and semi-automatically convey it through a video.

3.2. Validation

Validation is a major challenge when developing digital creation tools: there is no ideal result to compare with, in contrast with more standard problems such as reconstructing existing shapes or motions. Therefore, we had to think ahead about our validation strategy: new models for geometry or animation can be validated, as usually done in Computer Graphics, by showing that they solve a problem never tackled before or that they provide a more general or more efficient solution than previous methods. The interaction methods we are developing for content creation and editing rely as much as possible on existing interaction design principles already validated within the HCI community. We also occasionally develop new interaction tools, most often in collaboration with this community, and validate them through user studies. Lastly, we work with expert users from various application domains through our collaborations with professional artists, scientists from other domains, and industrial partners: these expert users validate the use of our new tools compared to their usual pipeline.

3.3. Application Domains

This research can be applied to any situation where users need to create new, imaginary, 3D content. Our work should be instrumental, in the long term, for the visual arts, from the creation of 3D films and games to the development of new digital planning tools for theater or cinema directors. Our models can also be used in interactive prototyping environments for engineering. They can help promoting interactive digital design to scientists, as a tool to quickly express, test and refine models, as well as an efficient way for conveying them to other people. Lastly, we expect our new methodology to put digital modeling within the reach of the general public, enabling educators, media and other practitioners to author their own 3D content.

Our current application domains are:

- Visual arts
  - Modeling and animation for 3D films and games.
  - Virtual cinematography and tools for theater directors.
- Engineering
  - Industrial design.
  - Mechanical & civil engineering.
- Natural Sciences
  - Virtual functional anatomy.
  - Virtual plants.
- Education and Creative tools
  - Sketch-based teaching.
  - Creative environments for novice users.

The diversity of users these domains bring, from digital experts to other professionals and novices, gives us excellent opportunities to validate our general methodology with different categories of users. Our ongoing projects in these various application domains are listed in Section 6.

4. Highlights of the Year

4.1. Highlights of the Year

- We had two papers accepted to Eurographics [23], [20] and a third paper was accepted for publications by Computer Graphics Forum and also presented at Eurographics [18]. We had one paper accepted for publication in ACM transactions on Graphics and presented at Siggraph [16].
- We co-organized the third Eurographics workshop on intelligent cinematography and editing, at the institut Lumière in Lyon on April 24, 2017.
- Three students defended their PhD within the team.
- ERC ADG EXPRESSIVE was successfully terminated in April 2017.
- We started three new ANR projects Anatomy 2020, E-Roma and Foldyn, and a new FUI project Collodi 2 with TeamTo and Mercenaries engineering.

5. New Software and Platforms

5.1. Expressive

KEYWORDS: 3D modeling - 3D - 3D interaction - 2D - Procedural - Terrain - Sketching
FUNCTIONAL DESCRIPTION: Expressive is a new C++ library created in 2013 for gathering and sharing the models and algorithms developed within the ERC Expressive project. It enables us to make our latest research results on new creative tools - such as high level models with intuitive, sketching or sculpting interfaces - soon available to the rest of the group and easily usable for our collaborators, such as Evelyne Hubert (Inria, Galaad) or Loic Barthe (IRIT, Toulouse). The most advanced part is a new version of Convol, a library dedicated to implicit modeling, with a main focus on integral surfaces along skeletons. Convol incorporates all the necessary material for constructive implicit modeling, a variety of blending operators and several methods for tessellating an implicit surface into a mesh, and for refining it in highly curved regions. The creation of new solid geometry can be performed by direct manipulation of skeletal primitives or through sketch-based modeling and multi-touch deformations.

- Participants: Antoine Begault, Cédric Zanni, Guillaume Cordonnier, Marie-Paule Cani, Maxime Garcia, Maxime Quiblier, Rémi Brouet and Ulysse Vimont
- Partner: INPG
- Contact: Marie-Paule Cani

5.2. MyCF

My Corporis Fabrica
KEYWORDS: Patientspecific - Anatomy - Ontologies - Health - Simulation - 3D modeling - Medical imaging
FUNCTIONAL DESCRIPTION: Knowledge-based 3D anatomical modeling using MyCF The MyCF software eases the creation of 3D anatomical models for visualization and mechanical simulation. As input, the user provides a list of anatomical entities or functions to simulate, using keywords or navigating in reference 3D model. As output, she gets a 3D model ready to visualize, or to simulate.

- Participants: Ali Hamadi Dicko, Federico Ulliana, François Faure and Olivier Palombi
- Partner: Université Joseph-Fourier
- Contact: Olivier Palombi
- URL: http://www.mycorporisfabrica.org

5.3. Natron

KEYWORDS: Computer vision - Image analysis - Video sequences
FUNCTIONAL DESCRIPTION: Compositing consists in combining computer-generated images and live-action videos, editing them, and adding visual effects. The applications range from green-screen compositing to the insertion of real characters in a virtual set. Natron performs all these tasks, with a professional quality user interface.

- Authors: Alexandre Gauthier-Foichat, Alexandre Gauthier-Foichat and Frédéric Devernay
- Contact: Frédéric Devernay
- URL: http://natron.fr/

5.4. Kino AI

Artificial intelligence for cinematography
KEYWORDS: Video analysis - Post-production
FUNCTIONAL DESCRIPTION: Kino AI is an implementation of the method described in our patent "automatic generation of cinematographic rushes using video processing". Starting from a single ultra high definitiion (UltraHD) recording of a live performance, we track and recognize all actors present on stage and generate one or more rushes suitable for cinematographic editing of a movie.

- Partner: IIIT Hyderabad
- Contact: Rémi Ronfard
- Publications: Multi-Clip Video Editing from a Single Viewpoint - Zooming On All Actors: Automatic Focus+Context Split Screen Video Generation

6. New Results

6.1. User-centered Models for Shapes and Shape Assemblies

- **Scientist in charge**: Stefanie Hahmann.
- **Other permanent researchers**: Marie-Paule Cani, Frédéric Devernay, Jean-Claude Léon, Damien Rohmer.

Our goal, is to develop responsive shape models, i.e. 3D models that respond in the expected way under any user action, by maintaining specific application-dependent constraints (such as a volumetric objects keeping their volume when bent, or cloth-like surfaces remaining developable during deformation, etc). We are extending this approach to composite objects made of distributions and/or combination of sub-shapes of various dimensions.

