RESEARCH CENTRE

Inria Centre at Université Grenoble Alpes

IN PARTNERSHIP WITH:

Université de Grenoble Alpes

2024 ACTIVITY REPORT

Team ANIMA

Authoring and directing animated story worlds

Inria teams are typically groups of researchers working on the definition of a common project, and objectives, with the goal to arrive at the creation of a project-team. Such project-teams may include other partners (universities or research institutions)

IN COLLABORATION WITH: Laboratoire Jean Kuntzmann (LJK)

DOMAIN

Perception, Cognition and Interaction

THEME

Interaction and visualization

Inria

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Team ANIMA

Creation of the Team: 2024 July 01

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1 Team members, visitors, external collaborators

Research Scientists

- Remi Ronfard [Team leader, INRIA, Senior Researcher]
- Melina Skouras [INRIA, Researcher]

Faculty Members

- Stefanie Hahmann [GRENOBLE INP, Professor]
- Olivier Palombi [UGA, Professor, until Nov 2024]

PhD Students

- Sandrine Barbois [UGA]
- Siyuan He [ENPC]
- Anandhu Sureshkumar [Télécom Paris]

Interns and Apprentices

- Sacha Bonicatto [INRIA, Intern, from Jun 2024 until Sep 2024]
- Theo Cantaloube [INRIA, Intern, until May 2024]
- Ofir Mirkin [UGA, Intern, from Sep 2024]
- Ofir Mirkin [INRIA, Intern, from May 2024 until Jul 2024]
- Ofir Mirkin [INRIA, Intern, until May 2024]

2 Overall objectives

ANIMA focuses on developing computer tools for authoring and directing animated movies, interactive games and mixed-reality applications, using virtual sets, actors, cameras and lights. This raises several scientific challenges. Firstly, we need to build a representation of the story that the user/director has in mind, and this requires dedicated user interfaces for communicating the story. Secondly, we need to offer tools for authoring the necessary shapes and motions for communicating the story visually, and this requires a combination of high-level geometric, physical and semantic models that can be manipulated in real-time under the user's artistic control. Thirdly, we need to offer tools for directing the story, and this requires new interaction models for controlling the virtual actors and cameras to communicate the desired story while maintaining the coherence of the story world.

2.1 Understanding stories

Stories can come in many forms. An anatomy lesson is a story. A cooking recipe is a story. A geological sketch is a story. Many paintings and sculptures are stories. Stories can be told with words, but also with drawings and gestures. For the purpose of creating animated story worlds, we are particularly interested in communicating the story with words in the form of a screenplay or with pictures in the form of a storyboard. We also foresee the possibility of communicating the story in space using spatial gestures. The first scientific challenge for the ANIMA team is to propose new computational models and representations for screenplays and storyboards, and practical methods for parsing and interpreting screenplays and storyboards from multimodal user input. To do this, we reverse engineer existing screenplays and storyboards, which are well suited for generating animation in traditional formats. We also explore new representations for communicating stories with a combination of speech commands, 3D sketches and 3D gestures, which promise to be more suited for communicating stories in new media including virtual reality, augmented reality and mixed reality.

2.2 Authoring story worlds

Telling stories visually creates additional challenges not found in traditional, text-based storytelling. Even the simplest story requires a large vocabulary of shapes and animations to be told visually. This is a major bottleneck for all narrative animation synthesis systems. The second scientific challenge for the ANIMA team is to propose methods for quickly authoring shapes and animations that can be used to tell stories visually. We devise new methods for generating shapes and shape families, understanding their functions, styles, material properties and affordances, authoring animations for a large repertoire of actions, and printing and fabricating articulated and deformable shapes suitable for creating physical story worlds with tangible interaction.

2.3 Directing story worlds

Lastly, we develop methods for controlling virtual actors and cameras in virtual worlds and editing them into movies in a variety of situations ranging from 2D and 3D professional animation, to virtual reality movies and real-time video games. Starting from the well-established tradition of the storyboard, we create new tools for directing movies in 3D animation, where the user is really the director, and the computer is in charge of its technical execution using a library of film idioms. We also explore new areas, including the automatic generation of storyboards from movie scripts for use by domain experts, rather than graphic artists.

3 Research program

The four research themes pursued by ANIMA are (i) the geometry of story worlds; (ii) the physics of story worlds; (iii) the semantics of story worlds; and (iv) the aesthetics of story worlds.

In each theme, significant advances in the state of the art are needed to propose computational models of stories, and build the necessary tools for translating stories to 3D graphics and animation.

3.1 Geometric modeling of story worlds

Scientist in charge: Stefanie Hahmann
Other participants: Rémi Ronfard, Mélina Skouras

We aim to create intuitive tools for designing 3D shapes and animations which can be used to populate interactive, animated story worlds, rather than inert and static virtual worlds. In many different application scenarios such as preparing a product design review, teaching human anatomy with a MOOC, composing a theatre play, directing a movie, showing a sports event, 3D shapes must be modeled for the specific requirements of the animation and interaction scenarios (stories) of the application.

We will need to invent novel shape modelling methods to support the necessary affordances for interaction and maintain consistency and plausibility of the shape appearances and behaviors during animation and interaction. Compared to our previous work, we will therefore focus increasingly on designing shapes and motions simultaneously, rather than separately, based on the requirements of the stories to be told.

Previous work in the IMAGINE team has emphasized the usefulness of space-time constructions for sketching and sculpting animation both in 2D and 3D. Future work in the ANIMA team will further develop this line of research, with the long-term goal of choreographing complex multi-character animation and providing full authorial and directorial control to the user.

3.1.1 Space-time modeling

The first new direction of research in this theme is an investigation of space-time geometric modeling, i.e. the simultaneous creation of shapes and their motions. This is in continuity with our previous work on "responsive shapes", i.e. making 3D shapes respond in an intuitive way during both design and animation.

3.1.2 Spatial interaction

A second new direction of research of the ANIMA team will be the extension of sketching and sculpting tools to the case of spatial 3D interaction using virtual reality headsets, sensors and trackers.

