Deforming and Animating Multi-Material Objects Using Multi-Valued Field Functions

Examples of phenomena that can be modeled using multiple field functions: Skinning [Vaillant13], Garment layers in contact [Buffet19], volcano lava (real photograph).

Place: LIX/Ecole Polytechnique, Palaiseau. VISTA team.

PhD supervisors : Damien Rohmer (damien.rohmer@polytechnique.edu), Marie-Paule Cani (marie-paule.cani@polytechnique.edu)

Contract duration : 36 months, starting at Fall 2023.

Context.

3D objects are often represented by meshes, enabling fast rendering of 3D scenes, but this representation becomes ineffective when volume or contact deformations of colliding objects are to be precisely controlled. They also lack robustness when the internal structure is complex and the object topology is to change over time. In these cases, volume-based representations such as 3D field functions are particularly adapted to represent, not only volumes, but density of material, in associating a scalar value to every position in space depending on the presence of material. The object surface can then be defined as an implicit surface (for instance the iso-surface where the field function is null), its inside being located where the function is larger than the iso-value (positive) and the outside where it is lower (negative).

The use of field functions is particularly well suited for assembling objects parts in a simple and unified manner while automatically handling changes in topology. They also explicitly represent both the objects inside and outside. These volume-based representations, initially developed in the 90's [Blomenthal97] are attracting a lot of attention in recent years for their ability to robustly represent arbitrary shapes whose embedding can be learned [JoonPark19, Sharp22], or as a way to provide an adapted representation for massively detailed, yet interactive, natural sceneries (terrains [Paris19], volcano eruption [Stora99, Lastic22], bio-inspired shapes

[Garnier22], etc), or for sketch-based shape modeling allowing art controllability [Angles17] using advanced blending operators [Gourmel13].

A particular interest of field function is their ability to efficiently detect collisions between different materials, and respond in modeling contact surfaces whose properties can be expressed via blending operators. This ability was explored to handle surface contacts in skinning deformation while preserving local details encoded with their respective field-value [Vaillant13-14], as well as solving collision for an arbitrary number of interleaved garments layers on top of each other for clothing application [Buffet19]. A key aspect of these approaches is to not only consider the surface as an isovalue of an arbitrary field, but to make use of the values of the field in space also beyond the iso-set in order to preserve details or model spatial interactions at distance.

Objective

This PhD aims at extending field-based operators toward animated complex multi-material. We want to explore the full potential of field functions where blending and/or self-compositing is to depend on the values of different fields modeling different materials, as well as on multi-valued fields representing the space-varying parameters of a given material.

This can be, for instance, used to animate a lava flow whose inner field value corresponds to the local temperature, and for which different inner behaviors are expected by range of temperature. In such cases, varying blending operators could be defined in order to handle collision, such as a contact operator where the crust is already solidified, versus soft blending to model the merging behavior of the underneath hot fluid layers. More generally, this methodology could benefit the animation of material exhibiting multi-phasic behavior from a liquid phase with various viscosity to granular and solid behavior (sand with different proportions of water, mud, snow…)

Another application could be to handle various levels of details in different fields in order to model highly detailed shapes. In such cases, some fields may carry texture-like details that will be expressed and blended differently depending on their environment. This may for instance be used to model organic shapes with details automatically adapting to their respective position, to branching structures and contact with other organs.

Context of the position

The successful candidate to this PhD will be hired by Ecole Polytechnique, and integrate the VISTA research team at LIX/CNRS (Laboratoire d'Informatique de l'Ecole Polytechnique) in Palaiseau. We offer a high-standard research environment (including facilities and equipment), within the vibrant academic and industrial environment of Institut Polytechnique de Paris.

This PhD will take place in the context of the ANR MultiForm, involving LIX/Ecole Polytechnique, IRIT/Université Paul Sabatier, LORIA/Université de Lorraine. The student hired on this PhD will benefit from the ANR funding dedicated to this project to develop his/her research. This funding includes regular meetings with the partner Universities, with the possibility of on-site exchange to benefit from partners expertise, engineering development, academic and industrial contacts.

The PhD will also benefit from dedicated access to the technical platforms developed by the partners such as the “Implicit Blending Library” [Gourmel13], “Radium Engine” [Radium] for efficient animation development, or the “Matisse” [Bernhardt08] software implementing implicit modeling tools for browsers.