6.1.1. Deformation Grammars: Hierarchical Constraint Preservation Under Deformation

Deformation grammars are a novel procedural framework enabling to sculpt hierarchical 3D models in an object-dependent manner [25]. They process object deformations as symbols thanks to user-defined interpretation rules. We use them to define hierarchical deformation behaviors tailored for each model, and enabling any sculpting gesture to be interpreted as some adapted constraint-preserving deformation. This is illustrated in Figure 1. A variety of object-specific constraints can be enforced using this framework, such as maintaining distributions of sub-parts, avoiding self-penetrations, or meeting semantic-based user-defined rules. The operations used to maintain constraints are kept transparent to the user, enabling them to focus on their design. We demonstrate the feasibility and the versatility of this approach on a variety of examples, implemented within an interactive sculpting system.

6.1.2. Patterns from Photograph: Reverse-Engineering Developable Products

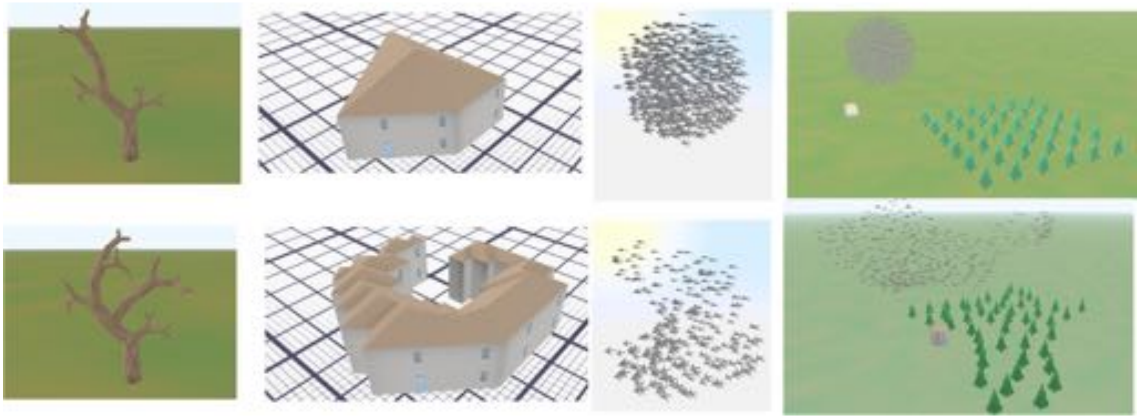

Figure 1. Deformation grammars [25] allow to freely deform complex objects or object assemblies, while preserving their consistency. Top row: Original hierarchical objects (tree, house, bird flock, scene with mixed elements). The tree and the bird flock are made of parts of the same type, while the other objects are hetegogeneous hierarchies. Bottom row: Deformed objects, where the interpretation of user-controled deformations through deformation grammars is used to automatically maintain consistency constraints.

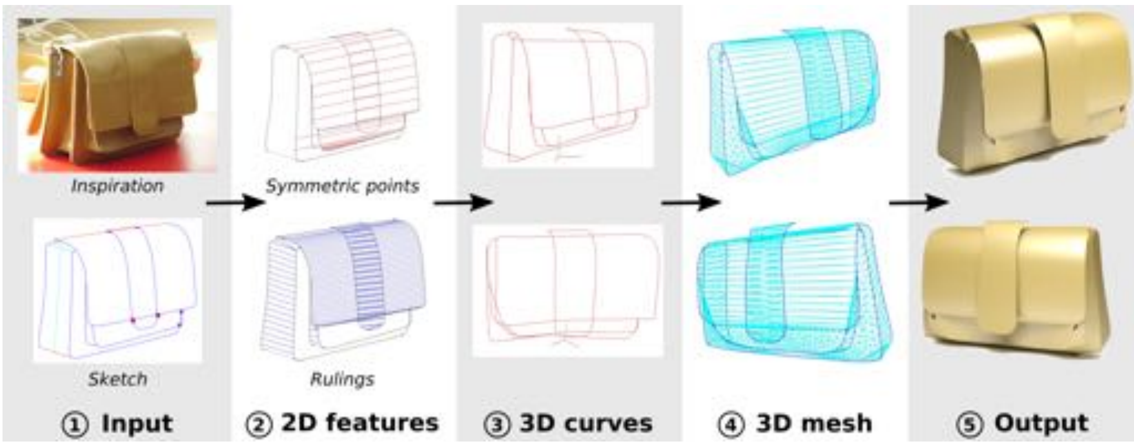

Figure 2. Patterns from Photograph: Reverse-Engineering Developable Products [17]. Overview of our approach. (1) Our system takes as input a photograph where the user has traced the object silhouette and the surface patch boundaries. We also ask users to annotate a global symmetry plane and to indicate symmetric curves. (2) We analyze these annotations to register symmetric curves and to propagate rulings from the silhouettes towards the interior of the surface patches. The detected symmetric points and rulings provide us with geometric constraints on the 3D curves, which we express as linear terms in an optimization. (3) Solving this optimization produces a 3D curve network, which we subsequently surface with developable patches. (4,5) These curves are used as boundaries to generate a piecewise developable mesh of the object.

Developable materials are ubiquitous in design and manufacturing. Unfortunately, general-purpose modeling tools are not suited to modeling 3D objects composed of developable parts. We propose an interactive tool to model such objects from a photograph [17]. This is illustrated in Figure 2. Users of our system load a single picture of the object they wish to model, which they annotate to indicate silhouettes and part boundaries. Assuming that the object is symmetric, we also ask users to provide a few annotations of symmetric correspondences. The object is then automatically reconstructed in 3D. At the core of our method is an algorithm to infer the 2D projection of rulings of a developable surface from the traced silhouettes and boundaries. We impose that the surface normal is constant along each ruling, which is a necessary property for the surface to be developable. We complement these developability constraints with symmetry constraints to lift the curve network in 3D. In addition to a 3D model, we output 2D patterns enabling to fabricate real prototypes of the object on the photo. This makes our method well suited for reverse engineering products made of leather, bent cardboard or metal sheets.