Even though 3D modeling can be regarded as an ideal application for Virtual Reality, it is known to suffer from the lack of control for freehand drawing. Our insight is to exploit the expressiveness of hand (controller) motion and simple geometric primitives in order to form an approximated 3D shape. The goal is not to generate a final well shaped product, but to provide a 3D sketching tool for creating early design shapes, kind of scaffolds, and for rough idea exploration. Standard 3D modeling systems can then take over to generate more complex shape details.

Research directions to be explored include (i) direct interaction using VR; (ii) applications to form a 3D shape from rough design ideas; (iii) applications to modify existing objects during design review sessions; and (iv) provide tools to ease communications about imagined shapes.

3.2 Physical modeling of story worlds

Scientist in charge: Mélina Skouras
Other participants: Stefanie Hahmann, Rémi Ronfard

When authoring and directing story worlds, physics is important to obtain believable and realistic behaviors, e.g. to determine how a garment should deform when a character moves, or how the branches of a tree bend when the wind starts to blow. In practice, while deformation rules could be defined a priori (e.g. procedurally), relying on physics-based simulation is more efficient in many cases as this means that we do not need to think in advance about all possible scenarii. In ANIMA, we want to go a step further. Not only do we want to be able to *predict* how the shape of deformable objects will change, but we also want to be able to *control* their deformation. In short, we are interested in solving inverse problems where we adjust some parameters of the simulation, yet to be defined so that the output of the simulation matches what the user wants.

By optimizing design parameters, we can get realistic results on input scenarii, but we can also extrapolate to new settings. For example, solving inverse problems corresponding to static cases can be useful to obtain realistic behaviors when looking at dynamics. E.g. if we can optimize the cloth material and the shape of the patterns of a dress such that it matches what an artist designed for the first frame of an animation, then we can use the same parameters for the rest of the animation. Of course, matching dynamics is also one of our goals.

Compared to more traditional approaches, this raises several challenges. It is not clear what the best way is for the user to specify constraints, i.e. how to define what she wants (we do not necessarily want to specify the positions of all nodes of the meshes for all frames, for example). We want the shape to deform according to physical laws, but also according to what the user specified, which means that the objectives may conflict and that the problem can be over-constrained or under-constrained.

Physics may not be satisfied exactly in all story worlds i.e. input may be cartoonish, for example. In such cases, we may need to adapt the laws of physics or even to invent new ones. In computational fabrication, the designer may want to design an object that cannot be fabricated using traditional materials for example. But in this case, we cannot cheat with the physics. One idea is to extend the range of things that we can do by creating new materials (meta-materials), creating 3D shapes from flat patterns, increasing the extensibility of materials, etc.

To achieve these goals, we will need to find effective metrics (how to define objective functions that we can minimize); develop efficient models (that can be inverted); find suitable parameterizations; and develop efficient numerical optimization schemes (that can account for our specific constraints).

3.2.1 Computational design of articulated and deformable objects

We would like to extend sketch-based modeling to the design of physical objects, where material and geometric properties both contribute to the desired behaviors. Our goal in this task will be to provide efficient and easy-to-use physics-aware design tools. Instead of using a single 3D idealized model as input, we would like to use sketches, photos, videos together with semantic annotations relating to materials and motions. This will require the conceptualization of *physical storyboards*. This implies controlling the matter and includes the computational design of meso-scale materials that can be locally assigned to the objects; the optimization of the assignment of these materials such that the objects behave as expected; the optimization of the actuation of the object (related to the point below). Furthermore, the design of the meta-materials/objects can take into account other properties in addition to the mechanical aspects. Aesthetics, in particular, might be important.

3.2.2 Physical storyboarding

Story-boards in the context of physical animation can be seen as a concept to explain how an object/character is supposed to move or to be used (a way to describe the high-level objective). Furthermore, they can be used to represent the same object from different views, in different scales, even at different times and in different situations, to better communicate the desired behavior. Finally, they can be used to represent different objects behaving "similarly".

Using storyboards as an input to physical animation raises several scientific challenges. If one shape is to be optimized; we need to make sure that the deformed shape can be reached (i.e. that there is a continuous path from the initial shape to the final shape) - e.g. deployable structures. We will need to explore different types of inputs: full target animations, key-frames, annotations (arrows), curves, multi-modal inputs. Other types of high-level goals, which implies that the object should be moving/deforming in a certain way (to be optimized), e.g locomotion, dressing-up a character.

3.3 Semantic modeling of story worlds

Scientist in charge: Olivier Palombi
Other participants: Rémi Ronfard, Nicolas Szilas

Beyond geometry and physics, we aim at representing the semantics of story worlds. We use ontologies to organize story worlds into entities described by well defined concepts and relations between them. Especially important to us is the ability to "depict" story world objects and their properties during the design process [13] while their geometric and material properties are not yet defined. Another important aspect of this research direction is to make it possible to quickly create interactive 3D scenes and movies by assembling existing geometric objects and animations. This requires a conceptual model for semantic annotations, and high level query languages where the result of a semantic query can be a 3D scene or 3D movie.

One important application area for this research direction is the teaching of human anatomy. The PhD thesis of Ameya Murukutla focuses on automatic generation of augmented reality lessons and exercises for teaching anatomy to medical students and sports students using the prose storyboard language which we introduced during Vineet Gandhi's PhD thesis [27]. By specializing to this particular area, we are hoping to obtain a formal validation of the proposed methods before we attempt to generalize them to other domains such as interactive storytelling and computer games.

3.3.1 Story world ontologies

We will extend our previous work on ontology modeling of anatomy [26, 29] in two main directions. Firstly, we will add procedural representations of anatomic functions that make it possible to create animations. This requires work in semantic modeling of 3D processes, including anatomic functions in the teaching of anatomy. This needs to be generalized to actor skills and object affordances in the more general setting of role playing games and storytelling. Secondly, we will generalize the approach to other storytelling domains. We are starting to design an ontology of dramatic functions, entities and 3D models. In storytelling, dramatic functions are actions and events. Dramatic entities are places, characters and objects of the story. 3D models are virtual actors, sets and props, together with their necessary skills and affordances. In both cases, story world generation is the problem of linking 3D models with semantic entities and functions, in such a way that a semantic query (in natural language or pseudo natural language) can be used to create a 3D scene or 3D animation.