Requirements and application

Candidate to this PhD must be:

- About to graduate (or recently graduated) from a Master level in Computer Science.

- Skilled in programming: Compiled languages such as C++, and possibly script languages such as Python, or C# in Unity as a supplement.

- Relevant good background in Computer Graphics such as 3D modeling, 3D Animation, Implicit Surface. Please detail this background experience in your application.

Please send your application to Damien Rohmer (Damien.Rohmer@polytechnique.edu) and Marie-Paule Cani (Marie-Paule.Cani@polytechnique.edu) with the following elements:

- Curriculum (please state clearly your Diplomas and field of study, previous experiences/internships, and current position).

- Motivation Letter

- Copy of your Master transcript

- Recommendation letter, or at least a possible referent that knows you, and working in Computer Graphics research or related field.

Bibliography

[**Angle17**] Baptiste Angles, Marco Tarini, Brian Wyvill, Loic Barthe, Andrea Tagliasacchi. Sketch-Based Implicit Blending. ACM Transactions on Graphics, 2017.

[**Bernhardt08**] Adrien Bernhardt, Adeline Pihuit, Marie-Paule Cani, Loic Barthe. Matisse: Painting 2D regions for Modeling Free-Form Shapes. SBIM 2008.

[**Bloomenthal97**] J. Bloomenthal, Chandrajit Bajaj, Jim Blinn, Marie-Paule Cani, Alyn Rockwood, Brian Wyvill, Geoff Wyvill. Introduction to Implicit Surfaces. Morgan Kaufmann, 1997.

[**Buffet19**] Thomas Buffet, Damien Rohmer, Loic Barthe, Marie-Paule Cani. Implicit Untangling : A Robust Solution for Modeling Layered Clothing. ACM SIGGRAPH, 2019.

[**Garnier22**] David-Henri Garnier, Martin-Pierre Schmidt, Damien Rohmer. Growth of oriented orthotropic structures with reaction/diffusion. Structural and Multidisciplinary Optimization, 2022.

[**Gourmel13**] Olivier Gourmel, Loic Barthe, Marie-Paule Cani, Brian Wyvill, Adrien Bernhardt, Mathias Paulin, Herbert Grasberger. A Gradient-Based Implicit Blend. ACM Transactions on Graphics, 2013.

[**JoonPark19**] Jeong Joon Park, Peter Florence, Julian Straub, Richard Newcombe, Steven Lovegrove. DeepSDF: Learning Continuous Signed Distance Functions for Shape Representation. CVPR, 2019.

[**Lastic22**] Maud Lastic, Damien Rohmer, Guillaume Cordonnier, Claude Jaupart, Fabrice Neyret, Marie-Paule Cani. Interactive simulation of plume and pyroclastic volcanic ejections. I3D, proceedings of PACM CGIT, 2022.

[**Paris19**] Axel paris, Eric Galin, Adrien Peytavie, Eric Guérin, James Gain. Terrain Amplification with Implicit 3D Features. ACM Transactions on Graphics, 2019.

[**Radium**] https://github.com/STORM-IRIT/Radium-Engine

[**Sharp22**] Nicholas Sharp, Alec Jacobson. Spelunking the Deep: Guaranteed Queries on General Neural Implicit Surfaces via Range Analysis. ACM SIGGRAPH, 2022.

[**Stora99**] Dan Stora, Pierre-Olivier Agliati, Marie-Paule Cani, Fabrice Neyret, Jean-Dominique Gascuel. Animating Lava Flows. Graphics Interface, 1999.

[**Vaillant13**] Rodolphe Vaillant, Loic Barthe, Guael Guennebaud, Marie-Paule Cani, Damien Rohmer, Brian Wyvill, Olivier Gourmel, Mathias Paulin. Implicit Skinning : Real-Time Skin Deformation with Contact Modeling. ACM SIGGRAPH 2013.

[**Vaillant14**] Rodolphe Vaillant, Guael Guennebaud, Loic Barthe, Marie-Paule Cani, Brian Wyvill. Robust Iso-Surface Tracking for Interactive Character Skinning. ACM SIGGRAPH Asia 2014.