6.1.3. Defining the Pose of any 3D Rigid Object and an Associated Distance

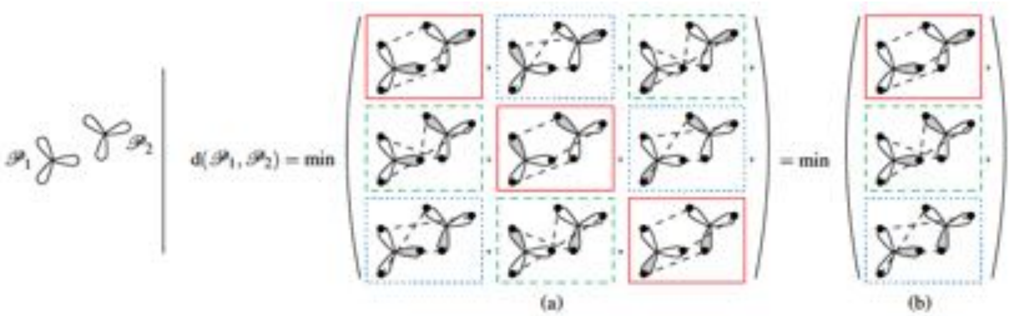

Figure 3. Defining the Pose of any 3D Rigid Object and an Associated Distance [13]. Illustration of our proposed distance for a 2D object with a rotation symmetry of 2p=3. (a) The distance between two poses consists in the minimum distance between two poses of an equivalent object without proper symmetry – here there are 3 possible poses of the equivalent object for each pose of the original object. The distance between poses of an object without proper symmetry corresponds to the RMS distance between corresponding object points (dashed segments). (b) Equivalently, the proposed distance can be considered as a measure of the smallest displacement from one pose to an other – here there are actually only 3 different displacements between those two poses (solid, dotted and dashed boxes).

The pose of a rigid object is usually regarded as a rigid transformation, described by a translation and a rotation. However, equating the pose space with the space of rigid transformations is in general abusive, as it does not account for objects with proper symmetries – which are common among man-made objects. In our recent work [13], we define pose as a distinguishable static state of an object, and equate a pose with a set of rigid transformations. This is illustrated in Figure 3. Based solely on geometric considerations, we propose a frame-invariant metric on the space of possible poses, valid for any physical rigid object, and requiring no arbitrary tuning. This distance can be evaluated efficiently using a representation of poses within an Euclidean space of at most 12 dimensions depending on the object's symmetries. This makes it possible to efficiently perform neighborhood queries such as radius searches or k-nearest neighbor searches within a large set of poses using off-the-shelf methods. Pose averaging considering this metric can similarly be performed easily, using a projection function from the Euclidean space onto the pose space. The practical value of those theoretical developments is illustrated with an application of pose estimation of instances of a 3D rigid object given an input depth map, via a Mean Shift procedure.

6.2. Motion & Sound Synthesis

- **Scientist in charge**: Damien Rohmer.
- **Other permanent researchers**: Marie-Paule Cani, Frédéric Devernay, Stéfanie Hahmann, Rémi Ronfard.

Animating objects in real-time is mandatory to enable user interaction during motion design. Physically-based models, an excellent paradigm for generating motions that a human user would expect, tend to lack efficiency for complex shapes due to their use of low-level geometry (such as fine meshes). Our goal is therefore two-folds: first, develop efficient physically-based models and collisions processing methods for arbitrary passive objects, by decoupling deformations from the possibly complex, geometric representation; second, study the combination of animation models with geometric responsive shapes, enabling the animation of complex constrained shapes in real-time. The last goal is to start developing coarse to fine animation models for virtual creatures, towards easier authoring of character animation for our work on narrative design.

6.2.1. Interactive paper tearing

Figure 4. Interactive paper tearing [23]. The path of a tear follows a geometrical curve but also presents stochastic details.

In this work, we proposed an efficient method to model paper tearing in the context of interactive modeling [23]. This is illustrated in Figure 4. The method uses geometrical information to automatically detect potential starting points of tears. We further introduce a new hybrid geometrical and physical-based method to compute the trajectory of tears while procedurally synthesizing high resolution details of the tearing path using a texture based approach. The results obtained are compared with real paper and with previous studies on the expected geometric paths of paper that tears.

6.2.2. A Generative Audio-Visual Prosodic Model for Virtual Actors

In this new work [9], we proposed a method for generating natural speech and facial animation in various attitudes using neutral speech and animation as input. This is illustrated in Figure 5. Given a neutral sentence, we use the phonotactic information to predict prosodic feature contours. The predicted rhythm is used to compute phoneme durations. The expressive speech is synthesized with a vocoder that uses the neutral utterance, predicted rhythm, energy, and voice pitch, and the facial animation parameters are obtained by adding the warped neutral motion to the reconstructed and warped predicted motion contours.

6.2.3. Which prosodic features contribute to the recognition of dramatic attitudes?

In this new work [10], we explored the capability of audiovisual prosodic features (such as fundamental frequency, head motion or facial expressions) to discriminate among different dramatic attitudes. We extracted

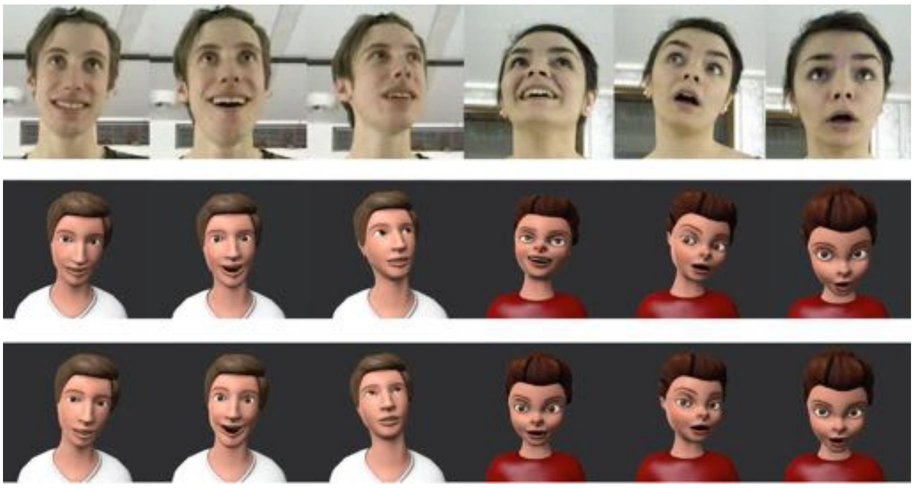

Figure 5. A Generative Audio-Visual Prosodic Model for Virtual Actors [9]. The rows present corresponding frames extracted from (a) the video, (b) ground-truth animation, and (c) synthetic animation. From left to right, the images correspond to comforting, fascinated, thinking (male actor), fascinated, ironic, and scandalized (female actor) attitudes.

the audiovisual parameters from an acted corpus of attitudes and structured them as frame, syllable and sentence-level features. Using Linear Discriminant Analysis classifiers, we showed that prosodic features present a higher discriminating rate at sentence-level. This finding is confirmed by the perceptual evaluation results of audio and/or visual stimuli obtained from the recorded attitudes.