3.3.2 Story world scenarios

While our research team is primarily focused on providing authoring and directing tools to artists, there are cases where we also would like to propose methods for generating 3D content automatically. The main motivation for this research direction is virtual reality, where artists attempt to create story worlds that respond to the audience actions. An important application is the emerging field of immersive augmented reality theatre [21, 11, 24, 25, 20, 15, 22]. In those cases, new research work must be devoted to create plausible interactions between human and virtual actors based on an executable representation of a shared scenario.

3.4 Aesthetic modeling of story worlds

Scientist in charge:Rémi Ronfard
Other participants: Stefanie Hahmann, Mélina Skouras, François Garnier

Data-driven methods for shape modeling and animation are becoming increasingly popular in computer graphics, due to the recent success of deep learning methods. In the context of the ANIMA team, we are particularly interested in methods that can help us capture artistic styles from examples and transfer them to new content. This has important implications in authoring and directing story worlds because it is important to offer artistic control to the author or director, and to maintain a stylistic coherence while generating new content. Ideally, we would like to learn models of our user's authoring and directing styles, and create contents that matches those styles.

3.4.1 Learning and transferring shape styles

We want to better understand shape aesthetics and styles, with the long-term goal of creating complex 3D scenes with a large number of shapes with consistent styles. We will also investigate methods for style transfer, allowing to re-use existing shapes in novel situations by adapting their style and aesthetics [23].

In the past exhaustive research has been done on *aesthetic* shape design in the sense of fairness, visual pleasing shapes using e.g. bending energy minimization and visual continuity. Note, that these aspects are still a challenge in motion design (see next section). In shape design, we now go one step further by focusing on *style*. Whereas fairness is general, style is more related to application contexts, which we would like to formalize.

3.4.2 Learning and transferring motion styles

While the aesthetics of spatial curves and surfaces has been extensively studied in the past, resulting in a large vocabulary of spline curves and surfaces with suitable control parameters, the aesthetics of temporal curves and surfaces is still poorly understood. Fundamental work is needed to better understand which geometric features are important in the perception of the aesthetic qualities of motions and to design interpolation methods that preserve them. Furthermore, we would like to transfer the learned motion styles to new animations. This is a very challenging problem, which we started to investigate in previous work in the limited domains of audiovisual speech animation [12] and hand puppeteering [19].

3.4.3 Learning and transferring film styles

In recent years, we have proposed new methods for automatically composing cinematographic shots in live action video [18] or 3D animation [16] and to edit them together into aesthetically pleasing movies [17]. In future work, we plan to apply similar techniques for the new use case of immersive virtual reality. This raises interesting new issues because spatial and temporal discontinuities must be computed in real time in reaction to the user's movements. We have established a strong collaboration with the Spatial Media team at ENSADLAB to investigate those issues. We also plan to transfer the styles of famous movie directors to the generated movies by learning generative models of their composition and film editing styles, therefore extending the previous work of Thomas [28] from photographic style to cinematographic style. The pioneering work of Cutting and colleagues [14] used a valuable collection of 150 movies covering the years 1935 to 2010, mostly from classical Hollywood cinema. A more diverse dataset including European cinema in different genres and styles will be a valuable contribution to the field. Towards this goal, we are building a dataset of movie scenes aligned with their screenplays and storyboards.

4 Application domains

The research goals of the ANIMA team are applicable to many application domains which use computer graphics and are in demand of more intuitive and accessible authoring and directing tools for creating animated story worlds. This includes arts and entertainment, education and industrial design.

Arts and entertainement

Animated story worlds are central to the industries of 3D animation and video games, which are very strong in France. Designing 3D shapes and motions from storyboards is a worthwhile research goal for those industries, where it is expected to reduce production costs while at the same time increasing artistic control, which are two critical issues in those domains. Furthermore, story is becoming increasingly important in video games and new authoring and directing tools are needed for creating credible interactive story worlds, which is a challenge to many video game companies. Traditional live action cinematography is another application domain where the ANIMA team is hoping to have an impact with its research in storyboarding, virtual cinematography and film editing.

Performance art, including dance and theater, is an emergent application domain with a strong need for dedicated authoring and directing tools allowing to incorporate advanced computer graphics in live performances. This is a challenging application domain, where computer-generated scenography and animation need to interact with human actors in real-time. As a result, we are hoping that the theater stage becomes an experimental playground for our most exploratory research themes. To promote this new application domain, we are organizing the first international workshop on computer theater in Grenoble in February 2020, under the name Journées d'Informatique Théâtrale (JIT). The workshop will assemble theater researchers, artists and computer engineers whose practice incorporates computer graphics as a means of expression and/or a creative tool. With this workshop, our goal is to create a new research discipline that could be termed "computer theater", following the model of computer music, which is now a well established discipline.

Education

Teaching of Anatomy is a suitable domain for research. As professor of Anatomy, Olivier Palombi gives us the opportunity to experiment in the field. The formalization of anatomical knowledge in our ontology called My Corporis Fabrica (MyCF) is already operational. One challenge for us is to formalize the way anatomy is taught or more exactly the way anatomical knowledge is transmitted to the students using interactive 3D scenes.

Museography is another related application domain for our research, with a high demand for novel tools allowing to populate and animate virtual reconstructions of art works into stories that make sense to museum audiences of all ages. Our research is also applicable to scientific museography, where animated story worlds can be used to illustrate and explain complex scientific concepts and theories.

Industrial design

Our research in designing shapes and motions from storyboards is also relevant to industrial design, with applications in the fashion industry, the automotive industry and in architecture. Those three industries are also in high demand for tools exploiting spatial interaction in virtual reality. Our new research program in physical modeling is also applicable to those industries. We have established strong partnerships in the past with PSA and Vuitton, and we will seek to extend them to architectural design as well in the future.

5 Social and environmental responsibility

5.1 Footprint of research activities

ANIMA is a small team of four permanent researchers and three PhD students, so our footprint is limited. We estimate that we run approximately twelve computers, including laptops, desktops and shared servers, at any given time.

Research in computer graphics is not (yet) data intensive. We mostly devise procedural algorithms, which require limited amounts of data. One notable exception is our work on computational editing of live performances, which produces large amounts of ultra high definition video files. We have opted for a centralized video server architecture (KinoAI) so that at least the videos are never duplicated and always reside on a single server.

On the other hand, our research requires powerful graphics processing units (GPU) which significantly increase the power consumption of our most powerful desktops.

The COVID19 crisis has changed our working habits heavily. We have learned to work from home most of the week, and to abandon international travel entirely. This holds the promise of a vastly reduced footprint. But it is too early to say whether this is sustainable. While the team as a whole has been able to function in adverse conditions, it has become increasingly difficult to welcome interns and Masters students.

5.2 Impact of research results

Our research does not directly address social and environmental issues. Our work on 3D printing may have positive effects by allowing the more efficient use of materials in the production of prototypes. Our work on virtual medical simulation and training may provide an alternative in some cases to animal experiments and costly robotic simulations.

Our most important application domain is arts and culture, including computer animation and computer games. Globally, those sectors are creating jobs, rather than destroying them, in France and in Europe. The impact of our discipline is therefore positive at least in this respect.

We are more concerned with the impact of the software industry as a whole, i.e. private companies who implement our research papers and include them in their products. We note a tendency to increase the memory requirements of software. While much effort in software engineering is devoted to improving the execution speed of graphics programs, there is not enough effort in optimizing their footprint. This is an area that may be worth investigating in our future work.

6 Highlights of the year

6.1 Computer theater conference / Journées d'informatique théâtrale

The third edition of the international conference on computer theater was co-organized by Rémi Ronfard and Cyrielle Garson, at the University of Avignon, October 9, 10 and 11, 2024.

The scientific committee selected 30 papers out of 40 submissions, both in English and French. Accepted papers will be published in the conference proceedings, due in June 2025.

The three-day conference was attended by 80 researchers, practitioners, and independent artists from France, Italy, Switzerland, UK, USA and Canada.

Many different academic disciplines were represented, including computer science, theatre studies, artificial intelligence, virtual reality, literature, media studies and applied arts.

The three-day conference featured keynotes by Brendan Bradley (NYU Tisch School of the Arts), Lisa Bretzner (Compagnie Atropos), Laurence Devillers (Sorbonne Université) and Serge Abiteboul (Inria).

6.2 Awards

Stefanie Hahmann was awarded with the John Gregory Memorial Award by the international Geometric Modeling community. The award ceremony took place at the Leibniz Center for Informatics in Schloss Dagstuhl, June 2024. View award site.

Stefanie Hahmann was awarded the T. Kunii Distinguished Researcher Award by the International Shape Modeling Committee during the Shape Modeling conference (SMI) in Detroit in July 2024. View award site

7 New results

7.1 3D sketching in immersive environments: Shape from disordered ribbon strokes.

Participants: Stefanie Hahmann, , Anandhu Sureshkumar.

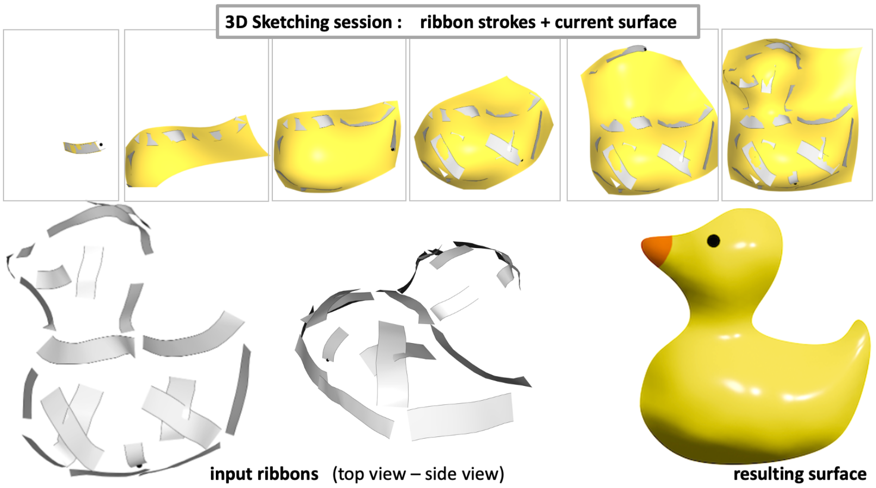

Figure 1: Interactive 3D sketching system.

This work is done with PhD student Anandhu Sureshkumar in collaboration with Georges-Pierre Bonneau (Maverick team), Amal Dev Parakkat (Télécom Paris) and Marie-Paule Cani (LIX/Ecole Polytechnique). We developed a new 3D sketching system in Virtual Reality. Indeed, immersive environments with head mounted displays (HMD) and hand-held controllers offer new possibilities for the creation of artistic 3D content. Some of them are exploited by mid-air drawing applications: the user's hand trajectory generates a set of stylized curves or ribbons in space, giving the impression of painting or drawing in 3D. We propose a method to extend this approach to the sketching of surfaces with a VR controller. The idea is to favor shape exploration, offering a tool, where the user creates a surface just by painting ribbons. These ribbons are not constrained to form patch boundaries for example or to completely cover the shape. They can be very sparse, disordered, overlap or not, intersect or not. The shape is computed simultaneously, starting with the first piece of ribbon drawn by the user and continuing to evolve in real-time as long as the user continues sketching. An example is shown in Figure 1. Our method involves minimizing an energy function based on the projections of the ribbon strokes on a proxy surface by taking the controller's orientations into account.

During this work we collaborated also with a visual artist, Pauline de Chalandar. In the corresponding publication, we show images of one of her artistic creations that combines stylized curve drawings in VR with our surface sketching tool.

7.2 Modern Dance Retargeting using Ribbons as Lines of Action.

Participants: Mélina Skouras, Rémi Ronfard.