6.3. Knowledge-based Models for Narrative Design

- **Scientist in charge**: Rémi Ronfard.
- **Other permanent researchers**: Marie-Paule Cani, Frédéric Devernay, Jean-Claude Léon, Olivier Palombi.

Our long term goal is to develop high-level models helping users to express and convey their own narrative content (from fiction stories to more practical educational or demonstrative scenarios). Before being able to specify the narration, a first step is to define models able to express some a priori knowledge on the background scene and on the object(s) or character(s) of interest. Our first goal is to develop 3D ontologies able to express such knowledge. The second goal is to define a representation for narration, to be used in future storyboarding frameworks and virtual direction tools. Our last goal is to develop high-level models for virtual cinematography such as rule-based cameras able to automatically follow the ongoing action and semi-automatic editing tools enabling to easily convey the narration via a movie.

6.3.1. Zooming On All Actors: Automatic Focus+Context Split Screen Video Generation

Recordings of stage performances are easy to capture with a high-resolution camera, but are difficult to watch because the actors' faces are too small. We present an approach to automatically create a split screen video that transforms these recordings to show both the context of the scene as well as close-up details of the actors [20]. This is illustrated in Figure 6. Given a static recording of a stage performance and tracking information about the actors positions, our system generates videos showing a focus+context view based on computed close-up camera motions using crop-and zoom. The key to our approach is to compute these camera motions such that they are cinematically valid close-ups and to ensure that the set of views of the different actors are properly

(a) (b)

Figure 6. Zooming On All Actors: Automatic Focus+Context Split Screen Video Generation [20]. Illustration of our approach showing a frame from the input video (a) and its corresponding split screen composition (b). The split screen view shows the emotions and expressions of the performers, which are hardly visible in the original view (master shot).

coordinated and presented. We pose the computation of camera motions as convex optimization that creates detailed views and smooth movements, subject to cinematic constraints such as not cutting faces with the edge of the frame. Additional constraints link the close up views of each actor, causing them to merge seamlessly when actors are close. Generated views are placed in a resulting layout that preserves the spatial relationships between actors. We demonstrate our results on a variety of staged theater and dance performances.

6.3.2. Make Gestures to Learn: Reproducing Gestures Improves the Learning of Anatomical Knowledge More than Just Seeing Gestures

Manual gestures can facilitate problem solving but also language or conceptual learning. Both seeing and making the gestures during learning seem to be beneficial. However, the stronger activation of the motor system in the second case should provide supplementary cues to consolidate and re-enact the mental traces created during learning. In this work [14], we tested this hypothesis in the context of anatomy learning by naïve adult participants. Anatomy is a challenging topic to learn and is of specific interest for research on embodied learning, as the learning content can be directly linked to learners' body. Two groups of participants were asked to look at a video lecture on the forearm anatomy. The video included a model making gestures related to the content of the lecture. Both groups see the gestures but only one also imitate the model. Tests of knowledge were run just after learning and few days later. The results revealed that imitating gestures improves the recall of structures names and their localization on a diagram. This effect was however significant only in long-term assessments. This suggests that: (1) the integration of motor actions and knowledge may require sleep; (2) a specific activation of the motor system during learning may improve the consolidation and/or the retrieval of memories.

6.4. Creating and Interacting with Virtual Prototypes

- **Scientist in charge**: Jean-Claude Léon.
- **Other permanent researchers**: Marie-Paule Cani, Frédéric Devernay, Olivier Palombi, Damien Rohmer, Rémi Ronfard.

The challenge is to develop more effective ways to put the user in the loop during content authoring. We generally rely on sketching techniques for quickly drafting new content, and on sculpting methods (in the sense of gesture-driven, continuous distortion) for further 3D content refinement and editing. The objective is to extend these expressive modeling techniques to general content, from complex shapes and assemblies to animated content. As a complement, we are exploring the use of various 2D or 3D input devices to ease interactive 3D content creation.

6.4.1. EcoBrush: Interactive Control of Visually Consistent Large-Scale Ecosystems

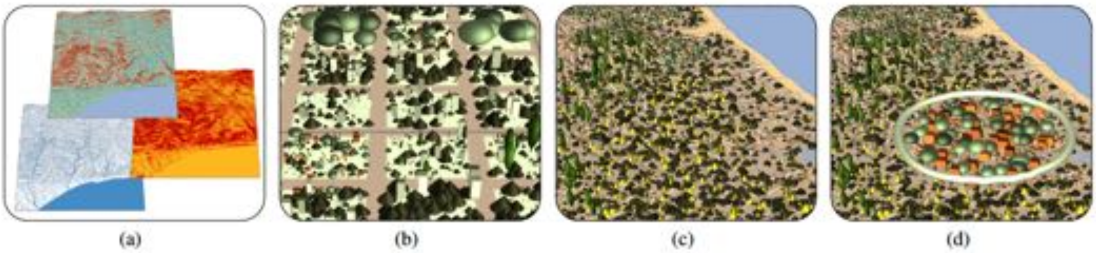

Figure 7. EcoBrush: Interactive Control of Visually Consistent Large-Scale Ecosystems [18]. Terrain conditions (a), such as temperature, soil moisture, and sunlight exposure, are used to index a database of plant distributions (b) and synthesise an initial complete ecosystem (c), which can then be modified with semantic brushes, to adjust age, density and variability (d).

One challenge in portraying large-scale natural scenes in virtual environments is specifying the attributes of plants, such as species, size and placement, in a way that respects the features of natural ecosystems, while remaining computationally tractable and allowing user design. To address this, we combine ecosystem simulation with a distribution analysis of the resulting plant attributes to create biome-specific databases, indexed by terrain conditions, such as temperature, rainfall, sunlight and slope [18]. This is illustrated in Figure 7.

For a specific terrain, interpolated entries are drawn from this database and used to interactively synthesize a full ecosystem, while retaining the fidelity of the original simulations. A painting interface supplies users with semantic brushes for locally adjusting ecosystem age, plant density and variability, as well as optionally picking from a palette of precomputed distributions. Since these brushes are keyed to the underlying terrain properties a balance between user control and real-world consistency is maintained. Our system can be be used to interactively design ecosystems up to 5 × 5 km 2 in extent, or to automatically generate even larger ecosystems in a fraction of the time of a full simulation, while demonstrating known properties from plant ecology such as succession, self-thinning, and underbrush, across a variety of biomes.

6.4.2. Authoring Landscapes by Combining Ecosystem and Terrain Erosion Simulation

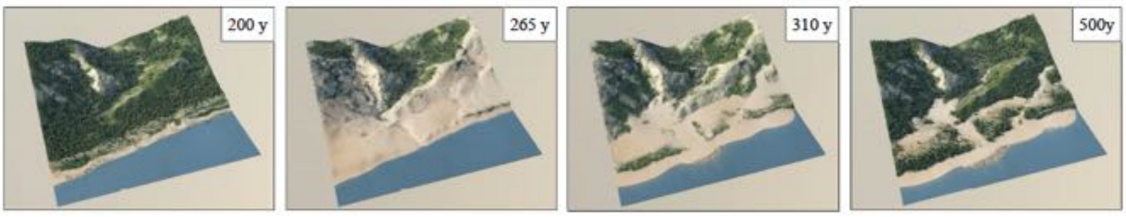

Figure 8. Authoring Landscapes by Combining Ecosystem and Terrain Erosion Simulation [16]. Results from different initial heightfield inputs produced using our simulation aer 300 years of evolution. From le to right: an Alpine landscape from the U.S. Rockies, a portion of the Grand Canyon, a Mediterranean landscape, and a forested valley.

In this new paper [16], we introduced a novel framework for interactive landscape authoring that supports bi-directional feedback between erosion and vegetation simulation. This is illustrated in Figure 8. Vegetation and terrain erosion have strong mutual impact and their interplay innuences the overall realism of virtual scenes. Despite their importance, these complex interactions have been neglected in computer graphics. Our framework overcomes this by simulating the eeect of a variety of geomor-phological agents and the mutual interaction between diierent material and vegetation layers, including rock, sand, humus, grass, shrubs, and trees. Users are able to exploit these interactions with an authoring interface that consistently shapes the terrain and populates it with details. Our method, validated through side-by-side comparison with real terrains, can be used not only to generate realistic static landscapes, but also to follow the temporal evolution of a landscape over a few centuries.

6.4.3. SPIROU: Constrained Exploration for Mechanical Motion Design

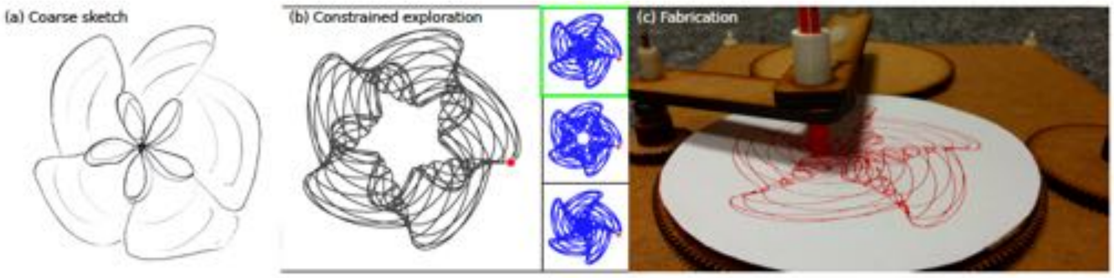

Figure 9. SPIROU: Constrained Exploration for Mechanical Motion Design [33]. The user first selects a mechanically feasible drawing by providing a rough sketch (a), and is then able to interactively explore local alternatives (b) by dening visual constraints directly on the pattern (here, the cusp position).

Mechanisms are ubiquitous in our daily lives, and the motion they are able to transmit is often a critical part of their function. While fabrication from a virtual model can be done relatively easily in a fab lab, creating or customizing a model according to functional specifications remains a challenging task. Devices such as the popular Spirograph can easily generate intricate patterns from an assembly of simple mechanical elements. Designing such machines, however , is made particularly tedious by the complex influence each configuration parameter has on the final drawing.

We propose a novel constrained exploration method that enables a user to easily explore feasible drawings by directly indicating pattern preferences at different levels of control [33]. This is illustrated in Figure 9. The user starts by selecting a target pattern with the help of construction lines and rough sketching, and then fine-tunes it by prescribing geometric features of interest directly on the drawing. The designed pattern can then be directly realized with an easy-to-fabricate drawing machine. Thee key technical challenge is to allow the user to interactively explore the high dimensional configuration space of such fabricable machines. To this end, we propose a novel method that dynamically reparameterizes the local configuration space in order to allow the user to explore drawing variations while preserving user-specifiied feature constraints. We tested our framework on several examples, conducted a user study, and fabricated a sample of the designed examples.

7. Bilateral Contracts and Grants with Industry

7.1. Bilateral Grants with Industry

7.1.1. CIFRE SILEANE (2017 - 2020)

Participants: Stefanie Hahmann, Jean-Claude Léon, Youna Le Vaou.

7.1.2. CIFRE PSA (2017 - 2020)

Participants: Stefanie Hahmann, Jean-Claude Léon, Youna Le Vaou.

8. Partnerships and Cooperations

8.1. Regional Initiatives

8.1.1. ARC6 PoTAsse (2015 - 2018)

Participants: Pablo Coves, Jean-Claude Léon, Damien Rohmer.