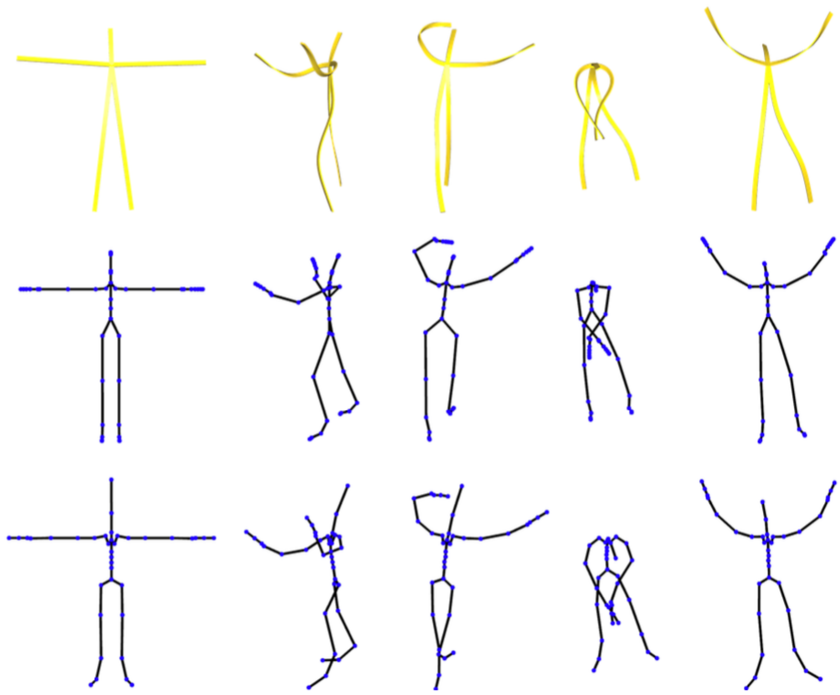

Figure 2: Retargeting results. From top to bottom: input ribbon, retargeted humanoid skeleton with the same morphology as the input data, retargeted skeleton with added bones and different T-Pose shape.

This work, done in collaboration with former PhD student Manon Vialle, presents a method for retargetting dancing characters represented as articulated skeletons with possibly different morphologies and topologies. Our approach relies on the use of flexible ribbons that can bend and twist as an intermediate representation, and that can be seen as animated lines of action. These ribbons allow us to abstract away the specific morphology of the bodies and to well transmit the fluidity of modern dance movement from one character to another.

7.3 Designing Bending-Active Freeform Surfaces.

Participants: Mélina Skouras, Stefanie Hahmann.

This work, done in collaboration with Georges-Pierre Bonneau and former PhD student Emmanuel Rodriguez, presents a method for designing bending-active structures, i.e. curved structures created using initially planar components that have been elastically bent so that they take on a three-dimensional shape. The 3D shape that the structure assumes depends not only on the applied external forces, but also on the elastic properties of the physical material used. By altering the fine-scale structure of this material, we are able to locally control its macroscopic elastic properties.

We introduce a computational framework for the inverse design of custom 3D surfaces using bending-active structures. We optimize the internal structure of laser-cut planar surface strips, so that they approximate a desired 3D freeform surface when being clamped at both extremities. The specific

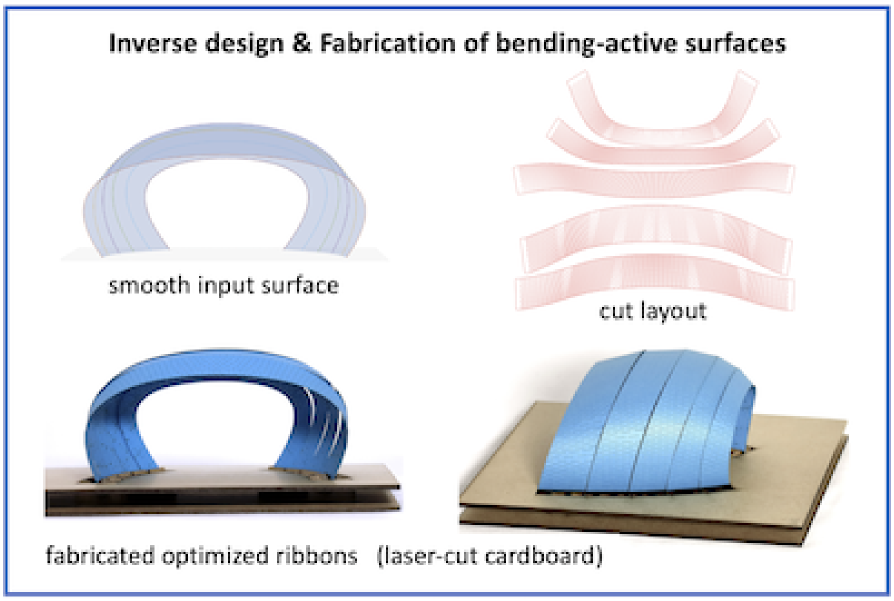

Figure 3: Given a freeform input surface segmented into strips by the user (top left), we automatically generate the layout of flat ribbons (i.e their external boundaries and their internal structures) such that their deformed shapes, when their are clamped at both ends, match the ruled surfaces at equilibrium (top right). Once laser-cut, the fabricated ribbons can be actively bent to approximate the given input surface (bottom).

orthotropic design of the structure of the strips allows us to locally control their bending behavior. In contrast to past work the planar surface strips can be of arbitrary shape, not necessarily rectangular, and when deformed, they form a piecewise continuous surface.

7.4 MatAIRials: Inflatable Metamaterials for Freefrom Surface Design.

Participants: Mélina Skouras, Siyuan He.

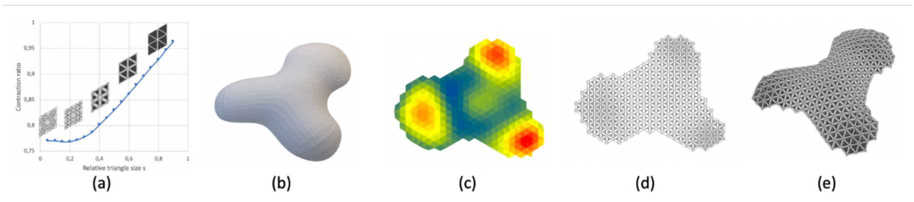

Figure 4: We propose isotropic inflatable metamaterials for creating inflatable structures of desired 3D shapes. Our approach starts by precomputing the mapping between the parameters of the sealing patterns and the contraction ratios of the inflated metamaterials (a). Then, given an input 3D triangular mesh (b), we flatten it to the plane using conformal parametrization (c) and use the local scaling factor (color plot in Figure (c)) of the surface to trace the layout of the sealing patterns of the triangles of a superimposed regular grid (d). The resulting graded patterns allows us to generate a curved inflated structure that approximates the input mesh through metric frustration (e).