We received a doctoral grant (AdR) from the ARC6 program to generate functional CAD assemblies from scanned data (*PoTAsse*: POint clouds To ASSEmblies) as a collaboration between Imagine team (LJK/Inria) and Geomod team (LIRIS). Our PhD student Pablo Coves was advised by Jean-Claude Léon and Damien Rohmer at Imagine, Raphaëlle Chaine and Julie Digne in Geomod team. This project was cancelled after Pablo Coves decided to abandon his PhD thesis.

8.2. National Initiatives

8.2.1. InriaHub ADT ULTRAHD (January-December 2017)

Participants: Rémi Ronfard, Frédéric Devernay, Alexandre Gauthier.

This one-year contract was funding Alexandre Gauthier as a research engineer, with the goal of re-writing the code from Vineet Gandhi's PhD thesis into a suite of NATRON plugins. The resulting software was entirely re-designed for supporting ultra high definition video. The suite of plugins is collectively known as "Kino AI". The software is being extensively tested on a large dataset of 4K video recordings of theatre rehearsals, in collaboration with the Litt&Arts team at Univ. Grenoble Alpes, theatre director Jean-Francois Peyret in Paris, Theatre de l'Hexagone in Meylan and Theatre de Vidy in Lausanne.

8.2.2. FUI LIVE360 (December 2015 - December 2018)

Participants: Frédéric Devernay, Sandra Nabil.

This 3-year contract with industrial partner GoPRO is funding the PhD thesis of Sandra Nabil.

8.2.3. FUI Collodi 2 (December 2016 - December 2018)

Participants: Remi Ronfard, Maguelonne Beaud de Brives, Julien Daval, Damien Rohmer, Marie-Paule Cani.

This 3-year contract with two industrial partners: TeamTo and Mercenaries Engineering (software for production rendering), is a follow-up and a generalization of Dynam'it and Collodi 1. The goal is to propose an integrated software for the animation and final rendering of high-quality movies, as an alternative to the ever-ageing Maya. This contract, started in December 2016, is funding 2 engineers for 2 years.

8.2.4. ANR E-ROMA (July 2018 - June 2021)

Participants: Remi Ronfard, Stefanie Hahmann, Damien Rohmer, Marie-Paule Cani, Pierre Casati.

This 3-year contract is a joint project with GeoMod team at LIRIS and the musée gallo-romain in Lyon. The contract started in July 2018 and is funding the PhD thesis of Pierre Casati.

8.2.5. ANR FOLDYN (July 2018 - June 2021)

Participants: Damien Rohmer, Marie-Paule Cani, Thomas Buffet.

This 3-year contract is a joint project with the University of Toulouse. The contract started in July 2018 and is funding the PhD thesis of Thomas Buffet.

8.3. European Initiatives

8.3.1. FP7 & H2020 Projects

8.3.1.1. ERC Grant Expressive

Title: EXPloring REsponsive Shapes for Seamless desIgn of Virtual Environments.

Programm: ERC Advanced Grant

Duration: 04/2012 - 03/2017

Inria contact: Marie-Paule Cani

To make expressive and creative design possible in virtual environments, the goal is to totally move away from conventional 3D techniques, where sophisticated interfaces are used to edit the degrees of freedom of pre-existing geometric or physical models: this paradigm has failed, since even trained digital artists still create on traditional media and only use the computer to reproduce already designed content. To allow creative design in virtual environments, from early draft to progressive refinement and finalization of an idea, both interaction tools and models for shape and motion need to be revisited from a user-centred perspective. The challenge is to develop reactive 3D shapes – a new paradigm for high-level, animated 3D content – that will take form, refine, move and deform based on user intent, expressed through intuitive interaction gestures inserted in a user-knowledge context. Anchored in Computer Graphics, this work reaches the frontier of other domains, from Geometry, Conceptual Design and Simulation to Human Computer Interaction. The contract ended successfully in March 2017.

8.3.1.2. PIPER

Title: Position and Personalize Advanced Human Body Models for Injury Prediction

Programm: FP7

Duration: November 2013 - April 2017

Inria contact: F. Faure

In passive safety, human variability is currently difficult to account for using crash test dummies and regulatory procedures. However, vulnerable populations such as children and elderly need to be considered in the design of safety systems in order to further reduce the fatalities by protecting all users and not only so called averages. Based on the finite element method, advanced Human Body Models for injury prediction have the potential to represent the population variability and to provide more accurate injury predictions than alternatives using global injury criteria. However, these advanced HBM are underutilized in industrial R&D. Reasons include difficulties to position the models – which are typically only available in one posture – in actual vehicle environments, and the lack of model families to represent the population variability (which reduces their interest when compared to dummies). The main objective of the project will be to develop new tools to position and personalize these advanced HBM. Specifications will be agreed upon with future industrial users, and an extensive evaluation in actual applications will take place during the project. The tools will be made available by using an Open Source exploitation strategy and extensive dissemination driven by the industrial partners.Proven approaches will be combined with innovative solutions transferred from computer graphics, statistical shape and ergonomics modeling. The consortium will be balanced between industrial users (with seven European car manufacturers represented), academic users involved in injury bio-mechanics, and partners with different expertise with strong potential for transfer of knowledge. By facilitating the generation of population and subject-specific HBM and their usage in production environments, the tools will enable new applications in industrial R&D for the design of restraint systems as well as new research applications. This contract ended successfully in April 2017.

9. Dissemination

9.1. Promoting Scientific Activities

9.1.1. Scientific Events Organisation

9.1.1.1. General Chair, Scientific Chair

Remi Ronfard was the scientific chair for the Eurographics workshop on intelligent cinematography and editing (WICED) in Lyon, France in April 2017.

9.1.2. Scientific Events Selection

9.1.2.1. Chair of Conference Program Committees

Marie-Paule Cani was the Technical Paper Chair of Siggraph 2017.

9.1.2.2. Member of the Conference Program Committees

- Marie-Paule Cani served in the Papers Committees of Eurographics 2017 and Siggraph 2017.
- Frédéric Devernay served as a member of the program committee for IEEE CVPR 2017, ECCV 2017, 3DV 2017, CVMP 2017, RFIA 2017.
- Damien Rohmer was member of the following International Program Committee: ACM SIGGRAPH General submissions and poster program; Symposium on Computer Animation (SCA); Symposium on Solid and Physical Modeling (SPM); Shape Modeling International; Fabrication and Sculpting Event (SMI-FASE). He was also member of the jury committee of the best paper for the "Journées d'Informatique Française 2017" (J.Fig).
- Remi Ronfard was a member of the Program Committees for Motion in Games (MIG 2017) and International Conference on Interactive Storytelling (ICIDS 2017).
- Stefanie Hahmann serves in the International Program Committee for Eurographics 2017 and Shape Modeling International (SMI) 2017.
- Jean-Claude Léon was member of the International Program Committee for Symposium on Solid and Physical Modeling (SPM) and Shape Modeling International-Sculpting Event (SMI-FASE)

9.1.2.3. Reviewer

- Damien Rohmer was a reviewer for the journals: ACM TOG, Computer and Graphics, Computing and Informatics.
- Remi Ronfard was a reviewer for ACM Siggraph, Siggraph Asia, Computer Vision and Pattern Recognition (CVPR) and Computer Human Interface (CHI) conferences.

9.1.3. Journal

9.1.3.1. Member of the Editorial Boards

- Marie-Paule Cani is an Associate Editor of ACM Transactions on Graphics (TOG).
- Stefanie Hahmann was a guest Editor of the journal CAD Vol. 78 (Elsevier): Special Issue on Solid and Physical Modeling SPMâ16, (eds.) Mario Botsch (Allemagne), Stefanie Hahmann, Scott Schaefer (USA).
- Jean-Claude Léon is an Associate Editor of CAD (Elsevier)

9.1.3.2. Reviewer - Reviewing Activities

- Remi Ronfard was a reviewer for the ACM transactions on Graphics, Computers and Graphics, and Graphical Models journals in 2017.
- Stefanie Hahmann was a reviewer for the journals CAGD and CAD
- Jean-Claude Léon was a reviewer for the journal ASME JCISE

- Frederic Devernay was a reviewer in 2017 for IEEE Robotics and Automation Letters, IEEE Transactions on Robotics, and Traitement du Signal.

9.1.4. Invited Talks

Rémi Ronfard gave the following invited talks

- Movie Making Machines, Xerox Research Center Europe, February 2017.
- Directing virtual worlds from script to screen, Officine Sintetiche Lab, CIRMA, Torino, May 2017.
- Computer science and visual arts, CNRS, May 2017.
- Synchonization of senses, ICCV workshop CVAM, Keynote invited speaker, October 2017.

Damien Rohmer gave an invited talk at the SIAM-GD (Geometric Design) conference on "Efficient Developable Surface Modeling: From Garment Design, to Paper Animation". Pittsburg, July 2017.

9.1.5. Scientific Expertise

- Marie-Paule Cani
  - was a reviewer for a consolidator and a starting ERC project.
  - did some consulting for Disney Research, Zurich.
- Remi Ronfard
  - was a member of the scientific committee at IMAGINOVE in 2017.
- Stefanie Hahmann
  - was an expert for the Netherlands Organisation for Scientific Research.
  - serves as a member of the Advisory Board (2014-2018) for the Europeen Marie-Curie Training Network ARCADES.
- Damien Rohmer was reviewer for an ANR submission and a "Grand Est Application" project.

9.1.6. Research Administration

- Marie-Paule Cani served as first Vice-Chair and chair of the Steering Committee of the Eurographics association.
- Marie-Paule Cani and Rémi Ronfard are elected members of the executive board (CA) of EG-France, the french chapter of Eurographics.
- Marie-Paule Cani was joint director of Laboratoire Jean Kuntzmann until April 2017.
- Damien Rohmer is member of the Conseil d'Administration of Association Française d'Informatique Graphique (AFIG).
- Stefanie Hahmann
  - is an elected member of the Executive Committee of SMA (Solid Modeling Association) since 2013.
  - is the head of the French working group "GTMG" (Groupe de travail en Modélisation Géométrique) part of the CNRS GDR IM and GDR IGRV.
  - was member of the Conseil de laboratoire of the LJK lab.

9.2. Teaching - Supervision - Juries

9.2.1. Teaching

- Marie-Paule Cani is responsible for two courses at Ensimag/Grenoble-INP: 3D Graphics (a course that attracts about 80 master 1 students per year) and IRL (Introduction à la recherche en laboratoire), a course enabling engineering students to work on a personal project in a research lab during one semester, to get an idea of what academic research is.

- Stefanie Hahmann is co-responsible of the department MMIS (Images and Applied Maths) at Grenoble INP with 120 students. (http://ensimag.grenoble-inp.fr/cursus-ingenieur/modelisation-mathematique-images-simulation-124674.kjsp)

  Stefanie Hahmann had teaching load of 192h per year. She is responsible of 3 courses at Ensimag/Grenoble INP: Numerical Methods (240 students, 3rd year Bachelor level), Geometric Modeling (60 students, Master 1st year) and Surface Modeling (30 students, Master 2nd year).
- Olivier Palombi is responsible of the French Campus numérique of anatomy. He is responsible and national leader of the project SIDES (http://side-sante.org/). All the French medical schools (43) have planed to use the same e-learning framework (SIDES) to manage evaluations (examen) and to create a large shared database of questions.
- Damien Rohmer is coordinator of the Math, Signal, Image program at the engineering school CPE Lyon in supervising the scientific and technical content of the program. He is also co-responsible of the *Image, Modeling & Computing* specialization program attracting 35 students per year. He gives, and is responsible, for of one Computer Science class (130 student, 3rd year Bachelor level), an introductory Computer Graphics class (110 students, Master 1st year), and 5 specialization classes on C++ programming, OpenGL programming, 3D modeling, animation and rendering (35 students, Master 1st and 2nd year). He coordinates the association between CPE and the new computer graphics master program ID3D (Image, Développement et Technologie 3D) from University Lyon1. He also coordinates the association between CPE and the Gamagora computer game project.
- Rémi Ronfard taught courses in Computational modeling of narrative texts, movies and games, MSTII Doctoral School, University Grenoble Alpes (18 hours in March-April 2017); Game Engine Programming, M2R IMAGINA, University of Montpellier (36 hours in October-December 2017) and Advanced 3D animation, M2R MOSIG, University of Grenoble Alpes (12 hours in December 2017).
- Jean-Claude Léon is in charge of the module Mechanical Systems at Grenoble-INP ENSE3 (300 students, 64h, coordination of three courses)
- Frederic Devernay teaches Computer Science at CPP - La prépa des ING, Grenoble (50h, 200 students).