This work, done in collaboration with Arthur Lebée, investigates the modeling of inflatable pads, made of two planar membranes sealed according to periodic patterns, typically parallel lines or dots, as metamaterials.

By considering novel sealing patterns with 6-fold symmetry, we are able to generate a family of inflatable materials whose macroscale contraction is isotropic and can be modulated by controlling the parameters of the seals. We leverage this property of our inflatable materials family to propose a simple and effective algorithm based on conformal mapping that allows us to design the layout of inflatable structures that can be fabricated flat and whose inflated shapes approximate those of given target freeform surfaces.

8 Partnerships and cooperations

8.1 International research visitors

8.1.1 Visits to international teams

Sabbatical programme From October 2023 to September 2024, Stefanie Hahmann benefited from an INRIA delegation at the rate of 66%. he therefore had a reduced teaching service at ENSIMAG of just 70 hours.

Research stays abroad Stefanie Hahmann spent three months (April-June 2024) as a guest in Professor Konrad Polthier's Mathematical Geometry Processing group. Her research interests include the approximation of free-form surfaces by developable ribbons. During this period, she gave a seminar at the Freie University of Berlin.

8.2 National initiatives

8.2.1 ANR SIDES-LAB

Participants: Olivier Palombi.

SIDES is a learning digital platform common to all French medical schools, used for official exams (tests) in faculties and for the training of students for the National Ranking Exam (ECN) which is fully computerized since 2016 (ECNi).

As part of this platform, Olivier Palombi is taking part in the SIDES LAB project (start date February 2022, end date January 2026) under the leadership of Franck Ramus, Laboratoire de Sciences Cognitives et Psycholinguistique, ENS, Paris.

Official web sites: anr.fr/Projet-ANR-21-CE28-0030and www.uness.fr/projets/recherche/sides-lab.

8.2.2 ANR MATAIRIALS

Participants: Mélina Skouras.

MatAIRialS (Architectured Inflatable mateRials for designing functional Shells) aims at investigating the design of large scale inflatable shells able to carry loads, made of superimposed membranes that are sealed according to quasi-periodic patterns and that locally behave as inflatable architected materials. Our idea is to pave the patterns and adjust their parameters so as to modulate the geometric and mechanical properties of the inflatable structure and in turn its deployed shape and stiffness. We intend to especially focus on the mechanical characterization of our architected materials, both numerically and experimentally, and to demonstrate the practical interest of our tools for real applications by fabricating prototypes of diverse sizes, including architectural-sized demonstrators.

This project is coordinated by Mélina Skouras and has as partners Laboratoire Navier (ENPC) and Laboratoire PMMH (ESPCI-CNRS-Université PSL).

9 Dissemination

Participants: Rémi Ronfard, Mélina Skouras, Stefanie Hahmann.

9.1 Promoting scientific activities

9.1.1 Scientific events: organisation

General chair, scientific chair Rémi Ronfard co-chaired the Computer Conference on Computer Theater (Journées d'Informatique Théâtrale).

9.1.2 Scientific events: selection

Chair of conference program committees Mélina Skouras was a chair for the ACM/Eurographics Symposium on Computer Animation 2024 (SCA 2024) and an area chair for the ACM Symposium on Computational Fabrication 2024 (SCF 2024).

Rémi Ronfard co-chaired the Scientific Committee for the Computer Conference on Computer Theater (Journées d'Informatique Théâtrale).

Member of the conference program committees Mélina Skouras was a program committee member for ACM SIGGRAPH, ACM Symposium on Geometry Processing (SGP) 2023 and Eurographics full papers.

Stefanie Hahmann was a program committee member for the Symposium on Solid and Physical Modeling (SPM'24) and Shape Modeling International (SMI'24).

Reviewer Mélina Skouras was a reviewer for the ACM Symposium on User Interface Software and Technology (UIST), and ACM TEI 2024 (the 18th International Conference on Tangible Embedded and Embodied Interaction).

Rémi Ronfard was a reviewer for ACM Siggraph 2024.

9.1.3 Journal

Member of the editorial boards Stefanie Hahmann is an associate editor of the Elsevier journals Computer Aided Design (CAD) and Computers & Graphics (CAG) since 2015.

Reviewer - reviewing activities Mélina Skouras was a reviewer for ACM Transactions on Graphics.

9.1.4 Invited talks

Mélina Skouras gave an invited talk at the ACM Symposium on Computational Fabrication 2024 (SCF 2024) and at the CIRM seminar Geometry & Computing (21-25 Oct 2024 Luminy).

Stefanie Hahmann gave an invited talk (award lecture) at the Shape Modeling Conference (SMI2024), Detroit, July 12-14, 2024.

Stefanie Hahmann was invited to the Dagstuhl seminar on Geometric Modeling, Leibniz Center for Informatics, Dagstuhl, Germany, June 9-14, 2024.

9.1.5 Leadership within the scientific community

Mélina Skouras is the coordinator of the ANR collaborative project MatAIRialS (Architectured Inflatable mateRials for designing functional Shells).

Stefanie Hahmann is a member of the SMI (ShapeModeling International Association) steering committee.

Rémi Ronfard is a member of the programming committee for the national research program on creative and cultural industries (PEPR ICCARE), and a coordinator of the performing arts chapter.

9.1.6 Scientific expertise

Stefanie Hahmann was Chair of the SMA Young Investigator Award committee, Solid Modeling Association.

Stefanie Hahmann was a Jury member in the SMA Pionneer Award committee, Solid Modling Association.

9.1.7 Research administration

Stefanie Hahmann is an elected member of the European Association for Computer Graphics – chapitre français (EGFR) and serves as secretary in the steering committee.

Stefanie Hahmann is an elected member of the Conseil Scientifique of Grenoble INP.

9.2 Teaching - Supervision - Juries

9.2.1 Teaching

- Stefanie Hahmann, Geometric Modeling, 21.5h HETD, M1, Ensimag/Grenoble-INP.
- Stefanie Hahmann, Surface Modeling, 37.5h HETD, M2, Ensimag/Grenoble-INP.
- Stefanie Hahmann, M2-projects, 10h HETD, M2, Ensimag/Grenoble-INP.
- Master: Mélina Skouras, Surface modeling, 13.5 HETD, M2, Ensimag-Grenoble INP.
- Master: Mélina Skouras, Computational Mechanics, 8.5 HETD, M2, Ensimag-Grenoble INP.
- Master: Mélina Skouras, Computer Graphics II, 18 HETD, M2, Ensimag-Grenoble INP (MoSIG).
- From September 2022 to August 2023, Stefanie Hahmann is beneficiary of a CRCT from Grenoble INP. From September 2023 to August 2024, she is in delegation Inria with a reduced teaching load of 64h. She taught 2 classes at Ensimag-Grenoble INP: Geometric Modeling (35 students, level M1 23h) and Surface Modeling (25 students, level M2, 37h). She was president of the jury for more than 10 Masters (PFE) thesis defences.
- Rémi Ronfard is an associate researcher with the SPATIAL MEDIA research group at ENSADLAB, Ecole des Arts Décoratifs, where he teaches and supervises PhD students in art and design.

9.2.2 Supervision

PhD in progress: Siyuan He, Inflatable metamaterials, since October 2022, supervised by Mélina Skouras and Arthur Lebée (Ecole des Ponts).

PhD in progress: Anandhu Sureshkumar, VR-based shape synthesis and editing with minimal inputs, since October 2023, supervised by Stefanie Hahmann and Amal Dev Parakkat (Télécom Paris), Marie-Paule Cani (Ecole Polytechnique).

PhD in progress: Rémi Sagot-Duvauroux, The practice of montage as a narrative, discursive and poetic vector for the creation and reception of virtual reality artworks, since September 2020, SACRE PhD, ED 540, ENS Paris, PSL University, supervised by Rémi Ronfard and Guillaume Soulez (Univ. Paris 3).

PhD in progress: Axel Belin, Theater Arts in the Digital Mirror: Incarnation in Virtual Reality through Staging and Theatrical Rehearsal, since September 2024, SACRE PhD, ED 540, ENS Paris, PSL University, supervised by Rémi Ronfard.

PhD defense of Emmanuel Rodriguez, Direct and inverse modeling of laser-cut meta-materials, supervised by Georges-Pierre Bonneau, Mélina Skouras and Stefanie Hahmann.

Sacha Bonicatto, Computer notation of theater staging, Master student internship, supervised by Rémi Ronfard and Paola Ranzini (Univ. Avignon).

9.2.3 Juries

Mélina Skouras was an examiner for the PhD thesis of Marco Freire, Université de Lorraine, 2023.

Mélina Skouras was a member of the recruitment jury for the preselections of the CRCN/ISFP positions at the Inria Centre at the University Grenoble Alpes.

Stefanie Hahmann was a reviewer for the PhD thesis of Eric Zimmermann at FU Berlin (Allemagne), January 2024.

Stefanie Hahmann was a member of the jury for the HDR of Poran Memari, LIX/Ecole Polytechnique.

Stefanie Hahmann was a member of the jury for the PhD thesis of Ana Granizo-Hidalgo, Université Grenoble Alpes.

Rémi Ronfard was interviewed by "Théâtral Magazine" in January 2024, resulting in a one-page article about the KinoAi research project, as part of a special issue on "theater and film".

10 Scientific production

10.1 Major publications

[1] Z. Chen, H.-Y. Chen, D. M. Kaufman, M. Skouras and E. Vouga. 'Fine Wrinkling on Coarsely Meshed Thin Shells'. In: *ACM Transactions on Graphics* 40.5 (21st Aug. 2021), pp. 1–32. DOI: 10.1145/3462758. URL: https://hal.inria.fr/hal-03519074.

[2] A. Fondevilla, D. Rohmer, S. Hahmann, A. Bousseau and M.-P. Cani. 'Fashion Transfer: Dressing 3D Characters from Stylized Fashion Sketches'. In: *Computer Graphics Forum* 40.6 (2021), pp. 466–483. DOI: 10.1111/cgf.14390. URL: https://ut3-toulouseinp.hal.science/hal-03280215.

[3] R. Ronfard. 'Film Directing for Computer Games and Animation'. In: *Computer Graphics Forum* 40.2 (May 2021), pp. 713–730. DOI: 10.1111/cgf.142663. URL: https://hal.inria.fr/hal-03225328.

[4] R. Ronfard and J. Valéro. 'KinoAI and the audiovisual notebook : a plural solution for rehearsal studies'. In: *European Journal of Theatre and Performance* 2 (2nd June 2020), pp. 334–375. URL: https://hal.inria.fr/hal-02797350.

[5] X. Zhang, G. Fang, M. Skouras, G. Gieseler, C. C. Wang and E. Whiting. 'Computational Design of Fabric Formwork'. In: *ACM Transactions on Graphics* 38.4 (July 2019), pp. 1–13. DOI: 10.1145/3306346.3322988. URL: https://hal.inria.fr/hal-02397265.

10.2 Publications of the year

International journals

[6] G.-P. Bonneau and S. Hahmann. '3D sketching in immersive environments: Shape from disordered ribbon strokes'. In: *Computers and Graphics*. SMI 2024 123 (Oct. 2024), p. 103978. DOI: 10.1016/j.cag.2024.103978. URL: https://inria.hal.science/hal-04661083.