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. It belongs to the doctoral school MSTII.

9.2.2. Supervision

- PhD: Sébastien Crozet, *Calcul de distance minimale entre solides B-Rep CAO pour des applications de simulations mécaniques temps réelles*, Janvier 2015- Décembre 2017. Supervised by Jean-Claude Leon.Defended in December 2017.
- PhD: Grégoire Niéto (Université de Grenoble Alpes), *Dispositifs de capture de type "caméra plénoptique" pour la vision à grande distance, et algorithmes de traitement et de visualisation*, supervised by Frédéric Devernay and James Crowley (LIG, Grenoble). Defended in October 2017.
- PhD: Tibor Stanko. *Modélisation de surfaces lisses maillées à partir de capteurs inertiels*. Thèse CEA. October 2014- September 2017. Supervised by Stefanie Hahmann and GP Bonneau. Defended in December 2017.
- PhD in progress: Romain Brégier (Univ. Grenoble Alpes), Detection and pose estimation of rigid object instances for robotics (Détection et estimation de pose d'instances d'objet rigide pour la manipulation robotisée). July 2014 - February 2018. Frédéric Devernay, James Crowley (LIG, Grenoble).
- PhD in progress: Guillaume Cordonnier. *Graphical simulation of mountains based on geology*. Grenoble university. October 2015-September 2018. Marie-Paule Cani and Eric Galin.

- PhD in progress: Geoffrey Guingo. *Synthesis of animated textures*. Grenoble university. October 2015-September 2018. Marie-Paule Cani, Jean-Michel Dischler and Basile Sauvage.
- PhD in progress: Sandra Nabil (Université de Grenoble Alpes), High resolution panoramic video creation and processing (Vidéo panoramique 360 dégrés à très haute résolution). October 2015 - October 2018. Frédéric Devernay, James Crowley (LIG, Grenoble).
- PhD in progress: Robin Roussel. *Function-aware design for objects to be fabricated*. UCL London. October 2015-September 2018. Niloy Mitra, Marie-Paule Cani and Jean-Claude Léon.
- PhD in progress: Amélie Fondevilla. Sculpting and animating developable surfaces with video embedding. Grant MENRT. October 2016 - September 2019. Stefanie Hahmann and Damien Rohmer.
- PhD in progress: Thomas Buffet. Efficient multi-layered cloth animation using implicit surfaces, Grant ANR FolD-Dyn. December 2017 - November 2020. Marie-Paule Cani and Damien Rohmer.
- PhD in progress: Maxime Garcia. *Expressive performance transfer*. Grant MENRT. October 2016-September 2019. Supervised by Rémi Ronfard.
- PhD in progress: Pierre Casati. *Animating 3D antique statues and engravings*. December 2017-November 2020. Supervised by Rémi Ronfard and Stéfanie Hahmann. Funded by ANR project E-ROMA.
- PhD in progress: Ameya Murukutla. *Authoring scenarios for augmented reality anatomy learning*. December 2017-November 2020. Supervised by Rémi Ronfard and Olivier Palombi. Funded by ANR project Anatomy 2020.
- PhD abandoned: Even Entem. *3D modelling from a sketch*. Grenoble University. November 2013-March 2017. Marie-Paule Cani and Loic Barthe (IRIT Toulouse). PhD Stopped in March 2017.
- PhD abandoned: Pablo Coves. From Point Cloud Data to Functional CAD Model. Grenoble. Univ. Jean-Claude Léon, Damien Rohmer, Raphaëlle Chaine (LIRIS), Julie Digne (LIRIS). May 2015 - Sept. 2017. PhD stopped in Sept. 2017. Pablo currently pursue his career as a software engineer in the company Anatoscope.
- M2R: Sarah Kushner. Master MOSIG. Sketch-Based Posing and Interaction of Multiple Characters: Animating Dancing Couples. Supervised by Marie-Paule Cani and Rémi Ronfard. Sarah Kushner is now a PhD Student at the University of Toronto.
- M2R: Tuan Hung Vu. Master MOSIG. Learning cinematographic style from pictures. Supervised by Karteek Alahari (THOTH team) and Rémi Ronfard. Tuan Hung Vu is now a PhD student at IMT Lille Douai.
- M1: Hugo Frezat. Master MOSIG. Story Generation from Pictures. Supervised by Rémi Ronfard.

9.3. Popularization

Starting in May 2017, our recent work on "3D animation by gesturing and drawing" has been featured in a live demo open to the general public at the new Espace Login in Inria Grenoble Alpes.

On November 8 and 9, that same demo was presented at Studio 104 in Paris during the celebration of Inria's 50th anniversary, to an audience of several hundred people.

Rémi Ronfard gave presentations on

- Directing virtual worlds, Ministère de la Culture, January 2017.
- Eyetracking and the arts, Institut d'Art Contemporain, Lyon, April 2017.
- Sketch-based character animation, CITIA, Annecy, May 2017.
- Computer science and theatre, ENSATT Lyon, December 2017.

Marie-Paule Cani was invited by France Inter's Dorothée Barba on December 25, 2016 to speak about the Imgine team and the future of cinema. A podcast of the the program (Demain la veille: cinema futurismo) can be obtained from https://www.franceinter.fr/emissions/demain-la-veille/demain-la-veille-25-decembre-2016.

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[7] D. Rohmer. *Interactive high-level models for 3D virtual shape creation & animation*, Université Grenoble - Alpes, June 2017, Habilitation à diriger des recherches, https://hal.inria.fr/tel-01587625

[8] T. Stanko. *Shape reconstruction of meshed smooth surfaces equipped with inertial sensors*, Université Grenoble Alpes, December 2017, https://hal.inria.fr/tel-01673779

Articles in International Peer-Reviewed Journals

[9] A. Barbulescu, R. Ronfard, G. Bailly. *A Generative Audio-Visual Prosodic Model for Virtual Actors*, in "IEEE Computer Graphics and Applications", November 2017, vol. 37, n^o^ 6, pp. 40-51 [*DOI :* 10.1109/MCG.2017.4031070], https://hal.inria.fr/hal-01643334

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