International peer-reviewed conferences

[7] E. Rodriguez, G.-P. Bonneau, S. Hahmann and M. Skouras. 'Designing Bending-Active Freeform Surfaces'. In: *Proceedings of the 9th ACM Symposium on Computational Fabrication*. SCF 2024 - 9th ACM Symposium on Computational Fabrication. article no. 3. Aarhus, Denmark, 7th July 2024, pp. 1–11. DOI: 10.1145/3639473.3665793. URL: https://inria.hal.science/hal-04661276.

[8] M. Vialle, R. Ronfard and M. Skouras. 'Modern Dance Retargeting using Ribbons as Lines of Action'. In: *EG 2024 - Short Papers*. Eurographics. Limassol, Cyprus: The Eurographics Association; The Eurographics Association, 2024. DOI: 10.2312/egs.20241019. URL: https://inria.hal.science/hal-04905809.

Doctoral dissertations and habilitation theses

[9] E. Rodriguez. 'Direct and inverse modelling of laser-cut meta-materials'. Université Grenoble Alpes [2020-....], 21st Feb. 2024. URL: https://theses.hal.science/tel-04700964.

Reports & preprints

[10] S. He, M. Wu, A. Lebée and M. Skouras. *MatAIRials: Inflatable Metamaterials for Freefrom Surface Design*. 2024. URL: https://inria.hal.science/hal-04562406.

10.3 Cited publications

[11] M. S. et al. 'Thespian : An architecture for interactive pedagogical drama'. In: *Artificial Intelligence in Education* 125 (2005), pp. 595–602 (cit. on p. 6).

[12] A. Barbulescu, R. Ronfard and G. Bailly. 'A Generative Audio-Visual Prosodic Model for Virtual Actors'. In: *IEEE Computer Graphics and Applications* 37.6 (Nov. 2017), pp. 40–51. DOI: 10.1109/MCG.2017.4031070. URL: https://hal.inria.fr/hal-01643334 (cit. on p. 6).

[13] H. Clarck. 'Depicting as a method of communication'. In: *Psychological Review* 123 (2016), pp. 324–347 (cit. on p. 5).

[14] J. E. Cutting, J. E. DeLong and C. E. Nothelfer. 'Attention and the Evolution of Hollywood Film'. In: *Psychological Science* 21.3 (2010), pp. 432–439 (cit. on p. 6).

[15] M. Eger and K. W. Mathewson. 'dAIrector: Automatic Story Beat Generation through Knowledge Synthesis'. In: *Proceedings of the Joint Workshop on Intelligent Narrative Technologies and Workshop on Intelligent Cinematography and Editing*. 2018 (cit. on p. 6).

[16] Q. Galvane, M. Christie, C. Lino and R. Ronfard. 'Camera-on-rails: Automated Computation of Constrained Camera Paths'. In: *ACM SIGGRAPH Conference on Motion in Games*. Paris, France: ACM, Nov. 2015, pp. 151–157. DOI: 10.1145/2822013.2822025. URL: https://hal.inria.fr/hal-01220119 (cit. on p. 6).

[17] Q. Galvane, R. Ronfard, C. Lino and M. Christie. 'Continuity Editing for 3D Animation'. In: *AAAI Conference on Artificial Intelligence*. Austin, Texas, United States: AAAI Press, Jan. 2015, pp. 753–761. URL: https://hal.inria.fr/hal-01088561 (cit. on p. 6).

[18] V. Gandhi, R. Ronfard and M. Gleicher. 'Multi-Clip Video Editing from a Single Viewpoint'. In: *European Conference on Visual Media Production*. London, United Kingdom: ACM, Nov. 2014 (cit. on p. 6).

[19] M. Garcia, R. Ronfard and M.-P. Cani. 'Spatial Motion Doodles: Sketching Animation in VR Using Hand Gestures and Laban Motion Analysis'. In: *Motion, Interaction and Games*. Oct. 2019. DOI: 10.1145/3359566.3360061. URL: https://hal.archives-ouvertes.fr/hal-02303803 (cit. on p. 6).

[20] D. Gochfeld, C. Brenner, K. Layng, S. Herscher, C. DeFanti, M. Olko, D. Shinn, S. Riggs, C. Fernández-Vara and K. Perlin. 'Holojam in Wonderland: Immersive Mixed Reality Theater'. In: *ACM SIGGRAPH 2018 Art Gallery*. SIGGRAPH '18. 2018 (cit. on p. 6).

[21] B. Hayes-Roth and R. V. Gent. 'Improvisational puppets, actors, and avatars'. In: *Proc Comp Game Dev Conf*. 1996 (cit. on p. 6).

[22] K. Layng, K. Perlin, S. Herscher, C. Brenner and T. Meduri. 'Cave: Making Collective Virtual Narrative'. In: *ACM SIGGRAPH 2019 Art Gallery*. SIGGRAPH '19. 2019 (cit. on p. 6).

[23] Z. Lun, E. Kalogerakis, R. Wang and A. Sheffer. 'Functionality Preserving Shape Style Transfer'. In: *ACM Transactions on Graphics* 35.6 (2016) (cit. on p. 6).

[24] B. Magerko, W. Manzoul, M. Riedl, A. Baumer, D. Fuller, K. Luther and C. Pearce. 'An empirical study of cognition and theatrical improvisation'. In: *Creativity and Cognition* (2009) (cit. on p. 6).

[25] J. H. Murray. *Hamlet on the Holodeck, The Future of Narrative in Cyberspace, Updated Edition*. MIT Press, 2017 (cit. on p. 6).

[26] O. Palombi, G. Bousquet, D. Jospin, S. Hassan, L. Revéret and F. Faure. 'My Corporis Fabrica: A Unified Ontological, Geometrical and Mechanical View of Human Anatomy'. In: *Proceedings of the 2009 International Conference on Modelling the Physiological Human*. 3DPH'09. 2009, pp. 209–219 (cit. on p. 5).

[27] R. Ronfard, V. Gandhi, L. Boiron and V. A. Murukutla. 'The Prose Storyboard Language: A Tool for Annotating and Directing Movies'. In: *WICED 2022 - 10th Workshop on Intelligent Cinematography and Editing*. Reims, France, Apr. 2022, pp. 1–16. URL: https://inria.hal.science/hal-03654906 (cit. on p. 5).

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